Papers on Anthropology

IX

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PREFACE

The Centre for Physical Anthropology at the University of Tartu has published its ninth collection of research papers on anthropology. We thank our colleagues from Tartu and Tallinn, from Israel, the Czech Republic and Belarus for their cooperation.

By paying ever greater attention to the individual peculiarities of human body build, we gradually approach one of the final aims of theoretical biology and medicine — establishing the constitutional characteristics of sick and healthy people, creating a model of the human being as a whole.

Wishing all of us success in this work,

Prof. Helje Kaarma
Head of the Centre for Physical Anthropology

CONTENTS

STATURE AND SEXUAL DIMORPHISM IN ESTONIANS OF THE 13TH–18TH CENTURIES

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ABSTRACT

Eight Estonian skeletal populations dating from 1200–1800 are analysed in the present paper. The aim was to find geographical differences and temporal changes in stature, long limb bones measurements and sexual dimorphism. Three different methods were used to estimate the stature of men and women.

Keywords: long limb bones, stature, sexual dimorphism, present and past populations.

MATERIAL AND METHODS

All Estonian material has been collected from village cemeteries, except St. Barbara which is a suburb cemetery of Tallinn.

The lengths of the long limb bones of eight different skeletal groups were measured by different authors according to the methodology of Martin and Saller [15]: Koikküla, Iisaku, Kaberla, Varbola and Kohtla-Järve by Dr. Karin Mark; Makita — by Dr. Leiu Heapost, Tääksi (1998) and St. Barbara by Raili Allmäe.

For comparison of Estonian skeletal populations with Scandinavian and Lithuanian osteological data, a number of publications were used [3, 6, 7, 10, 12, 13, 17, 18, 19].

- Three different methods were used to calculate the average body height of skeletal populations [16, 20, 21]. The bones of the right side of the body were used for calculations. The stature of present-day population has been estimated by Dr. Juhan Aul [4, 5], and the ratio of the lengths of upper and lower limbs was calculated according to his data (intermembral index).

Table 1. Geographical localisation of Estonian skeletal populations and corresponding present-day populations

Skeletal populations of 13th–18th centuries		Present-day populations (according to Aul 1964, 1977)	
Sample	Period	Men	Women
Iisaku	1600–1800	Eastern-Virumaa	Northern Estonia
Kaberla	1200–1700	Eastern-Harjumaa	Northern Estonia
Kohtla-Järve	1600–1800	Kohtla-Järve	Northern Estonia
Koikküla	1500–1700	Valgamaa	Central Estonia
St. Barbara	1300–1700	Tallinn	Tallinn
Varbola	1500–1700	Western-Harjumaa	Western-Estonia
Makita	1200–1700	Southern-Tartumaa	Tartumaa
Tääksi	1300–1800	Southern-Viljandimaa	Central Estonia

The comparison of skeletal and present-day populations was carried out as follows:

- the stature of Estonian skeletal populations was estimated on the basis of maximum lengths of *femur* and *humerus.*
- the stature and ratio of upper and lower limbs and sexual dimorphism of Estonian present-day and skeletal populations was compared.
- sexual dimorphism in body height of Estonian, Lithuanian and Scandinavian skeletal groups was analysed. Here the stature of skeletal populations was calculated on the basis of the maximum lengths of *femur* using the method of Trotter and Gleser [21].

RESULTS AND DISCUSSION

1. Measurements of long bones of upper and lower limbs and their proportions

The averages of the maximum lengths of the long limb bones of men and women (except fibula) are presented in Table 2. Also the sum of the lengths of five long limb bones is also shown in Table 2. It characterises the approximate stature of the persons who once lived and is does not differ very much from the stature calculated by the method of Pearson and Lee [16] (see Table 3). The sum of the lengths of five bones can be used for rough preliminary estimation of stature.

Table 2. The average lengths of long limb bones (mm) and their sum in cm

	Sample	humerus	radius	ulna	femur	tibia	Sum
Women	Iisaku	303.89	224.75	247.00	419.35	335.42	153.04
	Kaberla	306.64	223.50	242.36	410.75	327.62	151.09
	Kohtla-Järve	288.64	208.30	232.83	391.17	311.22	143.22
	Koikküla	304.18	221.40	243.75	425.50	347.38	154.22
	Barbara	296.52	221.23	239.28	409.50	332.83	149.94
	Varbola	302.75	222.60	240.56	415.46	323.46	150.48
	Makita	309.20	229.79	247.92	413.14	346.50	154.66
	Tääksi	298.33	216.33	237.47	416.69	331.58	150.04
	Average	301.27	220.99	241.40	412.70	332.00	150.83
Men	Iisaku	334.40	249.30	271.50	458.40	365.50	167.91
	Kaberla	334.10	253.00	275.30	458.60	367.30	168.83
	Kohtla-Järve	326.20	244.70	260.30	443.90	346.30	162.14
	Koikküla	321.10	242.00	262.90	441.00	357.40	162.44
	Barbara	324.20	244.10	264.60	444.10	359.30	163.63
	Varbola	331.90	249.10	273.10	454.00	365.00	167.31
	Makita	317.20	242.60	264.00	440.50	343.50	160.78
	Tääksi	329.00	239.50	263.30	445.00	359.20	163.60
	Average	327.26	245.54	266.88	448.19	357.94	164.58

Men from Iisaku, Koikküla and Kaberla had the longest upper and lower long limb bones. The women from Iisaku, Koikküla and Makita indicated great numerical values in the lengths of long limb bones —

though the picture is not as homogenous as in the men's samples (Table 2).

The ratio of the lengths of upper limb bones (*radius+humerus*) and lower limb bones (*femur+tibia*) is presented in Table 3. The intermembral indices for present-day populations have been calculated on the basis of the somatological data of Estonians [4, 5] and are also presented in Table 3. The above mentioned ratio shows that 13th–18th-century men from Varbola, Kohtla-Järve and Koikküla had relatively long bones of upper limbs. Present-day men from Valgamaa, Kohtla-Järve and Southern-Viljandimaa also show relatively long upper limbs according to somatological data. Thus it seems that relatively long upper limbs of men have been characteristic of some districts for centuries.

Table 3. The ratio of the lengths of upper and lower limbs

Men	Skeletal sample	Somatological sample	Skeletal hum+rad/ fem+tib	Somatological (Aul, 1964)
	Varbola	Western-Harjumaa	0.722	0.832
	Kohtla-Järve	Kohtla-Järve	0.714	0.835
	Koikküla	Valgamaa	0.711	0.838
	Average		**0.711**	**0.832**
	Kaberla	Eastern-Harjumaa	0.709	0.833
	Iisaku	Eastern-Virumaa	0.708	0.832
	Makita	Southern-Tartumaa	0.707	0.834
	Tääksi	Southern-Viljandimaa	0.707	0.835
	St. Barbara	Tallinn	0.705	0.826

Women	Skeletal sample	Somatological sample	Skeletal hum+rad/ fem+tib	Somatological (Aul, 1977)
	Kaberla	Northern-Estonia	0.718	0.815
	Varbola	Western-Estonia	0.711	0.816
	Kohtla-Järve	Northern-Estonia	0.707	0.815
	Makita	Tartumaa	0.701	0.818
	Iisaku	Northern-Estonia	0.700	0.815
	Average		**0.700**	**0.815**
	St. Barbara	Tallinn	0.697	0.810
	Tääksi	Central Estonia	0.688	0.817
	Koikküla	Central Estonia	0.680	0.817

The female skeletal data indicate different trends. The women from Kaberla, Varbola, and Kohtla-Järve had relatively long upper limbs. According to skeletal material, short upper limbs were typical of Central Estonia (Tääksi, Koikküla). On the basis of somatological data, relatively long upper limbs are characteristic of Tartumaa, Central and Western-Estonia; short upper limbs are typical of Northern Estonia. Thus, here we have a discrepancy between skeletal and somatological data (Table 3). It may result from different causes: migration and mixing of people or from the changes in working habits, social strata and environment, or from too little material.

2. Stature reconstruction

Body height of men and women was reconstructed on the basis of three different methods (Table 4).

The method of Trotter and Gleser [21] always gives bigger stature on the basis of *humerus*. It is interesting to mention that Telkkä's method [20] gives different results for women. In most cases the stature calculated on the basis *femur* is bigger as compared to that compared on the basis of *humerus*. For men's stature the method of Pearson and Lee [16] gives the same results.

In the 13th–18the centuries the tallest men and women lived in Koikküla and Iisaku villages. The shortest people lived in Kohtla-Järve village and in the suburb of Tallinn (the material from St. Barbara cemetery).

At present the tallest men and women live in the Western part of Estonia [4, 5]. Unfortunately we do not have any skeletal material from this area. Nowadays the shortest stature is characteristic of men from Eastern-Virumaa and Petserimaa; the shortest women live in South-West Estonia and in Central Estonia [1, 2]. The skeletal material indicates the presence of one of the tallest populations — Iisaku — and the shortest population — Kohtla-Järve — in the eastern part of Estonia. The same concerns populations of Central Estonia: Koikküla has one of the tallest and Tääksi is one of the shortest populations.

The discrepancies in data can result from the different size of skeletal samples in comparison with somatological ones. We should also keep in mind that stature reconstruction is just a model, and femoral length (often used to estimate stature) of men is more susceptible to environmental influence than real adult body height [11]. And last: the living conditions of past and present populations are different.

Table 4. The stature of 13^{th}–8th cc. Estonian populations according to different methods

	Trotter& Gleser	Pearson& Lee	Telkkä	Trotter&G leser	Pearson& Lee	Telkkä
Women	**Humerus**			**Femur**		
Iisaku	160.08	155.17	155.96	157.68	154.41	157.04
Kaberla	161.00	155.92	156.70	155.56	152.73	155.50
Kohtla-Järve	154.95	150.97	151.84	150.72	148.93	151.97
Koikküla	160.17	155.25	156.04	159.20	155.60	158.15
St. Barbara	157.60	153.14	153.97	155.25	152.49	155.27
Varbola	159.69	154.85	155.65	156.72	153.65	156.34
Makita	161.86	156.63	157.40	156.15	153.20	155.93
Tääksi	158.21	153.64	154.46	157.02	153.89	156.56
Average	**159.20**	**154.44**	**155.25**	**156.04**	**153.11**	**155.85**
Variance	4.24	2.85	2.73	5.41	3.35	2.87
Men	**Humerus**			**Femur**		
Iisaku	173.45	167.42	170.91	170.51	167.49	170.11
Koikküla	173.35	167.33	170.83	170.56	167.52	170.16
Varbola	170.92	165.04	168.62	167.06	164.76	167.07
St. Barbara	169.35	163.57	167.19	166.37	164.21	166.46
Tääksi	170.30	164.46	168.06	167.11	164.80	167.11
Kaberla	172.68	166.69	170.21	169.46	166.66	169.19
Kohtla-Järve	168.15	162.44	166.10	166.25	164.12	166.36
Makita	172.17	166.22	169.76	168.68	166.04	168.50
Average	**171.26**	**165.36**	**168.92**	**168.08**	**165.57**	167.97
Variance	3.29	2.91	2.72	2.80	1.75	2.18

4. Sexual dimorphism

The term sexual dimorphism is used to describe systematic biological difference between men and women. It can be quantified using measurements.

Sexual dimorphism in stature in 13^{th}–18^{th} cc. populations and in Estonian people of the 1930s is given in Table 5. The lengths of *humerus* and *femur* were used for calculations and then the average was taken. This was done to decrease the error caused by the different proportions of upper and lower limbs.

In the 13th–18th centuries sexual dimorphism has been bigger in Northern Estonia and smaller in Central and Western Estonia. Decrease of sexual dimorphism from north to south in Sweden and Denmark has been described earlier [18]. In the 20^{th} century the trend is opposite in Estonia — sexual dimorphism is bigger in Central, Southern and Western Estonia. The average difference in sexual dimorphism is about 2 cm for the comparative time-periods in Estonia (Table 5). At the beginning of this century the difference in stature between men and women was smaller than in the 13^{th}–18^{th} centuries. The same tendency has also been described in Denmark [6].

Sexual dimorphism in stature of Danish, Swedish, Norwegian (later on Scandinavian countries), Estonian and Lithuanian (summarised) samples is presented in Table 6. Both rural and urban populations are represented. Estonian and Lithuanian populations seem to be shorter in comparison with Scandinavian ones.

The average sexual dimorphism for comparable skeletal series is 12.3 cm, which means that the average height of females is 92.8% of that of males.

The biggest differences in stature — men were over 15 cm taller than women, were found in Kohtla-Järve, Westerhus and St. Mikkel (Viborg). It means that the body height of women was about 91% of men's stature. The smallest difference in stature appeared in Sola (too little material), Grena and Tääksi where the stature of women was 94% and more of men's body height. Lithuanian 16^{th}–18^{th} cc. rural populations and Estonian St. Barbara, the suburban population of Tallinn, indicated relatively small sexual dimorphism — 10.96 cm and 11.12 cm accordingly. Sexual dimorphism of rural populations of Estonia and of Scandinavia was 12.14 cm and 11.96 cm on the average. There is evidence of bigger sexual dimorphism in

Table 5. Sexual dimorphism in the 13th–18th cc. and in the 1930s in Estonia

Skeletal populations 1200–1800				Somatological data 1932–1936				
Samples	Stature (cm)		Difference (cm)	Samples		Stature (cm)		Difference (cm)
	men	women				men	women	
Iisaku	171.98	158.88	13.10	E-Viru	N-Estonia	170.72	161.80	8.92
Koikküla	171.95	159.69	12.26	Valga	Central Estonia	171.31	161.07	10.24
Kaberla	171.06	158.28	12.78	E-Harju	N-Estonia	171.80	161.80	10.00
Kohtla-Järve	167.20	152.84	14.36	E-Viru	N-Estonia	170.72	161.80	8.92
Varbola	168.98	158.21	10.77	W-Harju	N-Estonia	172.70	161.80	10.90
St. Barbara	167.86	156.42	11.44	Tallinn	Tallinn	172.72	163.16	9.56
Tääksi	168.70	157.62	11.08	S-Viljandi	Central Estonia	171.54	161.07	10.47
Makita	170.23	158.80	11.44	S-Tartu	S/W-Estonia	171.61	160.81	10.80
Average	**169.74**	**157.59**	**12.15**		**Average**	**171.64**	**161.49**	**10.15**

Table 6. Sexual dimorphism of different populations

Name of the sample	Country	Period	Urban/Rural	Stature of men		Stature of women		Sexual dimorphism	
				n	cm	n	cm	in cm	in %
Lithuanian	**Lithuania**	**1500–1800**	**rural**	**116**	**168.29**	**116**	**157.33**	**10.96**	**93.5**
Kohtla-Järve	Estonia	1600–1800	rural	27	166.24	12	150.72	15.52	90.7
Koikküla	Estonia	1500–1700	rural	9	170.55	12	159.20	11.35	93.3
Iisaku	Estonia	1600–1800	rural	12	170.51	15	157.68	12.83	92.5
Tääksi	Estonia	1300–1800	rural	16	167.10	16	157.02	10.07	94.0
Varbola	Estonia	1500–1700	rural	7	167.05	13	156.72	10.33	93.8
Makita	Estonia	1200–1700	rural	13	167.32	13	156.36	10.96	93.4
Kaberla	Estonia	1200–1700	rural	26	169.46	16	155.56	13.91	91.8
Estonian	average	1200–1800	rural	110	168.32	97	156.18	**12.14**	**92.8**
	variance				2.90		1.57	2.25	0.71
Tirup	Denmark	1100–1320	rural	82	173.27	50	161.64	11.63	93.3
Grena	Denmark	1000–1350	rural	34	170.70	12	160.80	9.90	94.2
Refshale	Denmark	1100–1260	rura	21	170.10	13	158.75	11.35	93.3
Risby	Denmark	1110–1400	rural	16	170.84	17	158.56	12.29	92.8
Löddenköpinge	Denmark	1050–1250	rural	158	168.89	125	156.58	12.31	92.7
Sola	Norway	1050–1536	rural	3	168.70	1	161.00	7.70	95.4
Mare	Norway	1050–1536	rural	2	178.10	7	164.10	14.00	92.1
Westerhus	Sweden	1050–1536	rural	61	174.10	71	158.80	15.30	91.2
Leksand	Sweden	1050–1536	rural	9	173.00	22	159.80	13.20	92.4
Norway, Sweden,	average	1000–1800	rural	386	171.97	318	160.00	**11.96**	**93.0**
Denmark	variance				8.93		4.75	5.00	1.50

Name of the sample	Country	Period	Urban/Rural	Stature of men		Stature of women		Sexual dimorphism	
				n	cm	n	cm	in cm	in %
St. Barbara,Tallinn	Estonia	1300–1700	urban	68	166.37	60	155.25	**11.12**	**93.3**
Svendborg	Denmark	1200–1600	urban	27	174.01	16	162.46	11.55	93.4
Sct. Oluf, Arhus	Denmark	1400–1800	urban	14	171.58	14	160.80	10.78	93.7
Domkirke, Viborg;	Denmark	1000–1800	urban	21	173.60	11	160.71	12.90	92.6
Sct.Jorgen, Odense	Denmark	1250–1450	urban	154	173.84	152	160.68	13.16	92.4
Sct. Mikkel, Viborg	Denmark	1000–1529	urban	58	174.25	37	159.10	15.15	91.3
Slotsbjergby	Denmark	1600–1800	urban	11	173.10	11	159.05	14.05	91.9
St. Stefan, Lund	Sweden	1000–1600	urban	359	172.60	278	158.75	13.85	92.0
Trondheim	Norway	1050–1536	urban	48	173.20	38	158.50	14.70	91.5
Lund	Sweden	1050–1536	urban	64	171.70	56	160.90	10.80	93.7
Norway, Sweden,	average	1000–1800	urban	756	173.10	613	160.11	**12.99**	**92.50**
Denmark	variance				0.93		1.73	2.66	0.84
All samples together		1000–1800	**Urban/Rural**	**1436**	**171.1**	**1204**	158.8	12.3	92.8

Scandinavian towns — 12.99 cm. St. Barbara, a representative of suburb population, indicates much smaller sexual dimorphism, namely 11.12 cm. Sexual dimorphism in the town population of Tartu in the 13th–14th centuries was also small — 10.3 cm; in Viljandi sexual dimorphism was 11.6–12.3 cm [14], but we must also take into consideration the differences in stature estimation.

Stature comparison of Estonian rural (Tääksi village) and (St. Barbara, suburb) urban children in the 14^{th}–18^{th} centuries indicated that village children had higher stature [1, 2]. This refers to better living conditions in the country in the 14^{th}–18^{th} centuries in Estonia. Probably lack of food appeared more acutely in towns and inhibited the growth process. Diseases and other stress-factors also affected townspeople more as population density was higher there. The demographic and osteometrical analyses of 14^{th}–18^{th} Lithuanian urban and rural populations also referred to better living conditions in rural settlements than in towns [8].

In Scandinavian countries the skeletal populations from towns (especially these who were buried into the churchyards) represented higher social strata [18]. At the beginning of the 20^{th} century, sexual dimorphism in stature was 10 cm and 94.1% in Estonia and Denmark [4, 5, 6].

CONCLUSIONS

- There are some geographical, temporal and sexual differences in the proportions of the lengths of upper and lower limbs of Estonians. The differences in proportions appear in stature reconstruction.
- In the 13th–18th centuries the tallest Estonian men and women lived in Iisaku and Koikküla villages. The shortest people lived in Kohtla-Järve village and in a suburb of Tallinn.
- In the 13th–18th centuries sexual dimorphism in stature was bigger in Northern Estonia. At the beginning of the 20th century the trend was opposite — sexual dimorphism was smaller in the populations of Northern Estonia.
- The average stature of Estonian rural and urban populations is smaller in comparison with the Scandinavian samples.

- Average sexual dimorphism in stature of Estonian rural populations is bigger in comparison with Lithuanian and Scandinavian ones.
- The smaller stature and sexual dimorphism of the town population (a suburb of Tallinn) in comparison with rural population refers to the better living conditions in 13th–18th-century Estonian villages than in the suburb of a town.

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ASSOCIATION OF BODY COMPOSITION WITH LEFT VENTRICULAR MORPHOMETRY IN YOUNG HEALTHY MALE SUBJECTS

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ABSTRACT

We studied the parameters of heart and body composition in young healthy male subjects to find significant correlations of prognostic value for evaluating the possible risk of myocardial hypertrophy. The group included 26 young healthy male subjects aged from 12–19 years, participating in residence training at least 4 times in week. Left ventricular morphometry was measured by the ultrasound system, and the parameters of body composition by the anthropometrical method. The possible relation of I/D polymorphism of the ACE gene with the measured and calculated parameters was also investigated. As result, we found statistically significant correlations between body composition, especially between LBM and parameters of the left ventricle mass.

LBM is a useful marker for evaluating the remodulation of the left ventricle during puberty. Correlations between morphogenic parameters and I/D polymorphic status were also established. The exact role of I/D polymorphism of the ACE gene on the growth of heart during puberty is a subject for further investigations.

Key words: body composition, left ventricle, hypertrophy, ACE gene, youngster

INTRODUCTION

Left ventricular hypertrophy (LVH) has been found to be one of the main reasons of sudden death. The genesis of LVH has been largely investigated but is still unclear. It is clear that LVH is of polyethiological origin, but the role and balance of genetic and environmental factors is still largely unknown [11]. The growth in the of mass of cardiac muscle in connection with the growth of body mass (BM) and sexual maturity during puberty has been described by other authors [2, 10]. The genetic base of these changes in the cardiac muscle is unclear.

It is believed that angiotensine 2, produced from angiotensine 1 by the angiotensine converting enzyme (ACE) in most vascular beds but also in cardiac as well as in other tissues plays an important role as a local growth factor [16, 17]. Presence of D allele at the ACE gene has shown to affect significantly the activity of ACE in order D/D > I/D > I/I [1, 8, 16, 23]. The presence of D allele of the ACE gene is also associated with myocardial infarction [5], body mass index, pathological myocardial hypertrophy, and training-related hypertrophy [16], showing its role in remodulation of heart parameters under different conditions. D allele carriers have also lesser or no effect at all from ACE inhibitors to hypertension related hypertrophy [9]. So we were interested in observing the peculiarities of body build of pubertal boys and also the allelic background of the ACE gene of respondents.

MATERIALS AND METHODS

We investigated 26 healthy Estonian schoolboys whose average age was 15.4±1.6 (12–19) years. All the boys were physically active. They had practised power-residence training at least for 3–5 times in week during 1–3 years. Somatometric measurements were taken according to the advice of the Canadian Society for Exercise Physiology [4]. 25 measurements and 11 skinfolds were measured. The mass of subcutaneous adipose tissue and mass of skeletal tissue were specified as by Matiegka [15], muscle mass as by Heyward [7]. Lean body mass (LBM) was calculated by the Wilmore formula [22]. Morphometry of the left ventricle was investigated with Sonos 5500-system according to ASC [20]. The following values were measured and calculated: left ventricular inner diameter in diastole (LVIDd), external long axis of left ventricle in diastole (LAXexd), inner long axis of left ventricle in diastole (LAXind), interventricular septum thickness in diastole (STd), posterior wall of left ventricle in diastole (PWd), left ventricular volume in diastole by Teichholtz ($LVVd_1$), left ventricular volume in diastole by the area length ellipsoid volume formula (LVVd), left ventricular mass by Devereux (LVMass) [3], also indices STd/PWd, LVVd/LVMass, and LVMass/$LVVd_1$.

ACE gene polymorphism detection:

DNA was purified from 200 μl of puffy coat using "High Pure™ PCR Template Preparation Kit" from "Roche". The ACE gene polymorphism was detected by two-primer system [19]. The primers and "AmpliTaq®" polymerase used were provided by "Perkin Elmer". The reaction solution was the same as described by Katsuya [8] except for 5% of DMSO added. DMSO was added to the reaction solution to avoid mismatching between D homozygous and heterozygous status, as described by V. Shanmugam and al. [21]. We believe that this was sufficient for establishing the correct genetic status in all cases. The reactions for D/D were run twice and no mismatch was observed. "Mastercycler Gradient" PCR equipment from "Eppendorf" was used. Results were visualised on electrophoresis using 0.5% TBE solution based 2% agarose ("Bio Top" by "NAXO Ltd.", Estonia) gel containing ethidium bromide.

Statistical analysis was performed using the statistical package STATISTICA.

RESULTS AND DISCUSSION

Preliminary analysis of the data of body composition and left ventricular measurements are presented in Tables 1 and 2. The mean body weight and height of the selected subjects was somewhat higher than the mean among the whole population at this age [6]. Approximately one-third of the subjects belonged, according to age in correspondence classification, to the group of accelerants (class large) [14]. Also the subjects' physical activity was higher than in the whole population of schoolboys. At that the parameters of the left ventricle (Table 2) did not differ from the standard values for their age group [12, 13].

Distribution of ACE allelic status was: group 1 — I/I 21% (n = 6), group 2 — I/D 46% (n = 11), group 3 — D/D 33% (n = 8). Distributions of both alleles were 0.46 and 0.54 for I and D allele respectively. These findings agree with the results of previous investigations [18].

Table 1. Somatometrical characteristics of subjects

Variable	Mean	SD	V	Range percentiles 25–75
1. Height (cm)	178.50	11.10	6.2	172.7–187.5
2. Weight (kg)	69.40	13.60	19.5	63.8–79.7
3. Body surface area (m^2)	1.78	0.11	6.1	1.72–1.88
4. Body mass index (BMI)	21.60	2.62	12.1	19.9–23.5
5. Mass of skeletal tissue (kg) (by Matiegka)	11.20	1.71	15.3	9.9–12.0
6. Relative mass of skeletal tissue (%) (by Matiegka)	16.30	1.96	12.0	14.7–16.8
7. Muscle mass (kg) (by Heyward)	35.5	7.0	19.5	33.4–39.7
8. Relative muscle mass (%) (by Heyward)	51.1	2.72	5.3	48.6–52.4
9. Mass of subcutaneous adipose tissue (by Matiegka)	5.57	1.25	22.4	4.8–6.8
10. Relative mass of subcutaneous adipose tissue (%) (by Matiegka)	8.1	1.2	15.3	7.3–9.2
11. Lean body mass (LBM) (kg) (by Wilmore)	63.1	10.3	16.3	59.1–70.7
12. Relative lean body mass (%) (by Wilmore)	91.6	3.8	4.1	89.0–92.0
13. LBM/BSA	35.2	4.21	12.0	32.4–38.3

Table 2. Values of left ventricular dimensions and indices of subjects

Variable	Mean	SD	Range percentiles 25–75
LVIDd (mm)	48.70	5.05	44.4–52.3
LAXexd (mm)	80.60	8.50	75.0–87.0
LAXind (mm)	68.30	8.20	62.0–73.0
STd (mm)	11.11	1.81	9.5–12.3
PWd (mm)	10.27	1.56	9.2–11.7
$LVVd_l$(ml) (by Teicholtz)	113.50	27.40	90.0–131.0
LVVd (ml) (by area-length)	88.60	34.70	60.0–122.0
LVMass (g)	196.50	53.60	146.6–237.0
LVMass/BSA (g/m^2)	107.80	27.80	81.2–129.6
LVVd/BSA (ml/m^2)	63.30	14.06	50.0–73.9
STd/PWd	1.08	0.13	0.98–1.18
LVMass/ $LVVd_l$ (g/ml)	1.66	0.33	1.54–2.0

Table 3 gives the characteristics of the somatometric peculiarities for ACE genetic status. The boys in group 2 were heavier. Values of body mass index and LBM adjusted to body surface area, were greater then in others groups. As shown in Table 5, strong positive linear correlation (r>0.5) was found between LVMass and mass of skeletal tissue, muscle mass, and LBM. Positive linear correlation sustains between LVMass

Table 3. Somatometrical characteristics of subjects according to gene polymorphisms

Variable	Type of gene					
	II n=6		ID n=12		DD n=8	
	M	SD	M	SD	M	SD
1. Height (cm)	175.1	11.1	178.3	12.7	179.2	19.5
2. Weight (kg)	65.3	15.1	72.2	15.6	66.6	10.6
3. Body surface area (m^2)	1.75	0.11	1.78	0.12	1.79	0.1
4. Body mass index (BMI)	21.03	2.37	22.3	2.4	20.7	3.13
5. Mass of skeletal tissue (kg) (by Matiegka)	10.41	1.76	11.23	1.97	11.3	1.61
6. Relative mass of skeletal tissue (%) (by Matiegka)	16.31	1.74	15.8	1.42	17.2	2.61
7. Muscle mass (kg) (by Heyward)	33.4	7.32	37.2	8.35	33.6	5.44
8. Relative muscle mass (%) (by Heyward)	51.2	3.13	51.5	1.89	50.6	3.72
9. Mass of subcutaneous adipose tissue (by Matiegka)	5.3	1.15	5.95	1.52	5.1	0.82
10. Relative mass of subcutaneous adipose tissue (%) (by Matiegka)	8.14	1.04	8.36	1.55	7.74	0.76
11. Lean body mass (LBM) (kg) (by Wilmore)	59.96	11.96	64.96	11.71	61.3	8.28
12. Relative lean body mass (%) (by Wilmore)	92.6	4.28	90.8	4.32	92.4	3.07
13. LBM/BSA	34.05	4.37	36.1	4.43	34.17	4.11

and LBM also when LVMass is adjusted to body surface area (LVMass/BSA). Negative correlation was found between LVMass and relative mass of subcutaneous adipose tissue (r = –0.479). The linear correlation between LVVd and components of body composition (r = 0.57...0.45) was lost when LVVd was adjusted to BSA. The thickness of left ventricular posterior wall is associated with absolute values as well as with relative values of skeletal and muscle mass of body composition (r = 0.58...0.48). No connection has been found between body composition and interventricular septum thickness.

Analysing the relations of heart morphology with ACE polymorphism (Table 4), we found a statistically significant difference ($p<0.05$) between the parameters of subjects in different groups. The values of LV inner long axis in diastole (LAXind), absolute (LVVd) and relative (LVVd/BSA) value of left ventricular volume, and relative left ventricular mass (LVMass/ BSA) were higher in the I/D group, when compared to both homozygous groups. Tendency, in relation of LVMass / LVVd, showing the highest values in I/D group

Table 4. Characteristic of left ventricle according to gene polymorphisms

	Type of gene						Significance
	I II n=6		II ID n=12		III DD n=8		
	M	SD	M	SD	M	SD	
LVIDd (mm)	49.00	4.30	48.20	5.41	48.80	5.70	
LAXexd (mm)	78.60	7.40	83.90	8.00	74.70	8.20	2:3
LAXind (mm)	65.00	9.40	71.30	7.10	63.40	7.10	2:3
STd (mm)	10.50	1.68	11.30	1.73	11.00	1.62	
PWd (mm)	9.80	1.68	10.50	1.64	10.20	1.61	
LVVd (ml)	182.80	72.00	196.00	55.60	146.50	3.70	
LVMass (g)	183.40	49.70	199.00	57.80	194.80	59.50	
LVMass/BSA (g/m^2)	103.90	23.10	112.70	28.40	104.00	33.20	2:3
LVVd/BSA (ml/m^2)	103.60	37.10	110.70	26.00	84.80	21.40	2:3
STd/PWd	1.09	0.17	1.10	0.13	1.07	0.14	
LVMass/LVVd (g/ml)	1.62	0.31	1.77	0.32	1.65	0.31	

comparing to others was found. No significant difference between genotypes was observed in LVIDd or thickness of left ventricular walls. This is in correlation with the observations of other investigators [11]. As D allele is considered to be a relevant factor modifying the left ventricle, we looked upon correlation of interventricular

Table 5. Correlation coefficients (by Pearson) between basic somatometric parameters and indices and left ventricle parameters and indices

Anthropometrical parameters	Heart parameters											
	LVIDd	LAXexd	LAXind	STd	PWd	$LVVd_1$	LVVd	LVmass	LVmass/ BSA	LVVd/ BSA	STd/ PWd	$LVVd_1$/ LVmass
1. Height (cm)	0.48	0.33	–	–	0.51	0.46	0.54	0.52	–	–	–	–
2. Weight (kg)	0.56	0.48	0.47	0.40	0.57	0.54	0.58	0.64	0.52	–	–	–
3. Body surface area (m^2)	0.48	–	–	–	0.51	0.49	0.49	0.52	–	–	–	–
4. Body mass index (BMI)	0.48	0.43	0.40	–	0.48	0.46	0.45	0.57	0.55	0.41	–	–
5. Mass of skeletal tissue (kg) (by Matiegka)	0.55	–	–	–	0.48	0.51	0.51	0.58	0.43	–	–	–
6. Relative mass of skeletal tissue (%) (by Matiegka)	–	–0.50	0.40	–	–0.39	–	–0.45	–	–	–	–	–
7. Muscle mass (kg) (by Heyward)	0.50	0.43	0.43	–	0.50	0.48	0.49	0.54	0.43	–	–	–
8. Relative muscle mass (%) (by Heyward)	–	–	–	–	–	–	–	–	–	–	–	–

Anthropometrical parameters	Heart parameters											
	LVIDd	LAXexd	LAXind	STd	PWd	$LVVd_1$	LVVd	LVmass	LVmass/ BSA	LVVd/ BSA	STd/ PWd	$LVVd_1$/ LVmass
9. Mass of subcutaneous adipose tissue (by Matiegka)	–	0.41	0.5	–	–	–	0.44	–	–	–	–	–
10. Relative mass of subcutaneous adipose tissue (%) (by Matiegka)	–	–	–	–0.48	–	–	–	–0.47	–0.45	–	–	–
11. Lean body mass (LBM) (kg) (by Wilmore)	0.56	0.49	0.46	0.43	–0.57	–0.52	–0.57	0.65	0.54	–	–	–
12. Relative lean body mass (%) (by Wilmore)	–0.55	–0.44	–0.45	–	–0.57	–0.52	–0.55	–0.59	–0.49	–	–	–
13. LBM/BSA	–	–	–	0.42	–	–	–	–	–	–	–	–

septum thickness (STd) and values of left ventricular mass to frequency of both alleles. In the cases when STd was = ≥11 mm the prevalence of D allele was 61%, STd <11 mm the frequency of D allele was 45%. In respondents with LVMass = ≥200g the frequency of D allele was 62.5%, with LVMass <200g – 45.5%.

Although the boys were physically active, participating in basketball practice at least four times a week, we believe that there is no basis to consider that the relative mass of heart muscle is related to training in this age group. This conclusion is based on our clinical experience (data not published) and on the results of other investigators [16]. In our opinion, it is more correct to assume that at this age the growth of organs, especially of the heart, and of the body as a whole is determined by the coexistence of many factors from which the genetic factors are not the least important, leaving physical activity as the outcome of genetic background. It is also our opinion that despite the small group, the indicated correlations between different parameters of body composition, especially between LBM and LVMass are reliable and useful markers evaluating the remodulation of heart during puberty. Whether it is useful in predicting possible hypertrophy of cardiac muscle, is to be seen in the future.

The polymorphism of ACE gene has been shown to have strong influence on morphological parameters of heart both in healthy subjects and in pathological conditions. The exact role of I/D polymorphism of the ACE gene on the growth of heart during puberty will be the subject of our further investigations.

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THE DESIRED BODY WEIGHT OF 15–17-YEAR-OLD ESTONIAN SCHOOLCHILDREN

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ABSTRACT

The aim of the present study was to investigate adolescents' attitude to their own body weight, using BMI as a characteristic of body composition. In the early 1990s, thinness became again a symbol of success for high-achieving young women. In healthy pediatric population BMI is a valid measure of fatness for both sexes. The average BMI of 15–17-year-old girls was 20.25±2.4 kg/m^2 and of boys 20.74±2.4 kg/m^2. A high proportion of normal-weight girls considered themselves overweight whereas the BMI 24 kg/m^2 was seen by all girls as a cut-off point for the desire to weight less. For both genders, satisfaction with their own weight decreased significantly as BMI increased. Girls, however, showed significantly greater dissatisfaction with their body weight than boys.

Keywords: adolescent, body mass index, weight

INTRODUCTION

The history of art shows us that thinness has become beautiful during the periods of upheaval, transition and war, and when new knowledge becomes important. Plumpness is seen as more attractive during periods of stability. If the standards of weight and beauty keep changing, and the importance of "ideal weight" has not really been established medically or objectively, how do we judge "how fat is fat?" W. Shakespeare has said in a poetic way: "Beauty is in the eyes of the beholder." [1] In the early 1990s, thinness once again became a symbol of success for high-achieving young women. Even classically beautiful women may see themselves as fatter than they really are and push to be "stringbean" thin[2]. Comparison of prevalence data on obesity in children and adolescents around the world is difficult because of the lack of standardisation and interpretation of indicators of being overweight or obese in these age groups; hence different percentile cut-off points are used for the definition of being overweight or obese (e.g. the 85th percentile in the USA, the 90th in Estonia, the 97th in France). WHO has tentatively recommended the use of body mass index (BMI) for age as an indicator of individuals' body composition [3, 4]. There exists a strong correlation between body mass index (kilograms per meter square) (BMI) and body composition components or skin-fold thickness, and BMI can be used as a screening tool for pediatric obesity. In healthy pediatric population BMI is a valid measure of fatness for both sexes [5, 6] as a safe, simple, non-invasive and reliable method both for research and clinical work. Measurements of weight and height, even those reported by the subjects themselves, are highly accurate and do not contribute importantly to errors in assessing body-mass index [6].

The aim of the present study was to investigate adolescents' attitude to their own body weight, using BMI as a characteristic of body composition.

SUBJECTS AND METHODS

The participants in the study were 488 girls and 336 boys, in total 824 schoolchildren, from four secondary schools in Tartu. According to their ethnic origin, 99.1% of the respondents were Estonians with the mean age of 15.9 years (15–17-years-olds). The data were collected in a classroom situation, using a self-administered questionnaire containing items on the adolescents' health status, perception of weight status and desired weight. The question asked about self-perceived weight was: "Would you like to weigh more, weigh less, or you are satisfied with your current weight?" The anthropological measurement of height and weight was made during the forenoon by the school nurse according to the classical methods of Martin [7]. The body mass index (BMI) as weight in kilograms divided by squared height in meters was calculated, and the respondents were grouped by BMI kg/m^2 into five classes as follows: 1) less than 17.5 kg/m^2 (in the medical sense "under-weight"); 2) from 17.5 to 19 ("thin"); 3) from

19 to 24 kg/m^2 ("normal-weight"); 4) from 24 to 27.5 kg/m^2 ("overweight") and 5) over 27.5 kg/m^2 ("obese"). All the computations were made using the Statistical Package for the Social Sciences (SPSS), version 8.0 for Windows. Chi-square was used to test significance of the difference between proportions, $p<0.05$ was selected as the criterion of statistical significance.

RESULTS

The average BMI of girls was 20.25±2.4 kg/m^2 and of boys 20.74±2.4 kg/m^2 (see Table 1). The biggest part, 62.0% of girls and 69.2% of boys, belonged to the third BMI class; 5,6% of girls and 7.5% of boys belonged to the fourth or fifth BMI class, whereas 32.4% of girls and 23.2% of boys belonged to the first or second BMI class. About every eleventh of girls and every eighteenth of boys belonged to the first BMI class (see Figure 1). In total 54% of girls and 78% of boys were satisfied with their own body weight and assessed it as desired, whereas in both genders the satisfaction with body weight was in statistically significant correlation with BMI ($p = 0.000$). The highest score (78.4%) of satisfaction of girls with body weight was in the second BMI class, but most (75.9%) of girls in the first BMI class were also satisfied with their own body weight. All girls in the fourth and fifth BMI class desired to weigh less. Only very few girls desired to weigh more, even in the first BMI class (see Figure 2a).

Boys were significantly more satisfied with their own body weight than girls. The highest prevalence of satisfaction was seen among the respondents who belonged to the third BMI class (84.3%), followed by the boys from the second BMI class with 69.5% and from the fourth BMI class with 65% of prevalence of satisfaction. Half of the boys in the first BMI class were satisfied with their body weight, and half of them desired to weigh more. All the boys in the fifth BMI class desired to weigh less (see Figure 2b). Satisfaction with one's own body weight did not differ by chronological age and by gender, but statistically significant correlation was found in female respondents between satisfaction with weight and sexual maturation, assessed by gynaecologic age. So, increased level of dissatisfaction with body weight was found in older gynaecologic age as follows: in the group of girls with the gynaecologic age of up to two years ($n = 195$) 63% of respondents were satisfied with their body weight and 34% desired to weigh less, in the group of respondents with the gynaecologic age of three or more years (n = 277) only 46% of respondents were satisfied with weight and 53% desired to weigh less (p = 0.000).

Table 1. Characteristics of BMI of respondents by age

Age in years		BMI of girls	BMI of boys
15	N	172	117
	Mean	19.77	20.03
	Minimum	13.68	15.32
	Maximum	29.75	31.14
16	N	179	123
	Mean	20.54	20.87
	Minimum	15.06	16.46
	Maximum	29.76	32.49
17	N	137	96
	Mean	20.49	21.29
	Minimum	16.14	16.41
	Maximum	30.67	28.73
Total	N	488	336
	Mean	20.26	20.69
	Minimum	13.68	15.32
	Maximum	30.67	32.49
Percentiles	3	16.42	16.99
	10	17.66	17.92
	50	19.96	20.45
	80	21.89	22.20
	90	23.18	23.48
	97	25.91	26.52
	99.8	30.67	32.49

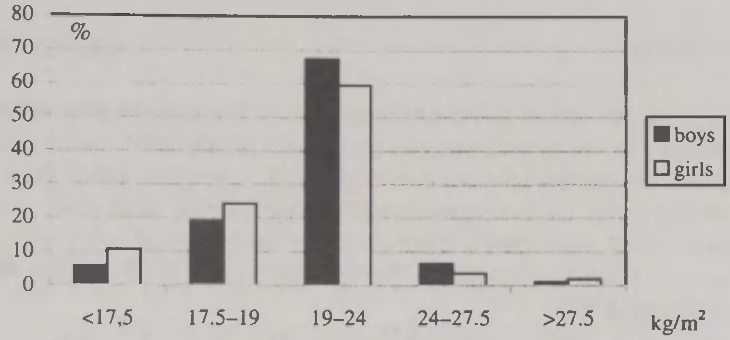

Figure 1. Distribution of respondents by BVI classes.

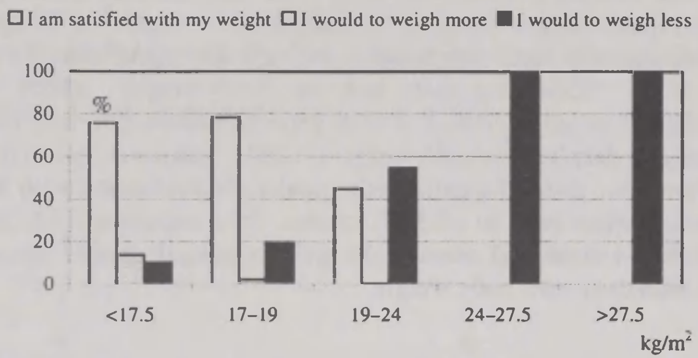

Figure 2a. Distribution of girls' answers to the question about satisfaction with their own body weight by BMI classes.

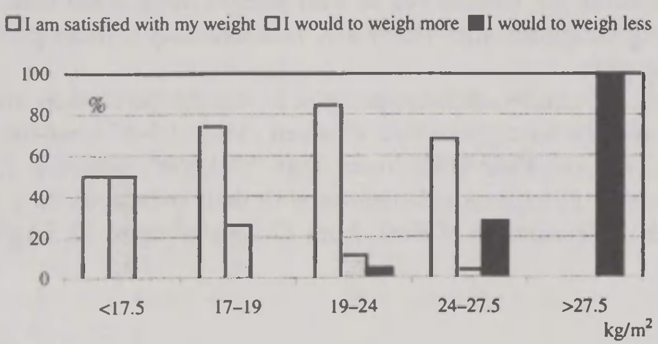

Figure 2b. Distribution of boys' answers to the question about satisfaction with their own body weight by BMI classes.

DISCUSSION

Adolescents' reports of whether they consider themselves overweight, underweight or of normal weight correlated poorly with the medical definitions of overweight, underweight and normal weight, particularly among girls. So three quarters of the girls in the BMI class lower than 17.5 kg/m^2 considered themselves as having ideal body weight, without any desire to change it, whereas every tenth in this group even desired to weigh less.

A high proportion of normal-weight (BMI from 19 to 24 kg/m^2) girls considered themselves as overweight (54.7%), whereas 24 kg/m^2 of BMI was seen by all the girls as a cut-off point for the desire to weigh less. Among boys, half of those with BMI less than 17.5 kg/m^2 and three quarters in the group with BMI from 17.5 kg/m^2 to 19 kg/m^2 were satisfied with their own weight. For boys 27.5 kg/m^2 was the cut-off point for considering their body as "over-weight", which was higher than reported by girls. For both genders, satisfaction with one's own weight decreased significantly as BMI increased ($p = 0.000$). Girls, however, showed significantly greater dissatisfaction with their body weight than boys in all BMI classes. In comparison with boys, both normal-weight and overweight girls expressed greater dissatisfaction with their own body weight.

CONCLUSION

1. Adolescents see themselves as over-weight more often than, considering their BMI, they really are. This tendency is more prevalent among girls.
2. Significant gender differences exist in weight perception and desired weight among teenage children. Thus 15–17-year-old girls desire to have their BMI lower than 19 kg/m^2, whereas 15–17-year-old boys express satisfaction with their own body in a wider stretch of distribution of BMI, from 17.5 kg/m^2 up to 27.5 kg/m^2.

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ASSESSMENT OF BODY COMPOSITION BY BIOELECTRICAL IMPEDANCE ANALYSIS IN CHILDREN: A REVIEW

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ABSTRACT

Bioelectrical impedance analysis (BIA) is a simple and quick *in vivo* body composition assessment method in children. The BIA method is based on the relationship between the volume of the conductor (i.e., the human body), the conductors' length, the components of the conductor and its impedance. Total body impedance, measured at the constant frequency of 50 kHz, primarily reflects the volumes of water and muscle compartments comprising the fat free mass and the extracellular volume. At low frequency, body impedance is a measure of extracellular water and at high frequency body impedance is a measure of intracellular water. Differences in the distribution of fluids between intra- and extracellular compartments, which occur during growth, could help to explain the variability in the prediction of fluid status or change in fluid status in children. The measurement of children's body composition using the BIA method utilises a resistance index (stature squared divided by resistance [S^2/R]) in different regression equations. There is a need to use additional anthropometric measures than stature alone to better predict body composition in children. It is important to add girth parameters to body stature in the prediction of children's body composition. In addition, segmental body impedance, which measures the resistance of different body segments, could be used to estimate regional body composition. However, it must be taken into account that age-specific prediction equations should be used in the measurement of body composition by the BIA method in children.

Keywords: body composition, bioelectrical impedance, children

During the last decades researchers have expressed an increased interest in the assessment of body composition. To track changes in body composition during childhood, there is a need for accurate assessment of body composition of children in laboratory, clinical and field settings. Many methods and prediction equations are currently available, but none are without limitations.

Bioelectrical impedance analysis (BIA) method is an appealing tool for *in vivo* assessment of body composition because it is simple, quick and inexpensive to perform. Theoretically, the bioelectrical impedance method is based on the relationship between the volume of the conductor (i.e., the human body), the conductors' length, the components of the conductor and its impedance. It is assumed that the total conductive volume of the human body is equivalent to that of total body water, most of which is contained in muscle tissue and that the hydration of adipose tissue is minimal [3, 9, 20]. Total body impedance, measured at the constant frequency of 50 kHz, primarily reflects the volumes of water and muscle compartments comprising the fat free mass and the extracellular water volume [3, 6, 20]. The resistance to current flow is greater in individuals with large amounts of body fat as adipose tissue is a poor conductor of electrical current due to its relatively small water content [9, 20]. Because the water content of fat free body is relatively large (73% water), fat free mass can be predicted from total body water estimates. Individuals with a large fat free mass and total body water have less resistance to current flowing through their bodies in comparison with persons having a smaller fat free mass [9, 20].

However, intracellular penetration is not complete at the frequency of 50 kHz. As the cell membrane behaves as an electric capacitor, alternating currents at low frequency are not able to penetrate the cell. Thus, at low frequency the impedance of the human body is a measure of intracellular water. With increasing frequency the reactance of the cell membrane decreases and finally disappears. Accordingly, at high frequency bioelectrical impedance is a measure of total body water [6, 9]. Measures of bioelectric impedance at higher frequencies have been reported to discriminate between the volumes of intracellular and total body water in the human body [3, 6, 9, 20]. Differences in the distribution of fluids between intra- and extracellular compartments, which occur during growth and development, could help to explain the variability in the prediction of fluid status or change in fluid status in children. It should be important to measure extracellular water compartment with bioelectrical impedance because extracellular water volume is about 20–30% of body mass, and changes in extracellular water volume also occur in malnutrition [6].

The new impedance instruments are able to measure body impedance at more than one frequency, ranging from low (about 1 kHz) to very high (> 1 mHz) [6, 9]. At low frequency, body impedance is a measure of extracellular water and at high frequency body impedance is a measure of intracellular water. Multifrequency impedance analysers could be used to monitor changes in fluid status in children, as the variation in hydration of fat free mass is relatively high in children [15].

Total body water and fat free mass are significantly related to the stature squared divided by resistance (S^2/R) [3, 14]. As in adults, the measurement of body composition in children using bioelectrical impedance analysis method utilises this resistance index (S^2/R) in different regression equations. Most researchers confirm that the presented index is applicable for the calculation of different body composition parameters [3, 6, 9, 17, 18, 19]. However, some researchers [14, 19] have recommended additional anthropometric parameters to stature to be used in prediction equations. In addition to the resistance index, the independent variables used most often by investigators in their prediction equations are body mass, arm circumference, sex and age [6]. The main problem is that stature is not the correct length of the conductor. The true length of the conductor could be better represented by acromial stature and arm length [5]. In our recent investigation [19], stature alone characterised only 1.9% ($p>0.05$) and 3.8% ($p<0.05$) of the total variance in prepubertal boys and girls, respectively. A better predictor of body resistance appeared to be body stature and mass combined (27.1% and 20.7%, respectively) [19].

There is a need to use additional anthropometric measures than stature alone to present new prediction equations for calculation of body composition in children. A study of young adults, using body mass, upper arm and calf circumferences, and seven skinfold thicknesses, found that about 70% of the variance in body resistance could be accounted for by a small set of anthropometric variables such as arm and calf circumferences [3]. Significant correlations with body resistance have been reported for body mass, upper arm and calf circumferences, upper arm and calf muscle areas, ratios of limb segments to their lengths, and also some skinfold thicknesses [3]. Our recent investigation of 9–11-year-old boys and girls also indicated that the best predictors of body resistance were girth parameters, which characterised about 30–50% of the total variance in body resistance [19]. This could be explained by the fact that the cross-sectional area of the human body is not constant, and the parts with the smallest cross-sectional areas primarily determine the resistance of the human body [3]. However, it is interesting to note, that not only small limb girths but also gluteal and waist girths in boys and girls, respectively, were added to the prediction model. Girth ratios such as waist/hip and waist/thigh have been used by most investigators as a measure of fat distribution with variable results. In our recent study in children [19], correlations between body resistance and waist/thigh ratio were only moderate, although significant, in boys and girls. Probably, the waist/thigh ratio is more important because this ratio contains the girth of lower limb in which body resistance is relatively high.

As in adults [2], body length parameters only slightly influence body resistance in children [19]. This is surprising as body resistance depends on the conductor length. Potentially, the very small girth of the upper and lower body in children is a higher predictor than the length of the limbs. The influence of skinfold thicknesses to the body resistance was also found to be low in children, characterising less than 10% of the total variance [19]. The sum of skinfolds characterised 7.2% of body resistance in girls and 2.4% in boys [19]. This is due to the fact that body fat is a very bad electric conductor [3]. It is apparent that the use of traditional body stature as a single anthropometric measure used in the presentation of equations for body composition measurement in children is not acceptable. It is important to add girth parameters to body stature in the prediction of body composition in children.

The influence of somatotype on body resistance in children has also been studied [18]. The impact of ectomorphy on body resistance was significant both in boys ($r = 0.33–0.48$) and girls ($r = 0.21–0.43$), while the impact of endomorphy on body resistance was non-significant in boys and partly significant ($r = –0.19–0.30$) in girls. The mesomorphic component influenced negatively the body resistance in boys ($r = –0.49–0.65$) and girls ($r = –0.31–0.45$) [18]. The high correlation between body resistance and the mesomorphic component is not surprising as this somatotype component characterises the relative musculoskeletal robustness of the human body and is derived from biepicondylar femur and humerus widths, arm and calf circumferences corrected for skinfolds [4]. The thinner segments of the body provide greatest resistance when they are also long [11]. Regression analysis predicting body resistance indicated that only the mesomorphic component in boys (45.8%) and mesomorphic and ectomorphic components combined in girls (51.3%) were significant predictors of body resistance [18]. According to the results, it is apparent that relative robustness, and relative linearity and robustness are the components which highly influence body resistance in 9–11-year-old boys and girls, respectively.

Our recent investigation was conducted to compare the results of body resistance measured at different sites of the body in 9–11-year-old boys and girls [17]. It was hypothesised that the best possibility to obtain the true measurement of body resistance is to measure between the right leg and the left hand or between the left leg and the right hand. In addition, the possible differences in body resistance were compared when body resistance was measured traditionally between arm-to-leg on the right side of the body or on the left side of the body or between lower and upper extremities in children [17]

In all cases, the mean body resistance was significantly higher in girls than in boys (Table 1). The mean difference between the right and left side measurements at 50 kHz was 16.6 Ω (2.8%) and 17.2 Ω (2.7%) in boys and girls, respectively [17]. Resistance has been reported to be systematically greater on the left side than on the right side of the body [13, 17]. For example, Graves *et al.* [13] found that resistance was about 8 Ω greater on the left side than on the right side of the adult human body. The side on which resistance is measured must be the side where the body resistance was measured during the development of body composition predictive equation. The values of body resistance measured diagonally (right hand — left leg or left hand — right leg) were similar and comparable with right side body resistance measurements in both groups (Table 1) [17]. The results of this investigation did not confirm the hypothesis that it is more precise to measure body resistance diagonally between a hand and the opposite leg than on the right side of the body. The measurement of body resistance on the right side of the body is correct in children [17]

Table 1. Resistances and total body water (TBW), intracellular water (ICW) and extracellular water (ECW) measured at different sites of the body in boys and girls ($\bar{X} \pm SD$)

	Boys (n = 104)	Girls* (n = 105)
Right side		
5 KHz (Ω)	622.4 ± 65.0	671.1 ± 68.9
50 KHz (Ω)	578.8 ± 58.3	626.8 ± 56.6
200 KHz (Ω)	522.8 ± 53.6	564.2 ± 50.6

	Boys (n = 104)	Girls* (n = 105)
TBW (l)	24.3 ± 2.6	20.1 ± 2.9
ICW (l)	12.3 ± 1.4	8.9 ± 1.2
ECW (l)	12.0 ± 1.3	11.3 ± 1.2
Left side		
5 KHz (Ω)	637.5 ± 66.0	692.9 ± 69.4
50 KHz (Ω)	595.4 ± 61.3	644.0 ± 60.6
200 KHz (Ω)	540.8 ± 58.5	587.3 ± 54.0
TBW (l)	23.8 ± 2.5	20.0 ± 2.3
ICW (l)	12.0 ± 1.5	8.8 ± 1.3
ECW (l)	11.9 ± 1.2	11.1 ± 1.1
Hand-hand		
5 KHz (Ω)	687.8 ± 74.4	759.9 ± 83.6
50 KHz (Ω)	650.3 ± 71.0	713.5 ± 72.5
200 KHz (Ω)	592.6 ± 65.2	653 3 ± 64.6
TBW (l)	23.1 ± 2.6	19.1 ± 2.2
ICW (l)	11.5 ± 1.7	8.5 ± 1.1
ECW (l)	11.6 ± 1.3	10.7 ± 1.3
Leg-leg		
5 KHz (Ω)	525.9 ± 53.5	581.3 ± 61.9
50 KHz (Ω)	485.1 ± 48.9	532.5 ± 60.0
200 KHz (Ω)	439.1 ± 47.3	480.5 ± 58.2
TBW (l)	25.9 ± 3.4	22.0 ± 2.7
ICW (l)	12.9 ± 2.1	9.8 ± 1.4
ECW (l)	13.0 ± 1.5	12.2 ± 1.4
Right hand-left leg		
5 KHz (Ω)	635.8 ± 67.3	711.1 ± 72.8
50 KHz (Ω)	592.7 ± 60.4	657.5 ± 65.0
200 KHz (Ω)	539.2 ± 55.8	595.9 ± 59.9
TBW (l)	23.8 ± 2.7	19.9 ± 2.4
ICW (l)	11.9 ± 1.8	8.8 ± 1.3
ECW (l)	11.9 ± 1.2	11.1 ± 1.5
Left hand-right leg		
5 KHz (Ω)	632.4 ± 68.1	702.8 ± 69.5
50 KHz (Ω)	592.4 ± 61.7	650.8 ± 62.6
200 KHz (Ω)	539.2 ± 57.1	593.3 ± 51.6
TBW (l)	24.0 ± 2.7	19.9 ± 2.3
ICW (l)	12.0 ± 1.7	8.8 ± 1.2
ECW (l)	12.0 ± 1.3	11.0 ± 1.2

* All values are significantly different from boys, $p<0.001$

The lower and upper body resistances were higher than the whole body resistance (right arm — trunk — right leg) because of the relatively smaller volumes of these body segments in comparison with the trunk. The measured body resistance between hands was significantly higher than that measured between legs (Table 1) [17]. This could be explained by the fact that the breadths of the hands are slightly smaller than these of the legs. Thinner segments of the body provide greatest resistance. [11, 13].

Segmental body impedance, which refers to the measurement of body resistance of different body segments, is potentially important in the estimation of regional body composition [3, 20]. It has been reported that resistance is larger for the parts of the human body with the smallest circumferences [3]. For example, the arm contributes to only about 4% of body mass but as much as 45% to the resistance of the whole body [11]. In contrast, the trunk, which has a large cross-sectional area, contributes to about 46% of body mass but is responsible for only about 11% of the whole body resistance [11]. Electrode placements for the separate measurement of the major body segments (e.g., arm, leg, trunk) have been described [5, 11], but a standardised procedure has yet not been recognised [8]. It has been demonstrated that the values of bioelectrical impedance were larger in women than in men for the limbs, while the sex differences were not significant for the trunk region of the body [20]. The same pattern of sex differences occurs in children, except that the bioelectrical impedance of the trunk is larger in boys than in girls [2].

The positioning of the electrodes appears to be important both for whole body and segmental bioelectrical impedance measurements [3]. The displacement of the source electrodes proximally by 1 cm, on either the hand or the foot, reduces the measured resistance by 2.1% [3]. It has been suggested that interobserver differences associated with the placement of electrodes can be reduced when the sites of electrode placement are marked [3]. However, when the source and receiving electrodes are placed closer together than 4–5 cm, electron polarization may occur that will increase the resistance [3.] This problem may limit the use of bioelectrical impedance methods to children [3]. For example, in their study of 3–10-year-old children, Barillas-Mury *et al.* [1] were able to separate the electrodes sufficiently to stabilise resistance on the feet but not on the hands. To solve the problem on the hand, the researchers placed one signal electrode on the dorsal wrist and one source electrode on the dorsal aspect of the forearm 6 cm proximal to the wrist [1]. It appears that the placement of electrodes is critical for obtaining accurate BIA measurements in children.

Age-specific prediction equations have also been recommended for bioelectrical impedance analysis (Table 2) [3, 7, 16, 20, 21]. Age-related differences in the electrolyte concentration in extracellular water space relative to intracellular water space may alter the relationship between bioelectrical resistance and total body water [7]. However, Houtkooper *et al.* [16] reported that including age as a predictor did not significantly improve the predictive accuracy of their bioelectrical impedance analysis equation. The prediction formula of Houtkooper *et al.* [16] for white boys and girls was developed using a three-component model that adjusted body density for total body water. This prediction equation has been cross-validated on samples from three different laboratories with its prediction error of 2.1 kg [16].

Table 2. Body composition prediction equations for children

Method	Gender	Age	Prediction equations	Reference
BIA	M/F	7–9	$FFM = 0.640 \times 10^4 \times S^2/R + 4.83$	Deurenberg *et al.* [7]
BIA	M/F	10–19	$FFM = 0.61 (S^2/R) + 0.25 (BW) + 1.31$	Houtkooper *et al.* [16]
BIA, and anthropometry	M	7–25	$FFM = -2.9316 + 0.6462 (BW) - 0.1159 (calf\ SF) - 0.3753 (midaxillary\ SF) + 0.4754 (arm\ CF) + 0.1563(S^2/R)$	Guo *et al.* [14]
	F	7–25	$FFM = 4.3383 + 0.6819 (BW) - 0.1846 (calf\ SF) - 0.2436 (triceps\ SF) - 0.2018 (subscapular\ SF) + 0.1822 (S^2/R)$	Guo *et al.* [14]

BIA — bioelectrical impedance analysis; M — males; F — females; FFM — fat-free mass; S — stature; R — resistance; BW — body weight; SF — skinfold; CF — circumference.

Other bioelectrical impedance prediction equations recommended to be used in children have been developed by Guo *et al.* [14]. These regression equations to predict the fat free mass for males and females had R^2 values of 0.98 and 0.95, and standard errors of estimates (SEEs) of 2.3

and 2.2 kg, respectively [14]. The retained predictor variables were body mass, calf and midaxillary skinfolds, S^2/R index and arm circumference in males [14]. For females, the retained predictor variables were body mass, calf, triceps and subscapular skinfolds, and S^2/R index [14]. There was no tendency for these equations to overpredict or underpredict for different parts of the distribution of values for fat free mass [14]. These regression equations have been used in Fels' longitudinal study to predict percent body fat in children [20]. In their study, Evetovich *et al.* [10] evaluated the validity of 11 existing bioelectrical impedance equations found in literature for a group of 11-year-old male athletes (n = 117) and found that the equation of Guo *et al.* [14] most accurately estimated the fat free mass of subjects (SEE = 1.99 kg).

Bioelectrical impedance technique has been cross-validated in children against dual energy X-ray absorptiometry (DEXA) [12], total body water [3] and total body potassium [3, 21] methods. Schaefer *et al.* [21] estimated the fat free mass from ^{40}K whole body counting in 112 healthy children and demonstrated that the fat free mass could be estimated from biolelectrical impedance and age with an R^2 value of 0.98. In another independent cross-validation investigation in 98 white children, the fat mass measured by DEXA (4.8±3.0 kg) was significantly different from the fat mass measured by bioelectrical resistance (5.7±3.4 kg), although the fat masses obtained by these two techniques were strongly related ($R^2 = 0.75$) [12].

In summary, it can be concluded that the BIA method is a promising method for the measurement of body composition in children. However, there is a great need for new regression equations to calculate body composition in children, because body impedance in children is mostly influenced by girth parameters.

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CHANGES DURING ONE YEAR IN THE ANTHROPOMETRIC PARAMETERS OF PREPUBERTAL BOYS

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ABSTRACT

The aim of the study was to investigate changes in different anthropometric parameters of prepubertal boys during one year. The subjects of the study were 104 boys aged 9–11 years at the first measurement. The second measurement in the same conditions was organised one year later. All children were classified as prepubertal according to Tanner stage 1, except 21 boys who were at Tanner stage 2. Stature was measured by Martin metal anthropometer and body mass with medical scales. In total, nine skinfold, 13 girth, eight length and eight breadth/length parameters were measured. During one year the mean body stature increased by 5.23 cm, body mass by 4.16 kg and BMI by 0.67 kg/m^2. Body stature, body mass and BMI tracked highly ($r = 0.88–0.97$, $p<0.01$). The measured skinfolds tracked between $r = 0.75–0.86$. Girth ($r = 0.75–0.96$), length ($r = 0.81–0.96$) and breadth/length ($r = 0.75–0.96$) parameters tracked also about the same level. It was concluded that all the measured anthropometric parameters increased significantly during one year in mostly prepubertal boys.

Keywords: skinfolds, girths, lengths, breadths/lengths, children

INTRODUCTION

Body size and proportions, physique and body composition are important factors in children's growth and anthropometric development. Historically, body stature and body mass, both indicators of overall body size, have extensively been used in combination with age and sex to identify the anthropometric development of children. Physique is the body form of an individual, the configuration of the entire body rather than of its specific features, and is commonly referred to as body build.

It has been demonstrated many years ago that organs grow at different rates, and that these rates can differ from the growth rate of the human body as a whole [6, 12]. Furthermore, children can grow up in a normal process, where growth proceeds in successive steps, or the growth process can be influenced by individual variation to genetic and/or environmental factors [12]. This variation makes it difficult to predict adult body composition from childhood measurements. However, numerous growth grids have been compiled and are used for the evaluation of the growth level of children [4, 10]. Most investigations concern the whole growth period from birth to maturity, especially these which are focused on ontogenetical changes in stature and body mass [2, 10, 13]. There are only very few longitudinal data about complete changes in the anthropometrical parameters (skinfolds, girths, lengths and breadths/lengths) in prepubertal children.

The aim of this study was to investigate the changes during one year in different anthropometric parameters in prepubertal boys.

METHODS

The subjects of this investigation were 104 boys aged 9–11 years at the first measurement. The second measurement in the same conditions was organised one year later. The boys were from several schools in Tartu and all of them were ethnic Estonians. Their physical education at school consisted of 2–3 physical education classes per week. All children, parents and teachers were thoroughly informed about the purposes and contents of the study and written informed consent was obtained from the parents or the adult probands before participation. The study was approved by the Medical Ethics Committee of the University of Tartu.

Measurements were performed at school in the morning after emptying the bladder. All the children had had a light traditional breakfast. The children did not exercise before testing. All children were classified prepubertal according to Tanner stage 1, except 21 boys who were at Tanner stage 2.

Stature was measured in centimetres (±0.1 cm) using a Martin metal anthropometer and body mass with medical scales in kilograms (±0.05 kg), and BMI (kg/m^2) was calculated. All the other parameters were measured according to the protocol recommended by the International Society for Advancement of Kinanthropometry [9]. In total, nine skinfolds (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, medial calf, mid-axilla), 13 girths (head, neck, arm relaxed, arm flexed and tensed, forearm, wrist, chest, waist, gluteal, thigh, thigh mid trochanter-tibiale laterale, calf, ankle), eight lengths (acromiale-radiale, radiale-stylion, midstylion-dactylion, ilospinale-box height, trochanterion-box height, trochanterion-tibiale laterale, tibiale-laterale to floor, tibiale mediale-sphyrion tibiale) and eight breadth/lengths (biacromial, biiliocristal, foot length, sitting height, transverse chest, A-P chest depth, humerus, femur) were measured. The anthropometric measurements were taken by a trained anthropometrist who had previously shown test-retest reliability of r = >0.90. The CENTURION KIT instrumentation was used (Rosscraft, Surrey, BC, Canada), except for skinfold thicknesses, which were measured using Holtain (Crymmych, UK) skinfold calipers.

Descriptive statistics (mean ± standard deviation [SD]) for each of the dependent variables were determined. Differences between the first and the second measurements were estimated with independent t-tests with an error of estimate set to 0.05. Pearson Product Moment Correlation coefficients (tracking coefficients) were used between the first and second measurements. An alpha level of 0.05 was used.

RESULTS

Changes in the anthropometric parameters of prepubertal boys during one year are presented in Table 1. Mean body stature increased by 5.23 cm, body mass by 4.16 kg and BMI by 0.67 kg/m^2. All these changes were highly significant ($p<0.001$). All the measured skinfold thicknesses also increased highly significantly ($p<0.001$). The girth parameters increased at the level of $p<0.001$, except the head and neck girths which increased at the level of $p<0.05$. Like other anthropometrical parameters, the measured lengths increased mostly at the level of $p<0.001$, except midstylion-dactylion and iliospinale box height ($p<0.05$). The measured breadths/lengths also increased at the level of $p<0.001$.

Table 1. Changes in anthropometrical parameters of prepubertal boys during one year

	First measurement	Second measurement	p	r
Stature (cm)	143.39±7.27	148.62±7.79	<0.001	0.97
Body mass (kg)	35.27±5.71	39.43±7.20	<0.001	0.94
BMI (kg/m^2)	17.07±1.78	17.74±2.14	<0.001	0.88
Skinfolds (mm)				
Triceps	9.97±3.01	11.54±4.24	<0.001	0.85
Subscapular	7.33±3.50	9.36±4.60	<0.001	0.83
Biceps	6.23±2.53	7.40±3.31	<0.001	0.75
Iliac crest	8.67±4.82	11.17±6.39	<0.001	0.80
Supraspinale	5.13±2.56	6.89±4.10	<0.001	0.79
Abdominal	8.73±5.07	11.32±6.91	<0.001	0.86
Front thigh	16.46±5.59	19.03±7.47	<0.001	0.86
Medial calf	12.32±4.49	14.41±5.34	<0.001	0.85
Mid-axilla	5.40±1.95	6.53±2.99	<0.001	0.82
Girths (cm)				
Head	53.25±1.43	53.43±1.38	<0.05	0.75
Neck	28.00±1.87	28.90±4.06	<0.05	0.87
Arm (relaxed)	20.08±2.00	21.00±2.32	<0.001	0.87
Arm (flexed and tensed)	21.70±2.01	22.90±2.62	<0.001	0.85
Forearm	19.79±1.37	20.58±1.69	<0.001	0.84
Wrist	13.58±0.86	14.42±0.82	<0.001	0.88
Chest	68.44±4.66	70.23±5.42	<0.001	0.89
Waist	59.96±4.39	62.38±5.43	<0.001	0.87
Gluteal	71.62±5.47	75.08±6.75	<0.001	0.84
Thigh	42.44±4.15	44.64±4.88	<0.001	0.90
Thigh (mid tro-tib-lat)	39.10±3.52	40.42±3.81	<0.001	0.77
Calf	28.44±2.37	29.81±2.74	<0.001	0.96
Ankle	18.66±1.48	19.68±1.52	<0.001	0.68
Length (cm)				
Acromiale-radiale	30.34±1.80	32.05±2.04	<0.001	0.96
Radiale-stylion	22.88±1.51	23.68±1.51	<0.001	0.88
Midstylion-dactylion	16.64±1.07	16.90±1.08	<0.05	0.90
Ilospinale b. ht	82.67±5.10	84.09±8.56	<0.05	0.89
Trochanterion	76.00±4.61	78.32±4.76	<0.001	0.93
Trochanterion-tibiale-laterale	38.94±2.73	40.14±2.48	<0.001	0.81
Tibiale-laterale to floor	37.02±2.54	38.24±2.61	<0.001	0.89
Tibiale mediale	29.33±2.21	31.57±2.28	<0.001	0.88

	First measurement	Second measurement	p	r
Breadths/lengths (cm)				
Biachromial	31.76±1.86	33.16±2.13	<0.001	0.75
Biiliocristal	21.87±1.56	23.30±1.68	<0.001	0.89
Foot length	22.32±1.63	23.40±1.56	<0.001	0.77
Sitting height	75.67±3.57	77.92±3.98	<0.001	0.88
Transverse chest	21.90±2.59	22.78±1.60	<0.001	0.81
A-P chest depth	15.07±2.19	16.43±4.81	<0.001	0.90
Humerus	6.10±0.38	6.17±0.46	<0.001	0.93
Femur	8.82±0.46	8.99±0.51	<0.001	0.96

The Pearson correlations (tracking coefficients) between the first and the second measurements are also presented in Table 1. The correlations of body stature and body mass were very high (r = 0.94–0.97) while the correlation of BMI was slightly lower (r = 0.88). Skinfold thickness tracked between 0.75–0.86. Girths (r = 0.75–0.96), lengths (r = 0.81–0.96) and breadths/lengths (r = 0.75–0.96) parameters tracked also at about the same level.

DISCUSSION

The main purpose of longitudinal studies is to investigate individual changes in time. Longitudinal data provide an opportunity to describe variation in intensity, velocity, and timing of individual patterns of growth. The longitudinal method "is the only approach which gives a complete description of the growth phenomena" [3]. Malina [8] has recommended to interpret tracking correlations as follows: <0.3 = low, 0.3–0.6 = moderate and >0.6 = high. However, Bloom [1] has suggested a correlation of 0.5 as a criterion for a minimum level of consistency over at least a one year interval.

In our study, body stature and body mass tracked very highly during one year (see Table 1). Other similar studies have presented slightly lower correlations [11]. However, the tracking time has been longer [11]. Body stature tracks at different degrees from infancy to adulthood. The correlation is weak during early childhood but rises steeply until five years of age. It decreases between the ages of 11 and 14 years and then raises to match the five-year level at the age of 15 [11].

Skinfold thicknesses tracked highly during one year in our boys (see Table 1). Research has demonstrated that fatter children have a stronger tendency to be obese in adult life [5]. However, a 20-year follow-up study by Garn and Lavelle [7] indicated that obesity does not track strongly.

There are no available data about the relatively short time tracking on different girth, length and breadth/length parameters in prepubertal children. Our results indicate that the tracking coefficients were high — higher than 0.70 in all time. It could be explained by the harmonious development of the child.

We could conclude that, in mostly prepubertal boys, all the anthropometric parameters increased significantly during one year. The tracking coefficients were also high.

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MEASUREMENT OF BODY COMPOSITION BY LIPOMETER AND BIOELECTRICAL IMPEDANCE ANALYSIS IN SPORTSMEN

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ABSTRACT

The aim of the study was to compare different body composition parameters in sportsmen using a new LIPOMETER device and bioelectrical impedance analysis (BIA). In total 30 sportsmen (21.7±3.1 yrs, 183.1±5.9 cm, 75.5 kg, BMI 22.6±2.0) were studied. They mostly practised endurance sport events or sport games. Their body composition was measured by LIPOMETER (Austria) measuring the subcutaneous adipose tissue thickness at 15 specified body sites. The body composition was also measured by the multiple-frequency impedance (BIA) device MULTISCAN-5000 (Bodystat Ltd, UK). The mean body fat percentage was slightly lower when measured by LIPOMETER as compared to BIA (9.76±4.68 and 10.50±2.07% respectively; $p>0.05$). There were highly significant relationships between body fat percentage as measured by the two different methods ($r = 0.89$). The correlation is also high between the two different methods on the lean body mass ($r = 0.87$). We can conclude that the body composition parameters measured by LIPOMETER and BIA are similar.

Keywords: lipometer, BIA, sportsmen

INTRODUCTION

As direct measurement of body composition in vivo is not possible in living humans, a series of indirect estimates of body components have been developed. The bioelectrical impedance analysis (BIA) method is an appealing tool for assessment of body composition because it is simple, quick and inexpensive to perform. Theoretically, the BIA method is based upon the relationship between the volume of the conductor (i.e. the human body), the conductors length, the components of the conductor and its impedance [1, 6]. It is assumed that the total conductive volume of the human body is equivalent to that of total body water, most of which is contained in muscle tissue and that the hydration of adipose tissue is minimal [1, 2]. The BIA method is generally accepted for measuring body composition in sportsmen. For this purpose several specific equations have been presented [1].

A new computerised optical system ("LIPOMETER") has been developed in order to permit a non-invasive, quick, precise and safe determination of the thickness of subcutaneous adipose tissue (SAT) at specific body sites. The technical characteristics of the device and a first validation of the results versus computed tomographically as standard for comparison have been published [5]. However, there is a lack of data about the possibility of using the new device on sportsmen.

The aim of this study was to compare different body composition parameters in sportsmen using a new LIPOMETER device and bioelectrical impedance analysis.

METHODS

A total of 38 sportsmen (21.7±3.1 yrs, 183.1±5.9 cm, 75.5±7.2 kg, BMI 22.6±2.0 were studied. All of them exercised 4–6 times per week. They mostly practised endurance sport events or sport games.

Stature was measured in centimetres (±0.1 cm) using a Martin metal anthropometer and body mass in kilograms (±0.05 kg) with medical scales. BMI (kg/m^2) was calculated.

The design of the LIPOMETER, a computerised optical measuring system for determining the SAT thickness, has been described previously [5]. LIPOMETER measurements were performed on each individual at 15 specified body sites. The subjects were standing. Measurements were taken at the right side of the body.

Body resistance was measured with a multiple-frequency impedance device MULTISCAN-5000 (Bodystat Ltd, UK). The sportsmen were placed in a supine position with limbs slightly abducted. Skin current electrodes were placed on the right dorsal surface at the hand and feet at the metacarpals and metadarsals. Only the data measured at 50 KHz (as a measure of total body water) were used. Both LIPOMETER and BIA measurements were taken on the same day with the maximum interval of 30 minutes.

Standard statistical methods were used to calculate the mean ($\bar{X}$) and standard deviation (±SD). Spearman correlation coefficients were used to determine the relationships between LIPOMETER and BIA data. Significance was set at $p \leq 0.05$.

RESULTS

The mean body fat percentage and lean body mass (LBM) parameters measured by LIPOMETER and BIA are presented in Table 1. The mean body fat percentage was slightly lower when measured by LIPOMETER as compared to BIA (0.76%), but the difference was not statistically significant ($p > 0.05$). There were also slight differences between the two methods in the LBM ($p > 0.05$).

Table 1. Mean body composition parameters measured by LIPOMETER and BIA ($\bar{X}$±SD)

	$\bar{X}$±SD
LIPOMETER:	
Fat %	9.76±4.68
LBM (kg)	67.93±6.21
BIA:	
Fat %	10.50±2.07
LBM (kg)	67.02±5.56

Spearman correlation analysis indicated that there were highly significant relationships between the body fat percentage measured by the two different methods ($r = 0.89$). The correlation in LBM between the two methods was also high ($r = 0.87$).

DISCUSSION

The measurement principles of LIPOMETER and BIA are different. LIPOMETER is using the optical principle and BIA electrical conductivity. However, our results indicate that the correlation between the two methods in sportsmen is high (r = 0.87–0.89).

Several field methods have been recommended to monitor changes in body composition. One of the most practical methods for predicting body fat percentage is the measurement of selected skinfold (SF) thicknesses. All the SF prediction equations in general use are based on a two-component model of body composition [4]. It is well recognised that SF thickness equations for body composition assessment are very population-specific, and estimates of body fat obtained from different regression equations may vary greatly among individuals [3]. The LIPOMETER measurements are connected with the measurement of the subcutaneous fat tissue. However the fat tissue is not compressed. LIPOMETER is excellent for presenting the topography of subcutaneous adipose tissue.

It can be concluded that the body composition parameters measured by LIPOMETER and BIA are similar.

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POSSIBILITIES FOR CLASSIFICATION OF THE ANTHROPOMETRIC DATA OF 16–18-YEAR-OLD TARTU SCHOOLGIRLS CONSIDERING THEIR AGE AND CONSTITUTIONAL PECULIARITIES

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ABSTRACT

All the schoolgirls from forms 10–12, aged 16–18 years, from the secondary schools of Tartu (total of 846) were investigated. The program of measurements included 42 anthropometric characteristics and 12 skinfolds. From these, 52 indices were calculated. The data were processed statistically at the Institute of Mathematical Statistics at the University of Tartu by Säde Koskel M.Sc. The studies of body structure revealed that uniform regularities of body structure appeared throughout the whole sample. All separate anthropometric characteristics and indices were determined by height, weight and age within the range of 20–70%. In combination with height and weight, the impact of age on regressions was insignificant. The regressions where only age was used as an argument, did not determine more than 2.21% of the variability of the other characteristics. Thus, it could be assumed that an appropriate anthropometric classification for this sample would be a 5 SD classification of height and weight. The results revealed that, analogously to our research carried out in other age groups, the body characteristics of 16–18-year-old girls formed a well-integrated system.

Key words: body structure of 16–18-year-old girls, anthropometric characteristics, height-weight classification.

INTRODUCTION

In medicine, health promotion, physical education and sports it is often necessary to analyse materials where one has to evaluate simultaneously age and individual constitutional peculiarities and find the most appropriate ways for classifying such data.

The aim of our present study was to investigate the above mentioned problem on the sample of 16–18-year-old schoolgirls from Tartu.

In order to systematise constitutional peculiarities we relied on the results we have achieved in body structure research since 1974 [7, 8, 9]. We found that the anthropometric model of the body as a whole consists of mutually well correlated characteristics, where height and weight have the strongest correlations with the other characteristics. The body as a whole is composed so that height and weight determine 50% of the variability of each characteristic. Only the remaining 50% is left to individual variability. A bivariate classification of height and weight makes it possible to systematise all the single variables, indices and body composition characteristics. The peculiarities of pure somatotypes — pycnomorphs and leptomorphs — are also based on different relations between the height and weight of these individuals.

Until now, our Centre has investigated the body structure of young women [9], neonates [19], 15–18-year-old schoolgirls [11, 14, 16, 18], schoolboys [15]. We have established that the main regularities of their body build are the same. We have developed classifications of 5×5, 3×3 and 5 SD classes which systematise well the data of subjects belonging to the same age class.

MATERIAL AND METHODS

The anthropometric study included all the girls of forms 10–12 in the secondary schools of the city of Tartu. The sample studied consisted of 846 girls — 274 of them aged 16, 358 aged 17 and 214 aged 18. All of them were practically healthy and their sexual development corresponded to their age. In different age groups the measuring program included 36–42 single anthropometric characteristics and 11–12 skinfolds. While processing the data, we computed from single characteristics 45–55 indices and body composition characteristics. Statistical processing of the data was carried out by Säde Koskel M.Sc. from the

Institute of Mathematical Statistics using the methods of multivariate statistical analysis.

RESULTS

In Table 1 we present the arithmetic means and standard deviations of the single anthropometric variables, indices and body composition characteristics for all the age groups. Statistical significance of the differences between the averages was checked by Scheffe-test.

Table 1. Averages of antropometrical measurements, indices and body composition characteristics for schoolgirls of ages 16, 17 and 18 (n=846). Asterisks in the last column indicate statistically significant differences of averages between age groups

No	Variable	16 n=274		17 n=358		18 n=214		Significance
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
1.	Weight (kg)	59.689	9.259	58.811	7.794	58.620	7.965	*
2.	Height (cm)	166.58	5.97	166.54	5.70	166.37	6.16	*
3.	Sternum length	14.07	1.66	14.12	1.89	14.06	1.97	–
4.	Abdomen length	36.51	2.76	36.82	3.38	36.63	3.27	–
5.	Trunk length	50.61	2.78	51.00	3.58	50.73	3.22	–
6.	Upper limb length	71.71	4.27	71.93	3.50	71.68	4.24	–
7.	Lower limb length	90.02	4.30	89.29	4.31	88.32	4.39	*
8.	Biacromial breadth	34.87	1.81	34.97	1.67	35.15	1.59	–
9.	Chest breadth	24.00	1.45	24.25	1.78	24.25	1.59	–
10.	Waist breadth	22.66	1.99	22.51	1.80	22.38	1.65	
11.	Pelvis breadth	27.11	1.59	27.02	1.44	26.62	1.40	*
12.	Chest depth	16.74	1.38	16.58	1.27	16.65	1.29	–
13.	Abdomen depth	15.66	1.58	15.53	1.44	15.51	1.51	–
14.	Femur breadth (cm)	8.76	0.61	8.69	0.61	8.61	0.56	*
15.	Ankle breadth	6.85	0.31	6.81	0.37	6.81	0.42	–
16.	Humerus breadth	6.15	0.40	6.12	0.34	6.21	0.42	*
17.	Wrist breadth	5.04	0.30	5.02	0.33	5.07	0.32	–

No	Variable	16 n=274		17 n=358		18 n=214		Signifi-cance
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
18.	Head circumference	55.24	1.41	55.27	1.33	55.05	1.40	–
19.	Neck circumference	31.84	1.78	31.60	1.40	31.59	1.34	–
20.	Upper chest circumference	78.74	5.08	78.34	4.35	78.57	4.76	–
21.	Lower chest circumference	75.45	5.50	75.05	4.98	75.56	5.46	–
22.	Waist circumference	68.52	6.11	67.66	5.27	67.72	5.88	–
23.	Pelvis circumference	85.33	6.80	84.23	6.17	82.38	6.23	*
24.	Hip circumference	90.67	6.44	89.75	5.30	88.95	5.49	*
25.	Upper thigh circumference	57.99	4.91	57.70	4.65	58.15	4.52	–
26.	Middle thigh circumference	48.15	4.58	48.02	4.17	47.76	3.93	–
27.	Upper leg circumference	34.98	3.08	35.09	2.68	35.14	4.38	–
28.	Lower leg circumference	22.19	1.61	22.10	1.77	21.98	1.31	–
29.	Arm circumference	25.80	2.57	25.66	2.41	25.89	2.34	–
30.	Forearm circumference	22.67	1.58	22.56	1.46	22.83	1.68	–
31.	Wrist circumference	15.57	0.77	15.48	0.74	15.51	0.77	–
32.	Chin skinfold (cm)	0.67	0.22	0.64	0.21	0.64	0.20	–
33.	Side skinfold	0.74	0.28	0.73	0.51	0.70	0.26	–
34.	Chest skinfold	0.98	0.44	0.91	0.43	0.90	0.39	–
35.	Waist skinfold	1.36	0.59	1.24	0.53	1.26	0.51	*
36.	Suprailiacal skinfold	0.97	0.47	0.91	0.43	0.86	0.44	*
37.	Umbilical skinfold	1.21	0.55	1.12	0.52	1.05	0.47	*
38.	Subscapular skinfold	1.16	0.55	1.12	0.53	1.12	0.49	–
39.	Biceps skinfold	0.75	0.35	0.70	0.31	0.68	0.33	–

No	Variable	16 n=274		17 n=358		18 n=214		Significance
		x̄	SD	x̄	SD	x̄	SD	
40.	Triceps skinfold	1.48	0.47	1.41	0.45	1.40	0.44	–
41.	Thigh skinfold	2.21	0.61	2.16	0.59	2.21	0.58	–
42.	Calf skinfold	1.46	0.60	1.33	0.52	1.27	0.42	*
43.	Hand skinfold	0.23	0.08	0.22	0.07	0.25	0.29	–
44.	Body mass index (BMI)	21.49	0.30	21.20	2.60	21.16	2.51	–
45.	Body surface area (m^2)	1.66	0.13	1.65	0.11	1.65	0.12	–
46.	Mean skinfold (cm)	1.18	0.39	1.12	0.36	1.10	0.33	–
47.	Mass of subcut. fat (kg)	10.90	0.35	9.84	3.12	8.16	0.291	–
48.	Relat. mass of subcut.fat (%)	14.72	3.98	14.02	3.76	13.92	0.03	–
49.	Body density (g/cm^2)	1.05	0.01	1.05	0.01	1.05	0.01	–
50.	Relat. mass of fat by Siri (%)	16.67	0.26	16.65	0.24	16.65	0.23	–
51.	Relat. trunk length	30.38	1.27	30.64	2.07	30.47	1.62	–
52.	Relat. upper limb length	43.04	1.94	43.18	1.41	43.07	1.90	–
53.	Relat. lower limb length	54.03	1.59	53.63	1.59	53.07	1.55	*
54.	Relat. biacromial breadth.	20.94	0.93	21.01	0.99	21.14	0.93	–
55.	Relat. chest breadth	14.42	0.84	14.57	1.05	14.58	0.93	–
56.	Relat. waist breadth	13.61	1.16	13.52	1.09	13.46	0.99	–
57.	Relat. pelvis breadth	16.28	0.91	16.23	0.84	16.00	0.73	*
58.	Relat. chest depth	10.06	0.83	9.96	0.78	10.02	0.79	–
59.	Relat. abdomen depth	9.41	0.97	9.43	0.89	9.33	0.95	–
60.	Relat. femur breadth	5.26	0.37	5.22	0.38	5.18	0.34	*
61.	Relat. ankle breadth	4.11	0.29	4.09	0.22	4.09	0.22	–

No	Variable	16 n=274		17 n=358		18 n=214		Significance
		x̄	SD	x̄	SD	x̄	SD	
62.	Relat. humerus breadth	3.70	0.22	3.68	0.18	3.73	0.22	*
63.	Relat. wrist breadth	3.02	0.15	3.02	0.19	3.05	0.18	–
64.	Relat. upper chest circumf.	49.97	3.13	49.73	2.99	49.88	2.99	–
65.	Relat. waist circumf.	41.15	3.64	40.66	3.31	40.73	3.62	–
66.	Relat. upper thigh circumf.	34.82	2.88	34.68	2.90	34.97	2.77	–
67.	Relat. arm circumf.	15.50	1.56	15.42	1.55	15.58	1.48	–
68.	Total cross-sectional area of arm (cm^2)	53.48	10.88	52.86	10.19	53.79	9.83	–
69.	Bone-muscle rate of the cross-sectional area of arm (cm^2)	39.84	6.58	40.02	6.73	40.98	6.61	–
70.	Fat rate of the cross-sectional area of arm (cm^2)	13.64	5.71	12.88	5.02	12.81	5.04	–
71.	Total cross-sectional area of thigh (cm^2)	269.48	46.52	266.61	43.62	270.68	42.70	–
72.	Bone-muscle rate of the cross-sectional area of thigh (cm^2)	208.77	33.41	207.84	34.02	209.73	32.22	–
73.	Fat rate of the cross-sectional area of thigh (cm^2)	0.91	19.85	58.94	18.35	60.95	18.62	–
74.	Bone-muscle rate of the cross-sectional area of arm/total cross-sectional area of arm	0.75	0.06	0.76	0.06	0.77	0.06	–

No	Variable	16 n=274		17 n=358		18 n=214		Significance
		x̄	SD	x̄	SD	x̄	SD	
75.	Fat rate of the cross-sectional area of arm/total cross-sectional area of arm	0.25	0.05	0.24	0.06	0.23	0.06	–
76.	Bone-muscle rate of the cross-sectional area of thigh/total cross-sectional area of thigh	0.78	0.05	0.78	0.05	0.78	0.05	–
77.	Fat rate of the cross-sectional area of thigh/ total cross-sectional area of thigh	0.22	0.05	0.22	0.05	0.22	0.05	–

As the Table reveals, the differences between the groups are not in logical correlation with age. The heaviest weight was observed in 16-year-olds and the lightest in 18-year-olds. There were 14 other variables that had the biggest values in 16-year-olds and the smallest in 18-year-olds. These were: lower limb length and relative lower limb length, pelvis breadth and relative pelvis breadth, femur breadth and relative femur breadth, humerus breadth and relative humerus breadth, pelvis and hip circumferences, and four skinfolds (waist, suprailical, umbilical and calf).

To get a comparative overview to what extent the difference in any single characteristic can be determined by age only, and to what extent by both body build (height, weight) and age, we present in Table 2 the results of respective regression analysis. As we can see, age mostly determines less than 1%, except in the case of pelvis circumference where it determines 2.21%. At the same time, however, each characteristic can be predicted statistically significantly from height and weight within the range of 20–70%. It is worth mentioning that everywhere the influence of age becomes insignificant as compared to height and weight.

Table 2. Coefficients of determination (in percentage) in predicting anthropometric measurements by age (column II) and by age, weight and height (column III)

Predicted variable	Coefficient of regression equation by age R-square	Coefficient of regression equation by age, weight and height R-square
1. Weight (kg)	0.02	–
2. Height (cm)	0.000	–
3. Sternum length (cm)	0.01	8.08*
4. Abdomen length	0.000	13.19*
5. Trunk length	0.01	22.84*
6. Upper limb length	0.01	48.62*
7. Lower limb length	1.70*	64.40*
8. Biacromial breadth	0.61*	30.62*
9. Chest breadth	0.75*	26.93*
10. Waist breadth	0.09	56.39*
11. Pelvis breadth	1.01*	24.53*
12. Chest depth	0.07	28.00*
13. Abdomen depth	0.04	46.24*
14. Femur breadth (cm)	0.39	26.54*
15. Ankle breadth	0.16	18.70*
16. Humerus breadth	0.59*	21.76*
17. Wrist breadth	0.14	22.40*
18. Head circumference	0.20	21.20*
19. Neck circumference	0.17	43.81*
20. Upper chest circumference	0.000	66.34*
21. Lower chest circumference	0.12	68.96*
22. Waist circumference	0.11	73.50*
23. Pelvis circumference	2.21*	70.20*
24. Hip circumference	0.65*	76.60*
25. Upper thigh circumference	0.19	72.80*
26. Middle thigh circumference	0.000	66.14*
27. Upper leg circumference	0.21	44.06*
28. Lower leg circumference	0.06	26.62*
29. Arm circumference	0.11	73.72*
30. Forearm circumference	0.33	52.92*
31. Wrist circumference	0.04	48.19*
32. Chin skinfold (cm)	0.05	14.63*

Predicted variable	Coefficient of regression equation by age R-square	Coefficient of regression equation by age, weight and height R-square
33. Side skinfold (cm)	0.05	14.63*
34. Chest skinfold	0.34	50.26*
35. Waist skinfold	0.45	50.78*
36. Suprailiacal skinfold	0.82*	51.43*
37. Umbilical skinfold	1.01*	43.27*
38. Subscapular skinfold	0.10	51.33*
39. Biceps skinfold	0.42	35.08*
40. Triceps skinfold	0.29	43.10*
41. Thigh skinfold	0.12	32.54*
42. Calf skinfold	1.67*	23.33*
43. Back of hand skinfold	0.52*	2.93*

* – statistically significant relation

This confirms once again the leading role of height and weight in body build structure. This enables us to use an integrated 5 SD classification of height and weight to classify the characteristics (see Fig. 1). Here we distinguished the classical somatotypes — pycnomorphs (class IV) and leptomorphs (class V), which revealed the greatest disproportion between height and weight. In the classes with proportional height and weight, we differentiated between three degrees of size (I — small height, small weight; II — medium height, medium weight, III — big height, big weight). The girls' anthropometric data were placed into this integrated five-class system according to their age groups. Thus, Table 3 presents the mean values of all the anthropometric variables of 16–18-year-old girls. The table reveals systemic changes in all the classes. In the system of small-medium-large classes all the length, breadth and depth measurements, thickness of bones and skinfolds increase gradually and significantly. Upper leg circumference (No. 27), which is an indicator of muscle mass, also increases significantly in classes I–III. Well-known characteristic differences could also be noticed between the individual body measurements of pycnomorphs and leptosomorphs (classes IV and V). Systemic changes can also be noticed in general characteristics of body composition and in cross-section areas of the upper arm. This led us to the conclusion that this kind of classification is appropriate for the given sample.

Table 3. Basic statistics of anthropometric measurements of girls aged 16–18 grouped into 5 height-weight classes (n = 846)

No	Variables	1. Small n=139		2. Medium n=137		3. Large n=119		Significance (1–2–3)	4. Pycnomorphous n=203		5. Leptomorphous n=248		Significance (4–5)
		x̄	SD	x̄	SD	x̄	SD		x̄	SD	x̄	SD	
1.	Weight (kg)	50.159	3.256	58.570	2.401	70.540	6.84	*	63.79	7.12	54.896	4.596	*
2.	Height (cm)	159.63	3.20	166.69	1.64	174.26	3.51	*	162.60	3.82	169.76	3.91	*
3.	Sternum length (cm)	13.60	1.69	14.02	1.56	14.66	1.90	*	13.64	1.93	14.51	1.79	*
4.	Abdomen length	34.85	2.21	37.17	3.78	38.18	2.88	*	36.28	3.44	37.01	2.58	*
5.	Trunk length	48.51	2.05	51.12	3.85	52.88	2.30	*	49.96	3.25	51.62	2.84	*
6.	Upper limb length	68.71	3.19	71.86	2.13	75.54	3.37	*	69.99	3.51	73.13	3.63	*
7.	Lower limb length	85.42	3.09	89.09	3.38	94.18	3.13	*	87.05	3.42	91.02	3.54	*
8.	Biacromial breadth	33.72	1.41	35.11	1.41	36.58	1.53	*	34.94	1.53	34.86	1.58	–
9.	Chest breadth	23.08	1.28	24.20	1.49	25.38	1.65	*	24.59	1.32	23.84	1.62	*
10.	Waist breadth	21.12	1.19	22.45	1.32	24.23	1.81	*	23.57	1.81	21.68	1.16	*
11.	Pelvis breadth	26.0	1.23	26.83	1.14	28.13	1.47	*	26.87	1.68	27.03	1.24	–
12.	Chest depth	15.91	1.12	16.54	1.12	17.61	1.23	*	17.13	1.29	16.27	1.16	*
13.	Abdomen depth	14.73	1.01	15.34	0.96	16.59	1.76	*	16.50	1.62	14.90	0.96	*
14.	Femur breadth (cm)	8.32	0.47	8.67	0.49	9.13	0.61	*	8.91	0.59	8.52	0.54	*
15.	Ankle breadth	6.55	0.34	6.86	0.54	7.12	0.36	*	6.81	0.43	6.82	0.33	–
16.	Humerus breadth	5.88	0.33	6.18	0.28	6.41	0.40	*	6.09	0.42	6.22	0.30	*
17.	Wrist breadth	4.81	0.32	5.09	0.28	5.26	0.25	*	5.01	0.31	5.06	0.28	–

No	Variables	1. Small n=139		2. Medium n=137		3. Large n=119		Significance (1–2–3)	4. Pycnomorphous n=203		5. Leptomorphous n=248		Significance (4–5)
		x̄	SD	x̄	SD	x̄	SD		x̄	SD	x̄	SD	
18.	Head circumference	54.35	1.30	55.39	1.35	56.15	1.24	*	55.22	1.36	55.11	1.18	–
19.	Neck circumference	30.63	0.99	31.69	1.15	32.84	1.25	*	32.41	1.68	31.09	1.25	*
20.	Upper chest circumference	74.46	2.87	78.43	2.74	83.43	4.09	*	81.24	4.70	76.26	2.94	*
21.	Lower chest circumference	71.02	2.79	75.32	3.19	80.15	4.99	*	79.04	5.02	72.27	3.23	*
22.	Waist circumference	63.48	2.94	67.39	3.58	73.16	5.31	*	72.15	5.73	64.81	3.23	*
23.	Pelvis circumference	78.99	4.11	83.42	3.85	90.10	6.24	*	88.49	5.88	80.90	4.57	*
24.	Hip circumference	84.46	3.25	89.20	3.14	96.11	5.72	*	93.54	4.87	87.13	3.66	*
25.	Upper thigh circumference	54.23	3.09	57.72	3.21	62.78	4.07	*	61.20	3.56	54.97	3.11	*
26.	Middle thigh circumference	44.89	2.99	47.84	2.71	51.92	3.80	*	51.00	3.58	45.45	2.91	*
27.	Upper leg circumference	32.99	2.17	35.01	1.65	37.82	5.08	*	36.72	2.47	33.59	2.32	*
28.	Lower leg circumference	21.17	1.61	22.11	0.86	23.25	1.13	*	22.64	1.70	21.61	1.57	*
29.	Arm circumference	24.01	1.41	25.90	1.45	27.83	2.11	*	27.71	2.15	24.07	1.57	*
30.	Forearm circumference	21.49	1.22	22.68	1.20	24.07	1.18	*	23.52	1.55	21.93	1.08	*

No	Variables	1. Small n=139		2. Medium n=137		3. Large n=119		Significance (1–2–3)	4. Pycnomorphous n=203		5. Leptomorphous n=248		Significance (4–5)
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
31.	Wrist circumference	14.84	0.56	15.55	0.50	16.32	0.65	*	15.74	0.68	15.30	0.62	*
32.	Chin skinfold (cm)	0.57	0.16	0.65	0.20	0.72	0.20	*	0.78	0.22	0.56	0.15	*
33.	Side skinfold	0.60	0.18	0.78	0.74	0.83	0.28	*	0.90	0.29	0.59	0.20	*
34.	Chest skinfold	0.73	0.22	0.87	0.30	1.13	0.48	*	1.26	0.47	0.71	0.25	*
35.	Waist skinfold	0.95	0.32	1.25	0.42	1.63	0.54	*	1.67	0.57	1.00	0.36	*
36.	Suprailiacal skinfold	0.72	0.30	0.87	0.34	1.13	0.50	*	1.27	0.45	0.66	0.27	*
37.	Umbilical skinfold	0.89	0.32	1.09	0.42	1.38	0.55	*	1.50	0.59	0.8	0.32	*
38.	Subscapular skinfold	0.89	0.27	1.05	0.31	1.37	0.57	*	1.55	0.63	0.86	0.30	*
39.	Biceps skinfold	0.58	0.24	0.69	0.31	0.88	0.34	*	0.91	0.36	0.56	0.21	*
40.	Triceps skinfold	1.24	0.30	1.39	0.33	1.64	0.44	*	1.77	0.45	1.18	0.38	*
41.	Thigh skinfold	1.96	0.44	2.12	0.50	2.44	0.58	*	2.58	0.61	1.91	0.48	*
42.	Calf skinfold	1.20	0.44	1.31	0.45	1.55	0.52	*	1.63	0.58	1.15	0.44	*
43.	Back of hand skinfold	0.21	0.06	0.23	0.21	0.28	0.30	*	0.24	0.07	0.22	0.10	*
44.	Body mass index (BMI)	19.69	1.27	21.09	1.01	23.24	2.29	*	24.11	2.40	19.03	1.25	*
45.	Body surface area (m^2)	1.50	0.05	1.65	0.03	1.85	0.08	*	1.68	0.10	1.63	0.08	*
46.	Mean skinfold (cm)	0.94	0.21	1.16	0.27	1.34	0.36	*	1.44	0.36	0.91	0.23	*
47.	Mass of subcut. fat (kg)	6.32	1.48	8.16	2.05	11.18	3.44	*	10.98	3.18	6.73	1.83	*

No	Variables	1. Small n=139		2. Medium n=137		3. Large n=119		Significance (1–2–3)	4. Pycnomorphous n=203		5. Leptomorphous n=248		Significance (4–5)
		x̄	SD	x̄	SD	x̄	SD		x̄	SD	x̄	SD	
48.	Relat. mass of subcut.fat (%)	0.13	0.03	0.14	0.03	0.16	0.04	*	0.17	0.04	0.12	0.03	*
49.	Body density (g/cm^2)	1.055	0.006	1.053	0.006	1.048	0.008	*	1.05	0.01	1.056	0.006	*
50.	Relat. mass of fat by Siri (%)	16.53	0.13	16.62	0.15	16.78	0.25	*	16.86	0.26	16.52	0.15	*
51.	Relat. trunk length (%)	30.40	1.23	30.66	2.34	30.35	1.16	–	30.72	1.93	30.40	1.63	–
52.	Relat. upper limb length	43.05	1.75	43.11	1.21	43.36	1.70	–	43.04	1.87	43.07	1.84	–
53.	Relat. lower limb length	53.52	1.51	53.44	1.82	54.04	1.31	*	53.54	1.70	53.63	1.59	–
54.	Relat. biacromial breadth.	21.13	0.85	21.07	0.84	21.00	0.87	–	21.50	0.91	20.54	0.94	*
55.	Relat. chest breadth	14.46	0.79	14.52	0.91	14.57	0.97	–	15.12	0.78	14.05	0.93	*
56.	Relat. waist breadth	13.24	0.74	13.47	0.80	13.91	1.06	*	14.50	1.07	12.77	0.68	*
57.	Relat. pelvis breadth	16.29	0.71	16.10	0.67	16.14	0.83	–	16.53	1.03	15.93	0.73	*
58.	Relat. chest depth	9.97	0.74	9.92	0.69	10.11	0.72	–	10.54	0.78	9.59	0.68	*
59.	Relat. abdomen depth	9.24	0.68	9.20	0.59	9.52	1.03	*	10.15	0.98	8.78	0.58	*
60.	Relat. femur breadth	5.22	0.30	5.20	0.29	5.24	0.36	–	5.48	0.37	5.02	0.31	*
61.	Relat. ankle breadth	4.11	0.21	4.12	0.32	4.09	0.21	–	4.19	0.26	4.02	0.19	*

No	Variables	1. Small n=139		2. Medium n=137		3. Large n=119		Significance (1–2–3)	4. Pycno-morphous n=203		5. Lepto-morphous n=248		Significance (4–5)
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
62.	Relat. humerus breadth	3.69	0.20	3.71	0.16	3.68	0.22	–	3.75	0.26	3.66	0.18	*
63.	Relat. wrist breadth	3.01	0.19	3.05	0.17	3.02	0.14	–	3.08	0.18	2.98	0.16	*
64.	Relat. upper chest circumf.	49.16	1.95	49.77	1.91	50.55	2.71	*	52.94	2.79	47.38	1.69	*
65.	Relat. waist circumf.	39.78	2.00	40.43	2.22	42.00	3.20	*	44.38	3.45	38.19	1.88	*
66.	Relat. upper thigh circumf.	33.98	2.02	34.64	2.05	36.04	2.43	*	37.65	2.14	32.39	1.77	*
67.	Relat. arm circumf.	15.05	0.98	15.55	0.93	15.98	1.29	*	17.05	1.31	14.18	0.94	*
68.	Total cross-sectional area of arm (cm^2)	46.05	5.40	53.56	6.25	61.99	9.58	*	61.47	9.64	46.29	6.05	*
69.	Bone-muscle rate of the cross-sectional area of arm (cm^2)	35.74	4.00	40.98	5.27	45.58	6.48	*	44.24	6.34	36.34	4.53	*
70.	Fat rate of the cross-sectional area of arm (cm^2)	10.32	2.93	12.58	3.49	16.41	5.28	*	17.27	5.56	9.94	3.27	*
71.	Total cross-sectional area of thigh (cm^2)	234.76	27.55	265.97	30.23	314.92	42.26	*	299.09	35.08	241.19	27.15	*

No	Variables	1. Small n=139		2. Medium n=137		3. Large n=119		Significance (1–2–3)	4. Pycnomorphous n=203		5. Leptomorphous n=248		Significance (4–5)
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
72.	Bone-muscle rate of the cross-sectional area of thigh (cm^2)	184.99	24.53	208.43	30.19	242.59	31.73	*	225.36	27.21	191.59	21.95	*
73.	Fat rate of the cross--sectional area of thigh (cm^2)	50.07	11.62	57.54	13.40	72.33	19.73	*	74.01	18.84	49.70	13.14	*
74.	Bone-muscle rate of the cross-sectional area of arm/total cross-sectional area of arm	0.21	0.04	0.77	0.05	0.74	0.06	*	0.72	0.06	0.79	0.06	*
75.	Fat rate of the cross--sectional area of arm/ total cross-sectional area of arm	0.22	0.05	0.23	0.05	0.26	0.06	*	0.28	0.06	0.21	0.06	*
76.	Bone-muscle rate of the cross-sectional area of thigh/total cross-sectional area of thigh	0.79	0.04	0.78	0.05	0.77	0.05	*	0.75	0.05	0.80	0.05	*
77.	Fat rate of the cross-sectional area of thigh/ total cross-sectional area of thigh	0.21	0.04	0.22	0.05	0.23	0.05	*	0.25	0.05	0.21	0.05	*

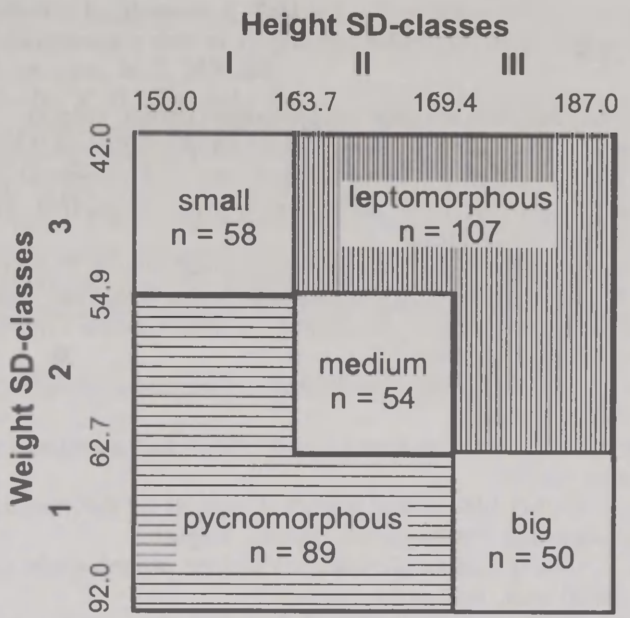

Figure 1. Classification of 17-year-old girls by 5 height = weight classes.

DISCUSSION

A considerable amount of data has been gathered in literature on regularities of body build [1, 2, 4, 5, 17, 20, 21]. Studies are continuing in order to find appropriate classifications to express the regularities of multidimensional variability in one or another sample [3, 6, 13, 19].

A complicating factor in the studies of schoolchildren is that one has to take simultaneously into account the impact of age and of constitutional peculiarities.

In the present paper we presented a research methodology that we recommend. We managed to form an integrated classification for systematising the characteristics of different age groups. In our classification different characteristics formed a well-organised system. When comparing our present results with the data published earlier on different age groups [11, 16, 18], we were able to notice the same regularities. This suggests that such a classification could be recommended for further studies of this kind.

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ABOUT THE STUDENT DAYS OF THE LATVIAN-AMERICAN ANATOMIST AND ANTHROPOLOGIST PROF. JĒKABS PRĪMANIS IN YURYEV (TARTU) IN 1911–1913

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In the 19th and early 20th centuries the University of Tartu (Dorpat, Derpt, Yuryev) was a centre of world importance in medical and natural sciences. In addition, it served as a link between the Russian and West-European research centres. The university's medical faculty was not only the main higher medical school of the Baltic countries but also one of the largest medical training centres in Czarist Russia. Thus, the overwhelming majority of Latvian and Lithuanian physicians and pharmacists of the period were graduates of this university [1]. Unfortunately, the biographies of some lecturers and graduates of the University of Tartu contain misinterpretations and omissions in the characterisation of this period.

In recent years we have studied the development of anthropology at the University of Tartu. Our articles intend to draw attention to inaccuracies in this field and correct them. We will begin with Prof. Jēkabs Prīmanis (1892–1971), the well-known Latvian-American anatomist and anthropologist, who studied at the University of Tartu in 1911–1913.

His studied at the medical faculty of the University of Tartu for nearly two years. There is a short file on him at the Estonian Historical Archives that contains some data about this period [2].

Jēkabs Prīmanis, an alumnus of the Riga Emperor Nicholas I Gymnasium, wrote an application to the Rector of the Imperial Yuryev University on June 30, 1911, for admission as a first-year student of the medical faculty. Instead of the required documents he submitted copies and a notarised photo. An additional remark explains that the original documents are located at the St Petersburg Academy of Military Medicine and will be sent to Tartu by August 10 of the same year. The applicant has provided his address as Albertov 1–20 in the city of Riga. The application was registered at the University's Office on the following day.

Let us take a look at the copies of the documents that are added to Prīmanis' application. A duplicate of the Certificate of Secondary Education No. 562, issued on June 4, 1911, informs us that Jēkabs Prīmanis, son of Jēkabs, born in Aahof (now Ādaži) in the Province of Livonia on February 28, 1892 (Old Style), is a son of a peasant. He was admitted to the Riga Gymnasium on August 15, 1904, and studied there until June 4, 1911, his conduct being exemplary.

He completed the full 8-year course with the following grades on a five-point scale: Religion — 5, Russian Language and Literature — 3, Propaedeutic Philosophy — 4, Latin — 4, Mathematics — 4, Mathematical Geography — 5, Physics — 5, History — 5, Geography — 5, German — 4, French — 4, Law — 4.

A duplicate of the Birth and Baptism Certificate No. 100, issued on May 16, 1903, informs us also that Jēkabs Prīmanis, born at one o'clock on February 28, 1892, was baptised on April 5 of the same year in the Neuermühlen Evangelical Lutheran Church by the local pastor Zimmermann.

A duplicate of Certificate No. 1668, issued by the Government of Ādaži Rural Township of Riga County of the Province of Livonia, tells us that J. Prīmanis had to show up for military service in the second district of Riga County in 1913.

A duplicate of document No. 1669, which certifies his background and was issued on the same day, proves once again that Jēkabs Prīmanis, son of Jēkabs, comes from a peasant family from the Ādaži Rural Township of Riga County of the Province of Livonia.

The Student Affairs Department of the University Office notified J. Prīmanis on August 8, 1911, that he would be admitted to the Medical Faculty of the Yuryev Imperial University after showing up in person at the University between August 10 and 25 of the same year and after paying a fee of 25 roubles for the benefit of the University and 6 roubles for the credit book.

The entries in Passport No. 401, issued on August 22, 1911, inform us that J. Prīmanis was single.

J. Prīmanis as a medical student was entered in the enrolment record of the University of Tartu under entry No. 24038 on August 24, 1911.

As requested in J. Prīmanis' application, the Imperial Academy of Military Medicine sent his original documents (General Certificate of Education No. 562, Birth Certificate No. 100, Military Draft Card No. 1668, Certificate of Social Status No. 1669) to Tartu on July 31, 1911, and they arrived at the University on August 4.

What kind of circumstances affected Jēkabs Prīmanis' choice in favour of the Medical Faculty at the University of Tartu? Was it because Wilhelm Friedrich Ostwald (1853–1932), a chemist and graduate of the University of Tartu who had come from Riga, had won the Nobel Prize in 1909? Or was it the knowledge that the University of Tartu had played an important role in scientific progress and the training of educated persons for the Baltic countries and Russia? During the previous one hundred years, over 1,100 master's and doctoral dissertations had been defended here. Or was it because a large number of well-known scientists who had developed their own schools of thought were employed by the University (let us mention the botanist N. Kuznetsov, the chemist I. Kondakov, and the clinician N. Savelyev)? Or was Jēkabs Prīmanis' choice influenced by the fact that Professor of Anatomy August Rauber (1841–1917) was the most famous lecturer in the medical faculty at the time [3]? Or were there any other reasons that we are not aware of?

Before Jēkabs Prīmanis became a medical student at Yuryev, August Rauber had retired as a Merited Professor on February 22, 1911. He delivered his last lectures in the autumn of 1910. At the beginning of the next semester he only examined his students and thereafter also gave up his chair at the Institute of Anatomy. After receiving great honours for 25 years of work, which had been a rare occasion in Yuryev so far, he never visited the Institute of Anatomy again [4].

After the retirement of A. Rauber the University Council elected V. Vorobyov, an outstanding professor of anatomy, to the position of the head of the institute, but the ministry did not confirm this decision [5].

Therefore, Jēkabs Prīmanis, who had started his studies at the medical faculty in 1911, began to attend the anatomy lectures of Hermann Ernst Adolfi M.D. (1863–1919), *Privatdozent* of Normal Anatomy, who was a disciple and a long-time colleague of Prof. August Rauber, had worked for twenty years as a professor at the Institute of Anatomy, and became Extraordinary Professor of Anatomy in the autumn of 1912. He was born in Vendel (now Cesis) in the Province of Livonia.

During the practical classes of anatomy the student Prīmanis got in touch with Abram Eber Landau M.D. (1878–1959), a superordinary assistant prosector of the Institute of Anatomy and *Privatdozent* of

Anatomy, who was teaching mostly anthropology at the time. He was born in Rezekne in the Province of Vitebsk. A few days after the retirement of Prof. August Rauber, A. E. Landau had also become the first director of the university's anthropological collection, and on June 20 of the following year he took up the post of the director of the anthropological museum. I have not found any other materials about this museum in the archives [6]. However, the museum of anatomy that was opened in 1890 by Prof. A. Rauber has been called exemplary in literature (Prof. A. Stefanis in 1903) [4]. The student J. Prīmanis may also have used for study the brief Russian-language manual of anthropology that *Privatdozent* A. E. Landau had published in Tartu in 1912 [7].

Thus, one can say that the student Jēkabs Prīmanis learned anatomy and anthropology from the disciples of Prof. Rauber, from Hermann Ernst Adolfi, who had a Latvian background, and from Abram Eber Landau, but not from the famous Professor Rauber himself, as many studies point out.

Next the file gives an overview of the academic proficiency of the medical student J. Prīmanis.

In his first year progress was assessed as follows: physics — 4¼, inorganic chemistry — 5, mineralogy and geology — 5, zoology — 4, comparative anatomy — 4¼, botany — 5; religion has not been assessed. The results of the second year: anatomy — 5, histology and embryology — 5, physiology and physiological chemistry — 5, organic chemistry — 5, pharmacy and pharmacognosy — 2, qualitative chemical analysis — 3.

The low marks in the latter subjects were given by Ivan Lavrentyevich Kondakov (1857–1931), Professor of Pharmacy, a graduate of the University of St Petersburg, a disciple of A. M. Butlerov and the inventor of synthetic rubber.

At that time the curriculum of the medical faculty of the University of Tartu for the first years was as follows: Semester 1 human anatomy (part I) — 6 hours per week; practical work in anatomy (part I) — 6 hrs; physics (part I) — 5 hrs; inorganic chemistry — 5 hrs; mineralogy and geology — 2 hrs; religion — 3 hrs.

Semester 2: anatomy (part II) — 6 hrs; practical work in anatomy (part II) — 6 hrs; physics (part II) — 5 hrs; inorganic chemistry — 5 hrs; comparative anatomy — 2 hrs; histology (part I) — 6 hrs; religion — 3 hrs.

Semester 3: physiology (part I) — 6 hrs; physiological chemistry (part I) — 4 hrs; histology (part II) — 6 hrs; pharmacy and pharmacognosy (part I) — 3 hrs; qualitative analysis — 3 hrs.

Semester 4: physiology (part II) — 6 hrs; physiological chemistry (part II) — 4 hrs; pharmacy and pharmacognosy (part II) — 4 hrs; qualitative analysis (part II) — 3 hrs; general pathology (part I) — 4 hrs.

The subjects of the introductory stage were followed by medical subjects.

As a student, J. Prīmanis did not lose contact with his parents in Riga, and he used the travel discounts that the students could obtain for visits. For example, on January 4, 1913, Jēkabs Prīmanis sent an open postcard from Riga to the University Office, where he applied for a certificate to be sent to Rytsarskaya 3-1 in Riga to enable him to purchase a discount ticket. The postcard was registered by the University Office on the next day already, which shows the efficiency of the postal service at the time.

On May 29, 1913, the second-year student of the Medical Faculty J. Prīmanis wrote an application to the Rector of the Imperial University of Yuryev, where he asked all of his documents, including the records of academic achievement, to be sent to the Academy of Military Medicine. The application contains no data concerning the reasons for doing so. On the same day the application was registered by the University Office, and the Medical Faculty issued Certificate No. 1075 about the academic proficiency of Jēkabs Prīmanis during four semesters. In addition to the examination results that are known to us already, the certificate adds data about passes in practical classes of anatomy (parts I and II) and attendance of lectures on general pathology (part I). The certificate was signed by Prof Vyatsheslav Alekseyevich Afanasyev (1859–1942), Dean of the Medical Faculty. The second-year student Jēkabs Prīmanis had attended his lectures during the last semester. V. A. Afanasyev, Professor of General Pathology and Pathological Anatomy, was a graduate of the St Petersburg Academy of Military Medicine and a disciple of the well-known Russian pathologists N. P. Ivanovski and V. V. Podvyssotski. Later he continued his studies abroad under the guidance of Virchow, Baumgarten, Roux, etc. He restored the laboratory of bacteriology at the University of Tartu at his own expense and sometimes taught bacteriology as well. In his research Afanasyev made an attempt to combine the data of pathological anatomy with experimental studies. A number of his papers deal with bacteriology. Some of the students from his Tartu period became renowned scientists, for example, the pathological anatomists I. I. Shirokogorov in Baku, A. Valdes in Tartu, and R. Adelhein in Riga, the pulmonologist G. R. Rubinstein in Moscow, etc. [3]

Jēkabs Prīmanis' academic certificate is accompanied by a letter of May 30 to the principal of the Academy of Military Medicine, signed by one of the prorectors, that informs us that no disciplinary punishments had been administered to Primanis during the studies. On June 1, 1913, a letter was attached to the previous documents, signed by the secretary of the University Office, which was addressed to the Academy Office with the information that the documents would be sent to St Petersburg at the request of Jēkabs Prīmanis.

It was only on November 26, 1913, when the University Office sent Certificate No. 9142, signed by the rector, concerning Jēkabs Prīmanis, son of Jēkabs (born in 1892), to the Riga County Government, which notifies about its exclusion from the list of medical students before the end of the course. This finishes the 33-page file on the student years of Jēkabs Prīmanis in Tartu [2].

Jēkabs Prīmanis' busy student years continued at the Academy of Military Medicine in St Petersburg. Afterwards he devoted his life to the study of anatomy and anthropology, first in Latvia and then in America.

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COMPARISONS OF BODY FAT ASSESSMENT DERIVED FROM BIOELECTRICAL IMPEDANCE METHOD AND DIFFERENT ANTHROPOMETRIC METHODS IN 17-YEAR-OLD BOYS

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ABSTRACT

This investigation compared bioelectrical impedance analysis (BIA) measured by OMRON® BF 300 body fat monitor results for body fat percentage assessment in 101 normal 17-year-old-boys to body fat percentage assessed by anthropometric methods. From anthropometric equations for body fat percentage assessment two skinfolds equations by Yuhasz and Sloan, four equations by Wilmore and Behnke, which included weight and circumferences, and two equations by Hechter and von Döbeln, which use body diameters and bone diameters, were used. All results of body fat percentage correlated with each other statistically significantly. The lowest were the results of body fat by skinfolds equations; they were below the results by BIA. The equations that include circumferences show medium results. They were slightly above the BIA-assessed results. The equations that include bone diameters yielded the highest evaluated body fat percentage.

These results show that body fat percentage in a population of healthy individuals can be estimated both by BIA and anthropometric-derived formulas.

Key words: bioelectric impedance, anthropometry, body fat assessment

INTRODUCTION

Simple anthropometric methods to estimate body fat and lean body mass can enhance the physician's armamentarium. The most precise methods currently used in various laboratories include measurements of total body water, total body potassium, helium dilution, radiography and body density-specific gravity. These methods are accepted as accurate. However, they share the common problems of requiring: 1. considerable time for a single determination, 2. relatively elaborate and expensive equipment and rather complex procedures. This determines the situation that the assessment of body fat and lean body weight has been restricted to a small number of investigated subjects within relatively few laboratories and for a purpose specific to a research study. To allow a more widespread use of these measurements for clinical and general evaluative purposes, many investigators have turned to simpler and more inexpensive approaches for determining body fat and lean body mass. Skinfold thicknesses, anthropometric circumferences and diameters are used for this purpose. Many investigations have shown that body density or specific gravity in males can be predicted from a few skinfold measurements with a high degree of accuracy ranging to $R^2 = 0.87$ [16, 19]. Other investigations have indicated that lean body weight can also be predicted from body circumferences and diameters [18].

More recently the application of bioelectrical impedance plethysmography for body fat and lean body mass assessment has been suggested as a simple, noninvasive, rapid and convenient method that provides sufficiently accurate body fat estimate for clinical and field studies.

The bioelectrical impedance analysis (BIA) method is based on measurements of changes in the conduction of electrical current through the body that contains intra- and extracellular fluids that act as electrical conductors and cell membranes that act as electrical capacitors and are regarded as reactive elements. Body fluids and electrolytes are responsible for electrical conductance and cell membranes are involved in capacitance. Lean body tissue has a far greater electrolyte content than fat. This difference in ionic content permits the estimation of lean body weight (LBW) from the assessment of body electrical conductivity. It has been shown that impedance and resistance to electrical flow of current are related to the volume of the conductor and the square of the conductor's length approximated by height. Equations take into account body weight, electrical reactance and sex [1, 12]. The methods mentioned above predict body fat and lean body weight from different indices. We decided to compare the results obtained from anthropometric-derived formulas and from BIA measurements in the same adolescent population.

MATERIAL AND METHODS

One hundred and one healthy 17-year-old boys volunteered to participate in the investigation. Each subject completed all tests on the same day between 9.00–12.00 a.m. The anthropometric measurements were performed by one of us (LS). The subjects were dressed in brief and thin cotton swim trunks.

The measurements were taken according to the classical method of R. Martin [10, 13]. In addition, midthigh circumference according to the recommendations of Lohman [11] and pelvis circumferences according to Gross [5] were measured. Pelvis circumference was obtained on the level of Michaelis rhombus upper corner, crista iliaca and the upper edge of symphysis as it is frequently used in obstetrics. Abdomen depth was measured at the level of umbilicus in sagittal projection plane at the end of expirium, the individuals being in an orthostatic position. It is analogous to the abdomen depth measured in a sitting position by Flügel, Greil and Sommer [14]. Weight, 10 measures of length, 10 measures of breadth and depth, 16 circumferences and 12 skinfolds were taken from every test person. Skinfolds thicknesses were measured at 12 sites using skinfold callipers with a constant $10g/mm^2$ pressure applied at right angles to the fold defined between the observer's thumb and index finger. Skinfold thicknesses were measured at standardised sites — cheek and chin by Parizková [14], chest, midaxillary, suprailiac, supraspinal, abdominal, subscapular, biceps, triceps, thigh, and calf by Lohmann *et al.* [11], Heyward and Stolarczyk [7]. The body diameters were measured with a pelvis compass, femur, ankle, elbow and wrist diameters with a small compass. For all diameter measurements an attempt was made to compress the underlying tissue to gain maximal proximity to the bone. Height was measured with the subject standing, feet flat, eyes looking straight ahead without contact with Martin anthropometer. From these data we calculated indices, 5 segments' lengths, Rohrer and body mass index, body surface area according to the formula of D. Du-Bois and E. F. Du-Bois [3], body density by Wilmore and Behnke [18], relative mass of fat by Siri [15], absolute and relative mass of subcutaneous fat. In addition we calculated local subcutaneous fat and the bone-muscle component on the cross-sectional areas of the arm and the thigh by De Koning, Binkhorst, Kauer and Thijssen [2]. Lower limb length was calculated by the formula of Jatsuta [19].

The subjects were weighed to the nearest 0.05 kg using a calibrated balance scale.

For BIA analyses an OMRON® BF 300 body fat monitor was used. This monitor device uses subjects' height, weight, age and gender data and after 10 seconds analyses time gives body fat percentage and body fat amount in kilograms. The instrument was held in hands straight ahead, the subjects being in a standing position [8].

Body density and the percentage of body fat were predicted from several equations proposed by different investigators.

The equation of Yuhasz [19] was used to predict the percentage of body fat. Fat percentage = 5.783 + 0.153 (triceps skinfold + scapula skinfold + abdominal skinfold + suprailiac skinfold).

The equation of Sloan [16] was used to predict body density. D = 1.1043 – 0.001327 thigh skinfold, mm – 0.00131 scapular skinfold, mm.

The equations of von Döbeln [17] and Hechter [6] were used to predict fat-free (FFW) and lean body weight(LBW).

By von Döbeln FFW = 15.1(height m^2 × femoral condylar breadth dm × bistyloid radioulnar breadth dm)$^{.712}$.

Lean body weight by Hechter was calculated as LBW = 519 × 10^{-5} (chest diameter cm$^{.75}$wrist diameter cm$^{.48}$ × height cm$^{1.18}$). From these equations we calculated fat kg = body weight – LBW or FFM. Fat percentage was calculated as (fat kg/body weight) ×100.

Body density D was also calculated by the equations of Wilmore and Behnke. According to their equation (3), D = 1.18351 + 0.00069 weight – 0.00202 pelvis circumference.

According to equation (4), D = 1.15114 + 0.00068 weight + 0.00146 bicristal diameter + 0.00057 chest circumference – 0.00192 pelvis circumference – 0.00124 thigh circumference.

According to equation (5), D = 1.11847 – 0.00078 abdominal skinfold – 0.00048 pelvis circumference.

According to equation (6), D = 1.05721 – 0.00052 abdominal skinfold + 0.00168 bicristal diameter + 0.00114 neck circumference +0.00048 chest circumference – 0.00145 pelvis circumference. In the prediction of density by these equations the multiple correlation coefficients ranged from 0.835 – 0.870. They were generated for males of approximately the same ages.

For further purposes density was converted to body fat percentage by the equation of Siri.

Descriptive statistics — mean, standard deviation, minimum, maximum, variation coefficient, 5, 50 and 95 percentile values were calculated. Pearson Product Moment Correlation analysis and Spearman nonparametric correlation were used to study the relationships between BIA and anthropometric equations derived by measurements of body fat. Statistical significance was set at $p<0.05$. Statistical package SAS® System for Windows™ release 6.12 version was used for these calculations.

RESULTS

Descriptive statistics of the subjects are presented in Table 1.

Table 2 presents the mean values of body fat percentage estimated by the BIA method and by eight regression equations on body fat values. Both Pearson Product Moment Correlation and Spearmann nonparametric correlation analysis show that the body fat percentage estimated by the BIA method was in significant relationship to the body fat percentage assessed by regression equations calculated according to the anthropometric method. If we take the body fat percentage evaluated by BIA as a reference, three anthropometric prediction equations show lower results — Yuhasz 11.88±3.20; Sloan 11,47±5.94 and Wilmore and Behnke [5] equation 9.22±1.99. Three anthropometric equations show very similar results — the third, fourth and sixth equations of Wilmore and Benke, also Hechter's equation — 15.04±4.68; 16.16±5.33, 15.97±4.52 and Hechter's equation 17.37±12,40. Only von Döbeln equation showed markedly higher results than BIA.

Table 3 presents multiple regression equations to predict body fat by equations containing BIA results. R square was in four cases higher than 70 percent of description level. Only Hechter equation results predicted less than 50 percent.

Table 1. Mean values of the anthropometric measurements

No.	Variable	mean	SD	minimum	max	CV	5%	50%	95%
1.	weight (kg)	70.09	12,54	50.30	126.90	17,89	52,9	68,4	91.3
2.	standing height (cm)	179.61	6.57	160.10	195.70	3.66	169.90	179.30	190.20
3.	sternum length	17.13	1.74	12.90	23.10	10.14	15.10	17.00	19.70
4.	abdomen length	35.16	2.69	27.10	41.40	7.64	31.10	35.30	39.10
5.	trunk length	52.28	2.70	44.00	60.80	5.15	48.10	52.40	56.70
6.	upper limb length	79.19	2.98	73.10	86.50	3.76	73.50	79.10	84.00
7.	lower limb length	94.82	4.35	86.00	105.10	4.58	88.40	94.45	101.95
8.	biacromial breadth	40.09	1.80	36.00	44.50	4.49	37.00	40.00	43.00
9.	chest breadth	26.63	1.81	22.00	32.00	6.78	24.00	26.50	30.00
10.	waist breadth	24.78	2.04	21.00	37.00	8.23	22.50	25.00	28.00
11.	bicristal breadth	27.00	1.93	18.00	28.00	7.16	25.00	27.00	30.00
12.	chest depth	19.29	2.18	13.00	26.00	11.30	16.00	23.00	
13.	abdomen depth	17.73	3.51	11.00	46.00	19.80	15.00	17.00	21.00
14.	femur breadth	8.71	0.69	7.30	11.00	7.94	7.70	8.80	9.70
15.	ankle breadth	7.50	0.46	5.60	8.70	6.11	6.90	7.50	8.20
16.	elbow breadth	7.36	0.30	6.80	8.40	4.06	7.00	7.30	8.00
17.	wrist breadth	5.90	0.43	5.10	7.70	7.24	5.40	5.80	6.70
18.	head circumference	57.10	1.51	51.30	59.80	2.64	54.40	56.90	59.20
19.	neck circumference	36.15	2.00	31.70	42.70	5.54	32.90	36.10	40.00
20.	chest circumference	91.34	7.48	79.50	129.50	8.18	81.50	90.60	104.70
21.	waist circumference	75.64	8.93	63.80	132.50	11.80	66.40	73.60	132.50
22.	pelvis circumference	82.84	8.75	71.40	134.80	10.56	72.90	81.40	95.70
23.	hip circumference	91.09	7.47	80.10	131.90	8.20	82.30	89.80	103.40

No.	Variable	mean	SD	minimum	max	CV	5%	50%	95%
24.	proximal thigh circumference	55.82	6.56	41.80	80.50	11.74	47.70	54.40	66.0
25.	midthigh circumference	46.99	5.20	33.30	64.10	11.05	40.40	46.20	55.30
26.	calf circumference	35.92	3.32	27.90	49.30	9.26	31.20	35.80	40.20
27.	ankle circumference	22.83	1.69	19.60	28.90	7.41	20.60	22.60	25.90
28.	arm circumference	28.15	3.29	20.60	41.00	11.69	23.10	27.50	34.40
29.	forearm circumference	25.64	1.98	20.70	31.70	7.71	22.40	25.80	28.60
30.	wrist circumference	17.19	0.91	15.10	20.20	5.31	15.80	17.20	18.70
31.	cheek skinfold								
32.	chin skinfold	0.488	0.209	0.2	1.9	42.90	0.3	0.4	0.8
33.	chest skinfold	0.571	0.272	0.3	1.8	47.76	0.3	0.5	1.1
34.	midaxillary skinfold	0.808	0.511	0.40	2.9	63.13	0.4	0.6	1.9
35.	suprailiac skinfold	1.073	0.563	0.4	3.5	52.44	0.5	0.9	2.2
36.	supraspinal skinfold	0.587	0.343	0.3	1.9	58.44	0.3	0.5	1.4
37.	abdominal skinfold	0.980	0.634	0.4	3.9	64.68	0.4	0.8	2.4
38.	subscapular skinfold	0.999	0.566	0.4	3.5	56.66	0.5	0.8	2.2
39.	biceps skinfold	0.551	0.311	0.3	2.2	56.49	0.3	0.5	1.0
40.	triceps skinfold	0.932	0.449	0.3	3.0	48.24	0.5	0.8	1.7
41.	thigh skinfold	1.385	0.517	0.5	3.5	37.35	0.8	1.3	2.4
42.	calf skinfold	0.985	0.408	0.45	2.8	41.36	0.5	0.9	1.7
43.	Rohrer index	1.21	0.23	0.73	2.42	18.97	1.007	1.15	1.53
44.	body mass index	21.72	3.89	14.07	42.11	17.91	18.05	20.89	42.11
45.	body surface area (m^2)	1.878	0.158	1.527	2.366	8.44	1.640	1.875	2.110
46.	mean skinfold	0.851	0.399	0.373	2.664	46.88	0.482	0.736	1.800
47.	mass of subcutaneous fat (kg)	7.38	4.23	2.91	28.36	57.25	3.81	6.11	28.36
48.	relative mass of subcutaneous fat (%)	10.06	3.42	5.60	22.35	34.03	6.44	9.17	17.71

Table 2. Comparison of values from various equations predicting percentage of body fat and their correlations with the BIA method

No.	Body fat percentage	Mean	SD	Pearson correlation with BIA	Spearman correlation
1.	BIA	13.19	6.12		
2.	Yuhasz	11.88	3.20	0.91***	0.81***
3.	Sloan	11,47	5.94	0.87***	0.67***
4.	Hechter	17.37	12,40	0.67***	0.70***
5.	von Döbeln	21.98	9.30	0.81***	0.73***
6.	Wilmore and Behnke (3)	15.04	4.68	0.76***	0.53***
7.	Wilmore and Behnke (4)	16.16	5.33	0.82***	0.69***
8.	Wilmore and Behnke (5)	9.22	1.99	0.90***	0.79***
9.	Wilmore and Behnke (6)	15.97	4.52	0.85***	0.69***
10.	relative mass of subcutaneous fat (%)	10.06	3.42	0.87***	0.71***

*** $p<0.001$

Table 3. Multiple regression analysis of BIA assessed body fat percentage in relation to predicting body fat percentage by different anthropometric equations

No.	Anthropometric method	Multiple regression equation	R^2
1.	Yuhasz	= 5.6172+0.4746BIA	82.4
2.	Sloan	= 0.3128+0.8456BIA	75.7
3.	Hechter	= – 0.5863+1.3614BIA	45.1
4.	von Döbeln	= 5.6441+1.2384BIA	66.0
5.	Wilmore and Behnke (3)	= 7.4198+0.5777BIA	57.0
6.	Wilmore and Behnke (4)	= 6.7476+0.7134BIA	67.2
7.	Wilmore and Behnke (5)	= 5.3580+0.2926BIA	80.2
8.	Wilmore and Behnke (6)	= 7.7099+0.6259BIA	71.6
9.	relative mass of subcutaneous fat (%)	= 3.65+0.4858BIA	75.3

DISCUSSION

Assessed by the BIA method, the mean value for fat percentage in the present study is 13.19 %. The equations by Yuhasz and Sloan reported values below that level —11.88% and 11.47%. Equation 5 by Wilmore and Behnke reported an even lower value — 9.22%. Three equations by Wilmore and Behnke (third, fourth and sixth) reported very close values to each other — 15.04%; 16.16% and 15,97%. The equation by Hechter is very close to above mentioned three equations — 17.37%. Von Döbeln equation reported the highest result — 21.98 %. However, all the anthropometric equations mentioned are in good correlation with the result assessed by BIA (Table 2.). The BIA estimated body fat percentage also predicts the body fat percentage of different anthropometric equations R^2 45,1– 82.4%.

The equations of Yuhasz and Sloan are combinations' four and two skinfolds. The equations by Wilmore and Behnke use diameters and circumferences. The Hechter equation uses two diameters and height. The equation by von Döbeln uses height and two condylar breadths. Thus it appears that various predictive equations' predictive power depends on the anthropometrical variables used in the equations. The equations using only skinfolds predict lower values, those using diameters and circumferences using — higher and the equations using bone diameters — the highest results. However, statistically the results of these equations were in good correlations. BIA method results correlated better with skinfolds and circumferences' equations and less with the equations using condylar breadth.

Further study of other samples is needed to confirm these results. There is an apparent need to investigate the relationship of a large number of anthropometric sites including a combination of skinfolds, diameters and circumferences to develop comprehensive predictive equations.

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THE TRACKING OF GROWTH AND FITNESS COMPONENTS IN 8 TO 11-YEAR-OLD GIRLS

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ABSTRACT

One of the basic questions in sports talent detection is to what extent the good performance of a 8–10–12-year-old child can be maintained in adult life. The capacity of an individual to maintain the same position in a group with passing of the time or to stay on a certain percentile position is called tracking. To establish the degree of tracking, longitudinal studies are as necessary as the determination of the interage correlation coefficiency. The purpose of this study was to investigate the dynamics and stability of growth and physical fitness in Estonian girls (8–11 years of age) in different height groups. Age-specific tracking, using interage correlations and performance-related scores were investigated.

Growth and physical performance of Estonian girls was followed longitudinally between 8 and 11 years. The informed consent was obtained in all the 76 girls. At the beginning of the study subjects were divided into 3 groups according to their height by standard deviation. Height and weight were used to characterize dimensions. Following motor ability tests were used: 60 m run with a low start, standing long jump, 4×10 m shuttle run, 1000 m run and hanging. Mean and standard deviataions were used to describe the data. Interage correlations were calculated for height, weight and fitness scores at each age between the ages of 8 and 11.

Our study proved that tall 8-year-old girls maintained the same position in a group after 3 years. The interage correlations of height were very stable (r=0.80–0.95). The biggest intergroup changes occurred in the medium group where only 64.3% of the subjects maintained the initial status. The stability of height was also apparent in motor performance tests. Performance-related fitness track significantly from 8 to 11 years of age, but correlations are very high. This indicated that anthropometrical dimensions and characteristics of performance-related fitness also played a big role in the prediction of adult fitness level.

Key words: Growth, physical performance, longitudinal, tracking

INTRODUCTION

Three types of design can be used in the studies of human growth and development: cross-sectional, longitudinal and so-called time-lag studies. In these designs each measurement taken as a subject at a particular point of time is influenced by three factors: age of subjects, birth cohort to which the subjects belong, time of measurement [18]. Cross-sectional studies are the descriptions of the present status and can only be used as a description of what may be expected when younger groups grow older. Cross-sectional studies of changes in body size and physical performance during adolescence, normally present smooth growth curves. Individual studies of growth, development and fitness can only be studied by longitudinal designs. Pure longitudinal designs are connected with age and time-of-measurement effects because one and the same cohort is studied at different times and consequently at different ages [2, 3, 7, 11, 12, 18]. Cohort and time of measurement effects confound time-lag designs, because different cohorts with the same age are measured at different points in time [18].

One of the basic questions in sports talent detection is to what extent the good performance of a 8–10–12-year-old child can be maintained in adult life. The capacity of an individual to maintain the same position in a group with passing of the time or to stay in a certain percentile position is called tracking. Most often autocorrelations or interage periods and time intervals are used as a tracking index [3]. To establish the degree of tracking longitudinal studies are as necessary as the determination of the interage correlation coefficiency. The level of stability is the more practical way to track the athlete once selected [10]. Using Bloom's [4] r = 0.5 as a criterion dash and jumping performance of girls is reasonably stable over time, in general, girls appear to be more stable in their motor performance than boys [5]. Morphological characteristics are more stable [1]. The growth status of children is perhaps the best indicator of the overall health [9] and motor development [17]. Among the anthropometric variables, body height has a stability of 0.65 to 0.99, when first measured at age of 3 years [1, 6]. Correlations for a longitudinal group of 10 to 14-year-old children were generally higher than those for a group aged 5 to 9. Stability coefficients of motor performance were found to be much lower than those of physical growth [6].

The purpose of this study was to investigate the dynamics and stability of growth and physical fitness in Estonian girls (8–11 years of age) in different height groups. Age-specific tracking, using inter-age correlations and performance-related fitness scores were investigated.

MATERIAL AND METHODS

Subjects

Growth and physical performance of Estonian girls followed longitudinally between 8 and 11 years. The same school was visited every year which made it possible for girls previously enrolled in the study to be reselected in the following years.

The informed consent was obtained in all the 76 girls. According to the medical examination all the children were considered to be healthy. The organized physical activity of the studied girls coincided with the activity prescribed by school curriculum (2×45 min per week). Habitual physical activity of children was not taken into account. At the beginning of the study subjects were divided into 3 groups according to their height by standard deviation. The number of girls in each group was the following:

Short	n= 27	$<(\bar{X}-0.5\sigma)$	<122 cm
Medium	n=28	$(\bar{X}\pm0.5\sigma)$	123–130 cm
Tall	n=21	$>(\bar{X}+0.5\sigma)$	>130 cm

All the subjects were studied 4 times and consequently at different ages (8, 9, 10 and 11 years of age).

The level of stability in individual's height and motor performance level was assessed by maintaining the same position in a group (short, medium, tall; low, medium, high) during 3 years.

Anthropometric Measurements

Height and weight were used to characterize somatic dimensions. All the measurements were taken according to generally accepted methods using a Martin-type metal anthropometer and a calibrated scale. The height measurements were recorded to nearest 0.1 cm and weight to nearest 0.1 kg.

Motor Ability Tests

Running speed: 60 m run with a low start. The time was fixed with the commercial stop-watch (measurements were recorded to the nearest 0.1 sec.).
Explosive strength: standing long jump (measurements were recorded to the nearest 0.5 cm)
Running speed, power, coordination: 4×10 m shuttle run. The time was fixed with the commercial stop-watch (measurements were recorded to the nearest 0.1 sec.).
Aerobic endurance: 1000 m run. The time was fixed to the nearest 0.1 sec.
Hanging: The time was fixed to the nearest 1 sec.

The measuring took place at the classes of physical activity. A proper warming-up preceded each test. The anthropometric measurements and motor testing were performed by the authors of the study with the aid of physical education teachers.

STATISTICS

Mean and standard deviation were used to describe the data. Inter-age correlations were calculated for height, weight and fitness scores at each age between the ages of 8 and 11. The significance level was set at 5% ($p<0.05$).

RESULTS

The interage correlations of height, weight and physical performance tests, as a tracking indexes are presented in Table 1. The tall group had statistically significant ($p<0.05$) interage correlations in anthropometrical dimensions and physical performance tests. The correlations changed only slightly with aging. The bigger differences in interage correlations occurred in the medium group in which the result of the 8-year-old girls' height was in low, but in statistically significant correlation ($p<0.05$) with the result of those at 9 and 10 (0.48 and 0.51, correspondingly). The correlation between height results of 8 and 11-year-old girls were nonsignificant ($p>0.05$). In other tests the correlations were statistically significant ($p<0.05$). In the short group the correlations between the results of 8-year-old girls in height and weight and the results of 9 to 11-year-old girls were lower (0.55–0.74 and 0.50–0.70, correspondingly). In other tests the interage correlations were very stable.

Table 1. Interage correlations of tall, medium and short girls in growth and physical performance tests ($p<0.05$).

Test	Age	Tall			Medium			Short		
	(yrs)	9	10	11	9	10	11	9	10	11
Height	8	0.95	0.93	0.80	0.48	0.51	NS	0.74	0.64	0.55
	9		0.93	0.83		0.92	0.86		0.81	0.68
	10			0.88			0.83			0.86
Weight	8	0.92	0.88	0.80	0.85	0.89	0.87	0.70	0.50	0.59
	9		0.94	0.90		0.95	0.85		0.76	0.86
	10			0.95			0.92			0.73
Shuttle run 4×10 m	8	0.97	0.93	0.89	0.98	0.95	0.90	0.98	0.93	0.91
	9		0.97	0.94		0.97	0.92		0.97	0.94
	10			0.98			0.95			0.98
60 m run	8	0.92	0.86	0.87	0.90	0.80	0.65	0.96	0.91	0.80
	9		0.93	0.88		0.95	0.74		0.93	0.79
	10			0.91			0.78			0.84
1000 m run	8	0.88	0.67	0.69	0.88	0.80	0.77	0.92	0.87	0.86
	9		0.89	0.86		0.89	0.87		0.92	0.90
	10			0.75			0.98			0.98

Test	Age	Tall			Medium			Short		
	(yrs)	9	10	11	9	10	11	9	10	11
Standing long jump	8	0.90	0.84	0.81	0.92	0.72	0.63	0.93	0.89	0.83
	9		0.92	0.91		0.86	0.76		0.96	0.93
	10			0.97			0.96			0.97
Hanging (grip strength)	8	0.93	0.85	0.80	0.95	0.89	0.79	0.96	0.92	0.83
	9		0.96	0.92		0.94	0.87		0.97	0.91
	10			0.97			0.95			0.97

DISCUSSION

The measurement of stature is the most widely used indicator of growth. All young people follow the same pattern of growth from infancy through adolescence but there are significant individual differences in both timing and the magnitude of change in stature. For a long time it was believed that childhood scores, especially the pubertal period, would not predict adult performance.

The prognosis can be positive only in case the changes in the development are stable. When they happen to be occasional, the prognosis cannot be significant. Let us suppose that we measured the development of several indices (height, velocity, etc.) with 8-year-old children. What about them in 3 or 5 years? Will the tall girls remain tall? Will those showing a high level in velocity keep it? How stable will the corresponding indices be when the child develops?

Our research showed that the body height of girls from 8–11 years of age proved very constant ($r = 0.80–0.95$), 87.5% from the subjects maintained the same position in a group during 3 years. The initial status of the medium and short group (at the age of 8) had lower, but statistically significant ($p<0.05$) or nonsignificant correlations with aging. In the medium and short group 64.3 and 70.4% of the subjects maintained the initial status. Consequently taller girls at 8–11 years of age had a more stable height than the shorter ones. It is an important factor in prognosing the body growth. We did not find indices about the stability of height with the girls of different height. The lower stability of the medium group may be related to sexual maturation. The course of puberty lasts for 10 years on an average with Estonian girls [15]. There is some evidence that in early puberty the stability coefficients decrease, but after puberty they increase significantly [10]. We also noticed this tendency during the research. Many studies have shown a high stability of body height and heritability with adolescents up to the adulthood [10, 19].

Running speed (60 m run) and 4×10 m shuttle run show a very high stability in our study. There are no differences between the groups. The stability coefficients were from 0.65 to 0.98. Several other researchers have found a high level of heritability in these tests, e.g. heritability of 0.89 for a 4×10 m shuttle run [8], 0.90 for dashes [14, 20]. The situation is analogical with aerobic endurance (1000 m run), muscle power (standing long jump) and isometric strength (hanging) where stability coefficients occurred from 0.72 to 0.98 (Table 1). The stability coefficient of aerobic power by other investigators is 70–90% [13], in muscle power 0.86 [16] and in isometric strength 0.70 to 0.80 [8].

Our study proved that tall 8-year-old girls maintained the same position in a group after 3 years. The interage correlations of height were very stable (r = 0.80–0.95). The biggest intergroup changes occurred in the medium group where only 64.3% of the subjects maintained the initial status. The stability of height was also apparent in motor performance tests. Performance-related fitness track significantly from 8 to 11 years of age, but correlations are very high. The stability goes on with aging [14]. This indicated that anthropometrical dimensions and characteristics of performance-related fitness also played a big role in the prediction of adult fitness level.

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ANTHROPOMETRIC PROFILE AND STRENGTH DEVELOPMENT IN BODYBUILDERS AT DIFFERENT AGES

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ABSTRACT

The purposes of this study were to assess: 1) the anthropometric profile and the strength performance status in bodybuilders of different ages through a cross-sectional design; 2) the changes in the anthropometric profile and trainability of strength through a 2-year-longitudinal design. The cross-sectional and longitudinal studies were carried out on Estonian men from 15 to 45 years of age. The subjects were divided into 3 age groups: 1) 15–20; 2) 21–25; 3) 26–45 years. All the subjects participated in the cross-sectional study of 1997, and 13 in the longitudinal study from 1997 to 1999. Anthropometric measurements (height, weight, BMI, and skinfold thickness) and strength tests (bench press, leg press and leg raises) were applied. The subjects underwent special bodybuilding training, based on generally accepted principles of bodybuilding. The cross-sectional study gave an overview of the anthropometric profile and muscle strength in bodybuilders of different ages. The differences between the age groups in body weight and BMI were statistically significant ($p<0.05$), but those between circumferences were statistically significant ($p<0.05$) only between the younger and the medium age groups. The average thickness of skinfolds measured in different parts of the body was biggest in the older group, whereas the difference with the younger and medium age groups was statistically significant ($p<0.05$). Maximum strength proved to be strongest in the medium age group. The longitudinal study showed a statistically significant development of muscle strength ($p<0.05$) in the medium age group and positive influence of regular strength training on body composition (the fat mass did not increase).

Key words: body composition, physical activity, trainability of strength

INTRODUCTION

Only a few studies have examined changes in strength and body composition during a longer period [15]. It has been established over the past 20 years that seniors benefit from the participation in a resistance training programme. Fiatarone et al. (1990) [8] demonstrated that even individuals over the age of 90 could gain strength over a 8-week training period. This finding generated great attention. Improvements in strength and functional ability (e.g. improved mobility) can enhance the quality of life even of individuals with chronic illnesses. Strength training is one of the ways to compensate for the age-related decline in strength and muscle and to improve the quality of life. Studies have shown that muscle strength starts to decline from the age of 50 [18]. From 50 to 60 the loss in muscle strength usually is 18–20% [17]. Cross-sectional as well as longitudinal data indicate that muscle strength declines by approximately 15% from the age of 60 to 70 [6]. Cross-sectional data show a 2% loss of grip strength per year with those over 65. The loss of hand grip strength followed longitudinally over a 4-year period and was 3% per year for men and nearly 5% to women [2]. It appears that muscle strength losses are most dramatic after the age of 70. Knee extensor strength of a group of healthy 80-year-old men and women was found to be 30% lower than that of 70-year-old men and women [6]. Age-related strength losses occur sooner and faster in the lower extremities than in the upper extremities [4].

Muscle power and its trainability in seniors has not received a great deal of study, although it may be even more important than strength for the functional abilities of the individuals, as many everyday activities (walking, climbing stairs, lifting objects) require rapid force development as a certain degree of power performance. Leg extensor power of elderly men (88.8±6.0 years) was significantly correlated with chair-raising speed, stair climbing speed and power, and walking speed [1]. Many researchers believe that muscle weakness in old age can be attributed primarily to inactivity rather than to age or sex [9]. The general conclusion is that elderly men and women can tolerate and positively adapt themselves to heavy weight training programs [5, 10], e.g. a group of sedentary older men (age 60 to 72 years), using a high-intensity resistance training regimen during 12 weeks demonstrated substantial strength gains and showed evidence of muscle hypertrophy [10].

Changes in the fat-free body (FFB) composition and the effect of these changes on the density of the FFB in the elderly has not been firmly established. Between the ages of 25 and 65 years, there is a substantial decrease in lean body mass [11]. The generalised skinfold [7, 12], anthropometric [19], and bioelectrical impedance [3] have been used for estimating body density.

The purposes of this study were to assess:

1. The anthropometric profile and the strength performance status of bodybuilders in different age groups through a cross-sectional design;
2. Changes in the anthropometric profile and trainability of strength through a 2-year-longitudinal design.

MATERIAL AND METHODS

Cross-sectional and a longitudinal studies were carried out on Estonian men from 15 to 45 years of age. The subjects were volunteers who trained at Tartu Bodybuilding Club. Habitual physical activity was not taken into account. The subjects were divided into 3 age groups:

Age (years)	15–20	21–25	26–45
Subjects (number)	24	14	12

All the subjects participated in the cross-sectional study of 1997, and 13 in a longitudinal study from 1997 to 1999.

Anthropometric measurements

The participants of this study were measured anthropometrically. The measurements were taken according to the classical method [13]. Weight and height were measured. All the persons were weighed in light clothes to the nearest 0.1 kg with a Philips electronic device, height was measured using a Martin anthropometer to the nearest 0.1 cm. Body Mass Index (BMI) was calculated from the measurements of body mass and height (kg/m^2). The circumferences of chest in three positions, proximal thigh, calf, flexed and tensed arm were taken using a tape. Skinfold thicknesses were measured at standardised sites [14] using skinfold callipers with a constant 10 g/mm^2 pressure applied at right angles to the fold defined between the observer's thumb and index finger at following sites: biceps, triceps, chest, abdominal, waist, subscapular and thigh.

Strength tests (20)

Bench press. It is an excellent basic movement that places intense stress on the pectorals, anterior and medical deltoids and triceps. Secondary stress is also placed on the muscles that import rotational stress on the scapulae.
Leg press. This fundamental exercise powerfully stresses the quadriceps, buttocks, and hamstrings. It places such intense stress on the cardio-respiratory system that is also good for burning body fat and improving one's physique for a competition.
Leg raises. Leg raises also stress the rectus abdominis, particularly the lower half of the frontal abdominal wall. Significant stress is also born by the hip flexors.

Training methods

Generally accepted methods for training muscle hypertrophy and strength were used (Table 1) [16].

Table 1. Methods for improving muscle hypertrophy and strength [16]

	Standard method I (Constant load)	Standard method II (progressively increasing load)	Bodybuilding method (extensive)	Bodybuilding method II (intensive)
Intensity load (%)	80	70, 80, 85, 90	60–70	65–95
Repetitions	8–10	12, 10, 7, 5	15–20	8–5
Sets	3–5	1, 2, 3, 4	3–5	3–5
Rest interval (min)	3	2	2	3

1) Standard method I (constant load): with a load of 80%, 3 – 5 sets of 8 – 10 repetitions are performed with rest intervals of 3 min.
2) Standard method II (progressively increasing load): with the number of sets the number of repetitions decreases. Frequently, the last

repetition in a set cannot be performed without assistance. In that case a training partner provides some slight manual help to allow completion of the prescribed repetition.

3) Bodybuilding method I (extensive stress): this classical type of training is widely used and aims at bringing about excessive depletion of musculature.
4) Bodybuilding method II (intensive stress): with this method an intensive depletion of the fast twitch fibres is sought.

Both bodybuilding methods aim at the total overloading and depletion of energy stores. The required number of sets and repetitions can only be fulfilled with the assistance of a partner. Variations of training strategies [20], such as forced repetitions, negative repetitions, supersets, burns, cheated-repetitions or the use of the pre-exhausting principle, provide a long and intensive training stimulus.

The subjects underwent a special bodybuilding training. The total volume of training load was assessed by the numbers of training sessions per week (3–4) and in hours (4.5–6 hours) per week. The training process was based on the generally accepted principles of bodybuilding [20].

Statistics

The data were processed on a personal computer using the statistical package Systat for Windows. For comparing the data of the first and the second investigation paired-sample t-test was used. Differences with p-value $p<0.05$ were evaluated as statistically significant.

RESULTS

The results of anthropometric measurements of the cross-sectional study in 1997 are given in Table 2.

Statistically significant differences ($p<0.05$) in anthropometric measurements occurred between the younger (15–20 years) and the medium age groups (21–25 years). Between the medium and the older groups (26–45 years) there were no statistically significant differences in height. The mean results of skinfold measurements had statistically significant differences between the medium and the older group but not between the younger and the medium group.

Table 2. The results of anthropometrical measurements of the cross-sectional study (means ± SD)

Parameter	Age group		
	15–20 n=24	21–25 n=14	26–45 n=12
Height (cm)	179.3±6.7	184.0±8.5*	182.4±8.1
Weight (kg)	71.8±7.2	81.2±9.7*	88.1±8.7*
BMI (kg/m^2)	22.4±2.2	24.0±2.4*	26.4±1.6*
Circumferences (cm)			
Chest (normal)	95.6±4.9	103.5±6.1*	105.7±5.1
Chest (breathing in)	99.7±5.4	106.5±5.7*	106.7±5.3
Chest (breathing out)	93.0±4.0	98.7±5.4*	101.6±4.5
Thigh	54.8±3.7	58.7±3.1*	61.0±2.6*
Calf	36.5±1.7	38.3±2.6*	40.1±1.6*
Biceps (flexed)	30.9±2.5	33.2±2.4*	35.0±2.0*
Biceps (tensed)	33.9±2.6	36.1±2.4*	36.1±37.1*
Skinfolds (mm)			
Biceps	3.5±0.8	3.3±0.7	4.5±1.3*
Triceps	8.4±2.6	7.5±1.6	10.0±2.2*
Chest	6.8±2.4	7.2±2.3	11.7±3.8*
Abdominal	10.0±4.2	8.9±3.9	17.0±4.8*
Waist	10.3±3.9	9.7±2.8	18.3±5.7*
Subscapular	7.8±2.1	8.0±1.3	12.3±3.6*
Thigh	10.8±2.9	10.4±4.2	13.2±3.2*

* differences between the age groups are statistically significant ($p<0.05$).

The results of strength tests in the cross-sectional study in 1997 are presented in Table 3.

Table 3. The results of strength tests (means ± SD)

Test	Age group		
	15–20 n=24	21–25 n=14	26–45 n=12
Bench press (kg)	72.3±10.8	87.6±18.1*	84.7±15.8
Leg press (kg)	168.7±19.5	206.4±34.3*	189.5±33.6*
Leg raises (times)	18.5±4.7	18.2±2.8	16.0±4.3*

* differences between the age groups are statistically significant ($p<0.05$).

The mean results of the medium age group are better ($p<0.05$) in bench and leg press as compared to the younger group. The mean result of leg raises reduces with ageing. The mean results of leg press and leg raises in the older group are significantly ($p<0.05$) lower as compared to the medium group.

The dynamics of anthropometric characteristics in the longitudinal study during two years (1997–1999) is given in Table 4.

Table 4. The results of anthropometrical measurements in the longitudinal study (means ± SD)

Parameter	Results measured at 1997	Results measured at 1999
Height (cm)	182.1±8.2	182.3±8.0
Weight (kg)	82.3±9.2	85.4±8.8*
BMI (kg/m^2)	24.9±2.7	25.7±2.5*
Circumferences (cm)		
Chest (normal)	103.4±5.9	106.7±5.0*
Chest (breathing in)	106.6±5.7	109.7±4.9*
Chest (breathing out)	100.0±5.4	101.6±4.5
Thigh	58.4±3.0	59.2±3.4
Calf	38.3±2.8	37.9±2.5
Biceps (flexed)	33.6±2.3	35.5±2.6*
Biceps (tensed)	35.9±1.9	37.5±2.6*
Skinfolds (mm)		
Biceps	4.4±1.3	4.4±1.4
Triceps	9.1±1.9	9.7±2.7
Chest	6.4±2.1	7.1±2.8
Abdominal	3.9±5.4	6.0±5.3
Waist	3.0±4.9	3.4±5.0
Subscapular	1.3±4.2	2.1±3.6
Thigh	2.2±2.5	3.9±4.0

* the development is statistically significant ($p<0.05$).

During the two-year training period some anthropometric parameters (weight, chest and biceps circumferences) increased significantly ($p<0.05$). There were no changes in skinfold measurements.

Strength improvement during the 2-year training period is given in Table 5.

Table 5. The strength improvement during the 2-year training period (means ± SD)

Tests	Results measured in 1997	Results measured in 1999
Bench press (kg)	80.0±10.0	98.9±21.3*
Leg press (kg)	178.3±18.4	215.8±37.9*
Leg raises (times)	15.7±3.2	18.5±3.4*

* the development is statistically significant ($p<0.05$).

DISCUSSION

Our cross-sectional study gave an overview of the anthropological profile and muscle strength in bodybuilders of different ages. Differences between the age groups in body weight and BMI were statistically significant ($p<0.05$), and those between the circumferences of the younger and medium age groups were also statistically significant ($p<0.05$). As for the differences between the medium and older groups, they were significant only in the circumferences of arms and legs (Table 2). The majority of circumferences are correlative with one another, which is statistically significant ($p<0.05$), except the thigh circumference, the correlations of which with the circumferences of other parts of the body were statistically insignificant ($p>0.05$) in all the age groups. Maybe the training methods that we used did not guarantee the harmonious development of the thigh muscles. At the same time it is known that the thigh muscle is one of the muscles which is difficult to train [20].

The average thickness of skinfolds measured in different parts of the body was biggest in the older group, whereas the difference with the younger and medium age groups was statistically significant ($p<0.05$). This certifies the common tendency that the amount of fat mass increases with age [12]. The majority of average indices of skinfolds were in correlation with the circumferences of the body parts, and they were statistically significant. This refers to an even thickening of the subcutaneous fat mass in men.

As for maximum strength (bench press, leg press), the men of the medium age group (21–25 years) proved to be the strongest. The difference with the younger group was statistically significant ($p<0.05$). This is logical, for this is the age at which the level of maximum muscle strength is achieved [17]. The men in the older age group maintained the level of muscle strength of the upper body as compared to the medium age group ($p>0.05$), while the strength of abdominals and leg muscles decreased significantly ($p<0.05$). The difference in the abdominals between the older and younger age groups may be related to the increase in the muscle mass of legs and thighs, characterised indirectly by the statistically significant increase in their circumferences ($p<0.001$, Table 3), which makes performing this exercise more difficult. The above mentioned was also proved by correlation analysis: it showed statistically significant negative correlation between the results of leg raise and the circumference of thigh and leg ($p<0.05$). One of the reasons of the lower level in the strength endurance of abdominals in the older group may be insufficient training of its members. The result of the leg press in the lying position was in significant correlation ($p<0.05$) with the circumferences of breast and upper arm in all age groups, while there was no significant correlation between the indices of leg press and the thigh circumference ($p>0.05$). Consequently the strength of leg muscles did not increase together with the growth of muscle mass but with the improvement of coordination inside muscles and between muscles.

Numerous studies have proved the good trainability of muscle strength in adolescence. The trainability of middle-aged people in the same respect has been less researched, and the studies have been of comparatively short duration. Our 2-year-longitudinal study (the average age of 26.7 years) showed a statistically significant increase in muscle strength ($p<0.05$–0.001). The increase in body weight was also statistically significant ($p<0.05$), but the circumferences of the thigh and leg ($p>0.05$) did not grow in spite of regular training. Practical life has proved that many bodybuilders have problems with increasing the muscle mass of thighs and legs. At the same time the strength of leg muscles increased considerably (37.5 kg on an average, $p = 0.002$) (Table 5).

The thickness of measured skinfolds increased very little ($p>0.05$) or even remained the same during the training period of 2 years. Consequently, we can state that the increase in body weight was mainly due to muscle mass, not to fat mass.

Our investigation showed that the people engaged in regular strength training had a certain age-related anatomical profile. Biggest differences occurred between the circumferences of the younger and the medium age groups. Our longitudinal study showed a statistically significant development of muscle strength ($p<0.05$) in the middle age and the positive influence of regular strength training on the body composition (the fat mass did not increase).

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CONTINUITY OF BODY TYPIFICATION AND DYNAMICS OF HEART MORPHOMETRY IN GIRLS OF MEDIUM-LATE PUBERTY

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ABSTRACT

During two years a longitudinal study was performed on 79 healthy schoolgirls (aged 15–17) in order to follow the continuity of body-build typification in puberty and to assess the dynamics of heart morphometry depending on transformations in body build. The subjects were studied anthropometrically and echocardiographically. The somatotypes of the girls were specified by a 5-class height-weight classification both at the age of 15 and 17.

67% of girls remained in the same somatotype class at the age of 17 as they were at the age of 15. Transition from one class to another occurred because of changes in weight.

Most important dynamic changes took place among the girls who belonged to the medium class according to the height-weight classification at the age of 15 and in those who were pycnomorphs by the age of 17.

In 80% of cases the heart measurements did not show any dynamics during the two years. A strong correlation ($r = 0.683$) appeared between growth in height and volume measurements of the left ventricle, and between the thickness of the intraventricular septum and growth in weight ($r = 0.56$).

Key words: somatotype, girl, puberty, heart measurements.

INTRODUCTION

Although the human body as a whole is linearly well-correlated system [5], the variability in body-build is large; therefore it is necessary to use typification in clinical practice.

For characterisation and typification of variations in body build a multivariate 5-class height-weight classification [7] has been applied, which is possibly appropriate for studying the internal structure of human build for medical purposes [6, 7].

Schoolchildren are complicated research subjects because of continuous changes in body build at that age. The individual constitutional peculiarities of healthy persons are formed at the age of adolescence. The dynamics of body growth is characterised by different velocity. Alternations in growth velocity are connected to the genetic factor, but the influence of external and internal environmental factors is not less important.

Although anthropometric studies of schoolchildren have been carried out in Estonia for a long time [1, 4, 9], the problems of their anthropometric characteristics and typification of dynamics have not been finally solved yet.

Contrary to somatic growth, the growth dynamics of internal organs, including the dynamics of heart growth, have hot been extensively analysed. A few longitudinal studies have displayed that generally there are no great differences between the intensity and timing of heart and body growth [8].

This study is aimed at obtaining basic information about the continuity of body typification in girls at the medium-late period of puberty and at assessing the dynamics of heart morphometry depending on transformations in body build.

MATERIAL AND METHODS

A longitudinal study was performed on 79 healthy Estonian schoolgirls. Their health status was estimated by personal histories of physical examination and reports of family doctors. The girls were aged 15 (±0.5) years at the beginning of the investigation and 17 (±0.5) years at the end. All the girls were examined anthropometrically [3] — 25 body dimensions and 11 skinfolds were measured and 5 indexes were calculated. Heart dimensions were obtained by echocardiography. Two-dimension measurements by the dopplerechocardiography system Sonos 5500 according to the recommendations of the American Society for Echocardiography were performed. All the measurements were repeated twice by the same team of observers. Intra-observer measurement error was less than 10%.

The following heart measurements were obtained: aortic cross diameter (AO), gross diameter of truncus pulmonalis (AP), right ventricular outflow tract (RVOT), anterior-posterior diameter of left atrium (LA), left ventricular maximal cross diameter in diastole (LVEDd), left ventricular inner diameter in diastole (LVIDd), ventricular septum thickness in diastole in basic (STd_1) and distal (STd_2) region of ventricular septum, left ventricular posterior wall thickness in diastole in basic (PWd_1) and distal (PWd_2) region of left ventricular posterior wall.

Left ventricular volume (LVVd) in diastole was calculated by Teicholtz formula, left ventricular mass (Mass) by the formula of Devereux [2].

According to somatometric data at the age of 15 and at the age of 17, the sample of data was classified into a 5-class SD-classification of height and weight [1] — 1. small, 2. medium, 3. large, 4. pycnomorphs, 5. leptomorphs.

The data were processed with the statistical packet STATISTICA. The correlation coefficients were calculated by Spearman's method.

RESULTS AND DISCUSSION

During the two-year period the means of all anthropometric and heart measurements of the girls increased significantly (Tables 1 and 2), except the index biacromial breadth / pelvis breadth, in which the change was not significant ($p>0.05$) and thoracal index, whose value decreased significantly. The mean increase in basic body-build parameters — height and weight — did not differ from the values obtained in similar studies by other Estonian authors [4, 9], being 2 cm for height and 4.9 kg for weight. However, detailed analysis of dynamics of parameters showed the large variability of changes (from 0 to 21 cm in height and from a decrease of 3.9 kg to an increase of 30.4 kg in weight). The changes in the girls' somatotypes at the age of 17 in comparison with age 15 are presented in Tables 3 and 4.

Table 1. Basic statistics of anthropometric parameters and indices of girls at age 15 and 17 and their dynamics during 2 years

	15 years			17 years			dynamics
	x	σ	v	x	σ	v	
1. height (cm)	165.5	5.83	3.5	168.1*	5.74	3.4	+2.02
2. weight (kg)	52.2	7.74	14.8	57.5*	7.3	12.6	+4.9
3. sitting height	85.8	4.11	4.8	88.2*	6.1	6.9	+1.21
4. biacromial breadth	35.5	1.9	5.4	36.5*	1.66	4.5	+4.1
5. pelvis breadth	26.8	1.8	6.7	28.2*	2.1	7.5	+3.3
6. chest circumf.	79.6	4.9	6.2	82.9*	4.3	5.2	+3.1
7. waist circumf.	65.0	5.1		67.1*	4.5		+2.99
8. pelvis circumf.	85.7	7.8	9.1	88.9*	7.3	8.2	+3.7
9. arm circumf.	24.4	2.4		25.8*	2.13		+1.45
10. BMI (kg/m^2)	19.0	0.23	1.2	20.6*	0.25	1.2	+1.22
11. thoracal index	69.7	6.64	9.5	62.4*	6.8	10.9	–8.6
12. biacromial breadth/ pelvis breadth	132.9	9.21	6.9	133.1	7.3	5.5	+0.72
13. Rohrer index	1.21	0.16	0.13	1.27*	0.19	0.14	+0.02
14. mean thickness of skinfolds (mm)	11.0	0.4	3.6	10.7*	0.3	2.8	–0.2

* $p < 0.001$

Table 2. Values of heart measurements of Estonian girls at ages 15 and 17

	15 years			17 years			Significance
	x	σ	v	x	σ	v	
LVEDd	41.80	2.90	20.90	42.60	2.65	6.2	0.01
LVIDd	41.70	2.70	6.47	42.70	2.52	5.9	0.001
LVVd	77.80	12.18	15.60	105.50	23.90	22.6	0.00
STd_1	7.40	1.70	22.90	8.46	1.61	19.0	0.00
STd_2	7.80	1.51	19.35	10.00	1.102	11.0	0.00
$PWTd_1$	8.30	0.36	4.33	8.90	1.27	14.3	0.005
$PWTd_2$	8.90	1.17	13.14	9.70	1.50	15.5	0.005
Mass	124.00	22.97	18.52	127.20	30.80	24.2	–
Mass/LVIDd	1.36	0.25	18.30	1.29	0.41	31.7	–
RVOT	24.50	2.99	12.20	26.30	3.12	11.9	0.00
LA	23.60	2.75	11.65	26.10	3.04	11.6	0.00
AO	26.00	2.81	10.80	27.40	2.82	10.3	–

	15 years			17 years			Significance
	x	σ	v	x	σ	v	
AP	17.80	1.56	8.76	17.90	2.23	12.6	–
ST/PW_1	0.86	0.16	18.60	0.92	0.17	18.4	0.03
ST/PW_2	0.85	0.16	18.80	0.82	0.14	17.0	–
RWT	0.43	0.06	13.90	0.45	0.07	15.5	0.02
LVVd/BSA	49.73	7.87	15.80	62.90	13.90	22.0	0.00
LVMass/BSA	67.16	12.34	18.30	77.92	15.90	20.4	0.00

Table 3. Dynamics of somatometric parameters grouped into 5 height-weight classes during two years

1. Grouped by height-weight values at age 15

Parameters	I Small N=14	II Medium N=13	III Large N=14	IV Pycno-morph N=17	V Lepto-morph N=21	Significance
1. height (cm)	2.00	1.60	1.00	0.680	2.60	–
2. weight (kg)	9.60	19.20	6.40	3.000	9.50	2:3,4,5
3. sitting height	1.71	2.40	0.90	0.000	0.90	–
4. biacromial breadth	4.99	5.90	2.00	3.700	4.00	2:3
5. pelvis breadth	0.79	3.70	1.90	6.100	3.90	–
6. chest circumf.	4.28	4.60	2.90	0.100	3.54	–
7. waist circumf.	2.98	3.90	3.00	1.700	2.90	2:4
8. pelvis circumf.	–2.70	2.60	–1.40	–0.100	0.80	–
9. arm circumf.	1.70	1.90	1.20	0.700	1.40	2:4
10. BMI (kg/m^2)	0.13	0.25	0.08	0.040	0.07	2:3,4,5
11. thoracal index	–5.10	–6.60	–11.20	–10.700	–9.30	–
12. biacromial breadth/pelvis readth	3.16	3.20	0.25	–3.100	0.03	–
13. Rohrer index	0.07	0.14	0.04	0.015	0.01	4:1,2,5 3:2
14. mean thickness of skinfolds (mm)	–5.30	–1.57	–2.29	–4,200	–3.00	1:2
15. body surface area	0.10	0.08	–0.03	0.090	0.09	–
16. mass of sub-cutaneous fat tissue	–3.70	–0.70	–1.80	–2.000	–2.10	2:1,4
17. relative mass of subcutaneous fat tissue	–7.20	–2.20	–4.10	–5.800	–5.40	–

2. rouped by height-weight values at age 17

Parameters	I Small N=17	II Medium N=14	III Large N=13	IV Pycno-morph N=11	V Lepto-morph N=24	Signifi-cance
1. height (cm)	1.40	1.400	1.60	1.40	2.00	–
2. weight (kg)	10.70	10.700	7.22	19.90	7.90	4:2,3,5
3. sitting height	1.80	1.670	1.80	2.70	0.00	5:4
4. biacromial breadth	4.45	2.100	3.20	4.80	4.70	–
5. pelvis breadth	1.54	0.370	5.30	4.80	4.00	–
6. chest circumf.	2.10	4.500	1.60	5.10	3.70	–
7. waist circumf.	2.10	3.300	2.80	4.90	2.70	4:1,5
8. pelvis circumf.					–1.40	–
9. arm circumf.	1.00	1.600	1.60	2.40	1.30	4:1,5
10. BMI (kg/m^2)	0.13	0.030	0.07	0.29	0.06	4:1,2,3,5
11. thoracal index	–7.80	–11.800	–12.10	0.50	–10.90	4:1,2,3,5
12. biacromial breadth/pelvis breadth	3.90	2.300	–2.70	0.55	–0.08	–
13. Rohrer index	0.07	–0.004	0.02	0.18	0.01	–
14. mean thickness of skinfolds (mm)	–2.50	–2.860	–2.80	–2.80	–3.80	–
15. body surface area	–0.07	0.060	0.07	0.08	0.08	–
16. mass of sub-cutaneous fat tissue	–1.60	–1.970	–2.30	–2.20	–2.70	–
17. relative mass of subcutaneous fat tissue	–4.60	–4.10	–4.60	–5.30	–6.30	–

Tables 4 and 5 present the dynamics of somatometric parameters depending on somatotype according to a 5-class height-weight classification grouped by values of height and weight at the ages of 15 and 17.

Table 4. Dynamics of affiliation of girls to height and weight classes (grouped into 3 classes at age 17, compared to age 15)

	By height	By weight
Remained	98%	71%
From bigger into smaller	–	16%
From smaller into bigger	2%	13%

Table 5. Dynamics of affiliation of girls to the classes of a 5-class height-weight classification at age 17 (compared to age 15)

Remained	67%
From correspondence class into non-correspondence class	28%
From non-correspondence class into correspondence class	30%

Although the growth process and increase in height continues, 98% of girls remained in the same height class at the age of 17 as they were at the age of 15.

The transition from one class to another was mostly caused by changes in weight. 67% of girls remained in the same somatotype class by the 5-class height-weight classification as they were at the age of 15. (Table 5) . In most cases of somatotype changes in height-weight correspondence classes, mainly in the medium class (II), the somatotype changed to leptomorphous (V). In the non-correspondence classes, mostly among pycnomorphs (IV), the change was to a correspondence class, namely small (I).

It appeared that the most important dynamic changes took place among the girls of the medium class in comparison with the girls of other classes grouped by values of height-weight at age 15. When grouped by height-weight values at age 17, the most significant dynamics of parameters occurred in pycnomorphous girls.

It is remarkable that in adolescent years the girls' absolute and relative values of subcutaneous fat tissue decreased significantly, and body surface area practically did not change during the two years.

The dynamics of heart measurements was not in linear correlation with somatometric growth. Still, a correlation ($r = 0.683$) was recorded between the growth of height and left ventricular maximal cross diameter's and inner diameter's values during the two years.

The thickness of intraventricular septum correlated with the growth of weight ($r = 0.56$) and of height ($r = -0.4$). In nearly 80% of girls no dynamics in heart measurements occurred during the two years.

CONCLUSION

According to our material, in most cases the somatotype of girls has been formed to the age of 15 years. One should assess the somatotype carefully if a girl has great retardation in sexual maturity, or if she has a medium or pycnomorphous somatotype with somatometric parameters on the border of these classes.

To predict heart measurements on the basis of body build, body surface area in combination with height can be used as a predictor for volume measurements, and body surface area in combination with weight for left ventricle's wall thickness and left ventricle mass.

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RELATIONSHIPS BETWEEN ANTHROPOMETRIC VARIABLES AND DIFFERENT ROWING ERGOMETER TESTS IN HEAVYWEIGHT AND LIGHTWEIGHT MALE ROWERS

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ABSTRACT

The aim of this study was to investigate the differences between heavyweight and lightweight male rowers in anthropometric parameters and different rowing ergometer tests and how their anthropometric parameters are related to the results of different rowing ergometer tests. Thirteen heavyweight (20.61±1.71 years, 189.97±5.45 cm, 88.63±4.30 kg) and eight lightweight rowers (23.00±7.91 years, 182.10±5.83 cm, 73.06±3.89 kg) took part in the investigation. The subjects performed a progressive incremental test ($\dot{V}O_{2max}$, AT_4, Pa_{max}), 2500 metre "all-out" test (T_{2500}), 20 maximal strokes test (P20, anaerobic lactic power) and five maximal strokes (P5, anaerobic a lactic power) test on a rowing ergometer. In heavyweight rowers, significant relationships ($p < 0.05$) were found between muscle mass and P5, P20, $\dot{V}O_{2max}$, Pa_{max} and T_{2500} indices ($r = 0.67–0.83$), between CSA thigh and P5, P20, Pa_{max} and T_{2500} indices ($r = 0.76–0.88$), and between skeletal mass and P5 indices ($r = 0.68$). In lightweight rowers, significant relationships were obtained between body fat percent and $\dot{V}O_{2max}$ and T_{2500} indices ($r = 0.76–0.87$), between lean body mass and P20, $\dot{V}O_{2max}$, Pa_{max} and T_{2500} indices ($r = 0.80–0.92$). It was concluded that in heavyweight rowers the best anthropometric parameters to predict competitional success are the muscle mass and CSA thigh, while in lightweight rowers the best parameter is lean body mass.

Keywords: anthropometry, rowing ergometer, heavyweight rowers, lightweight rowers

INTRODUCTION

A typical rowing competition takes place on a 2000 metre course and lasts six to seven minutes. A rower has to perform more than 200 strokes with a peak force of 800 to more than 1000 N [15]. Rowing demands a high level of strength and endurance [6]. A large body mass is involved in rowing and body size and body mass undoubtedly are performance-related factors [1, 15]. However differences in anthropometric characteristics have been observed between rowers in three categories: sculling, sweep rowing and lightweight rowing.

In rowing, maximal oxygen uptake is known to be a good predictor of competition success, although its predictive influence varies in different analyses [12, 15]. Maximal oxygen uptake is often large in oarsmen; this finding reflects their large body dimensions [12]. The relative oxygen uptake is low in oarsmen as compared to other endurance athletes because their body weight is high [6, 12, 15]. Only in some, mainly lightweight oarsmen, relative oxygen uptake reaches 75 $ml \cdot min^{-1} \cdot kg^{-1}$ [12, 15]. Thus, specific anthropometric characteristics may influence the performance characteristics of heavyweight and lightweight rowers.

The aim of this study was to investigate: (a) the differences in anthropometric parameters and different rowing ergometer tests between heavyweight and lightweight male rowers; and (b) how the anthropometric parameters are related to different rowing ergometer tests in heavyweight and lightweight male rowers.

MATERIAL AND METHODS

Twenty one experienced male rowers, including eight lightweight rowers, volunteered to participate in the study (Table 1). The subjects were training regularly and had being doing so for the last 4.95±1.86 years. Measurements took place at the beginning of the winter session (in November). The rowers were familiarised with the laboratory procedures and possible risks before providing their consent to participate in the experiment. Each rower was tested on three separate occasions over a three week period with at least three days between the tests. The rowers were asked not to participate in any physical activity within 24 hours before testing and to abstain from eating for three hours before testing. This study was approved by the Medical Ethics Committee of the University of Tartu.

The height (Martin metal anthropometer) and body mass (medical balance scale) of the subjects were measured and body mass index (BMI) ($kg \cdot m^{-2}$) was calculated. The sum of six skinfold thicknesses (i.e., *triceps, subscapular, abdominal, supraspinale, front-thigh* and *medial-calf*) was measured (Holtain skinfold calliper, UK) [2]. Body density was determined according to the skinfold prediction equation of Durnin and Womersley [3], and the percentage of body fat was calculated from body density according to the equation of Siri [14]. In addition, muscle mass was calculated according to Martin *et al* [7], while skeletal mass was calculated according to Martin [8]. The cross-sectional area (CSA) of thigh was estimated according to Hawes [5].

All exercise tests were performed on a wind resistance braked rowing ergometer (Concept II, Morrisville, USA). Heart rate (HR) was measured continuously and stored at five second intervals during all exercise tests by sporttester Polar Vantage NV (Kempele, Finland). At the first measurement session, a progressive incremental exercise test to maximal intensity was performed to determine the maximal oxygen consumption ($\dot{V}O_{2max}$) (in $l \cdot min^{-1}$ and $ml \cdot min^{-1} \cdot kg^{-1}$), maximal aerobic power, defined as the mechanical power where $\dot{V}O_{2max}$ is reached (Pa_{max} in W) and the power corresponding to the 4 $mmol \cdot l^{-1}$ blood lactate concentration as the anaerobic threshold (AT_4 in W) [9, 16]. Capillary blood samples for enzymatic determination of blood lactate concentrations (Lange, Germany) [4] were taken from the fingertips during a 30 second rest interval at the end of each intensity [9, 16]. Expired gas was sampled continuously for the measurement of $\dot{V}O_{2max}$ (TrueMax 2400 Metabolic Measurement System, Parvo Medics, USA).

At the second measurement session, the subjects were asked to cover a distance of 2500 metres on a rowing ergometer in as little time as possible (T2500 in sec). Capillary blood samples for enzymatic blood lactate analyses were taken from the fingertips three and five minutes after the exercise (Lange, Germany) [4].

The third measurement session consisted of five maximal strokes (P5 in W, anaerobic alactic power) and 20 maximal strokes (P20 in W, anaerobic lactic power) on a rowing ergometer. Capillary blood samples for enzymatic blood lactate analyses were taken from the fingertips three and five minutes after the exercise (Lange, Germany) [4].

Descriptive statistics (mean ± standard deviation [SD]) for each of the dependant variables were determined. Differences were estimated with independent t-tests with an error of estimate set to 0.05. Pearson

Product Moment Correlation coefficients were used to determine the strength of relationship between each of the dependent variables. An alpha level of 0.05 was used.

RESULTS

Mean (±SD) anthropometric parameters of the heavyweight and lightweight rowers are presented in Table 1. Significant differences between heavyweight and lightweight rowers were found in all the measured anthropometric parameters. The results of different rowing ergometer tests are summarised in Table 2. Again, all the measured parameters on rowing ergometer were statistically different between lightweight and heavyweight male rowers.

Table 1. The anthropometric parameters of heavyweight and lightweight male rowers

	Heavyweight (n=13)	Lightweight (n=8)
Height (cm)	189.96±5.45	182.10±5.83*
Body mass (kg)	88.63±4.29	73.06±3.89*
BMI ($kg.m^{-2}$)	24.62±1.57	22.08±1.25*
Body fat%	12.04±2.03	8.45±1.17*
LBM (kg)	78.00±3.37	66.92±4.05*
Muscle mass (kg)	53.31±4.40	42.63±4.28*
Skeletal mass (kg)	12.42±0.84	10.79±0.88*
CSA thigh (cm^2)	276.89±23.71	226.18±13.40*

BMI — body mass index; LBM — lean body mass; CSA thigh — the cross-sectional area of a thigh; * — $p<0.05$.

Table 3 presents the relationships between anthropometric parameters and different rowing ergometer tests. In heavyweight rowers, significant correlations were found between lean body mass and P5 indices, between muscle mass and P5, P20, $\dot{V}O_{2max}$, Pa_{max} and T_{2500} indices; between skeletal mass and P5 indices and between CSA thigh and P5, P20, Pa_{max} and T_{2500} indices. In lightweight rowers, significant correlations were found between body fat percent and $\dot{V}O_{2max}$ and T_{2500} indices; and between lean body mass and P20, $\dot{V}O_{2max}$, Pa_{max} and T_{2500} indices.

Table 2. The metabolic parameters of different rowing ergometer tests in heavyweight and lightweight male rowers

	Heavyweight (n=13)	Lightweight (n=8)
P5 (W)	795.69±132.05	591.50±74.94*
P20 (W)	697.82±118.04	506.23±61.56*
AT_4 (beats·min^{-1})	177.61±7.05	170.14±5.79*
Pa_{max} (W)	399.42±53.79	308.62±37.49*
$\dot{V}O_2$ (l·min^{-1})	5.21±0.46	4.31±0.62*
$\dot{V}O_2$ (ml·min^{-1}·kg^{-1})	58.89±4.51	58.70±7.68
T_{2500} (sec)	500.62±16.49	535.85±20.24*

P5 —five maximal strokes on a rowing ergometer; P20 —20 maximal strokes on a rowing ergometer; $\dot{V}O_2$ —maximal oxygen consumption; Pa_{max} — maximal aerobic power; AT_4 —anaerobic threshold; T_{2500} —2500 metre "all-out" rowing ergometer test.

Table 3. Correlations between the anthropometric parameters and rowing ergometer tests in heavyweight and lightweight (in brackets) male rowers

	P5 [1] (W)	P20 (W)	$\dot{V}O_{2max}$ (l·min^{-1})	Pa_{max} (W)	T_{2500} (sec)
Height (cm)	0.44	0.18	0.26	0.17	–0.21
	(0.51)	(0.62)	(0.23)	(0.67)	(–0.50)
Weight (kg)	0.53	0.42	0.29	0.48	–0.55
	(0.53)	(0.75)	(0.43)	(0.62)	(–0.65)
BMI (kg·m^{-2})[1]	0.07	0.20	0.01	0.26	–0.28
	(–0.16)	(–0.10)	(0.11)	(0.26)	(0.04)
Body fat%	–0.12	–0.14	–0.12	–0.05	0.03
	(–0.52)	(–0.63)	(–0.87*)	(–0.65)	(0.76*)
LBM (kg)	0.71*	0.59	0.42	0.60	–0.67
	(0.70)	(0.92*)	(0.80*)	(0.83*)	(–0.91*)
Muscle mass (kg)	0.83*	0.67*	0.80*	0.74*	–0.81*
	(0.40)	(0.61)	(0.68)	(0.47)	(–0.67)
Skeletal mass (kg)	0.68*	0.53	0.36	0.51	–0.40
	(0.63)	(0.63)	(0.35)	(0.67)	(–0.55)
CSA thigh	0.81*	0.76*	0.60	0.79*	–0.88*
	(0.04)	(0.33)	(0.32)	(0.14)	(–0.35)

[1] — abbreviations are the same as in Tables 1 and 2; * — statistically significant p<0.05.

DISCUSSION

It has been reported that the anthropometric parameters of lightweight rowers differ radically from those of heavyweight rowers [13]. This was also the case in our study were all the measured anthropometrical parameters were significantly higher in heavyweight rowers (see Table 1).

In rowing, which is a strength endurance type of sport, body size and body mass are undoubtedly performance-related factors [1, 13]. Ideally, the body mass should contain a high proportion of muscle [13, 15]. In our study, the heavyweight rowers had relatively high muscle mass (53.31±4.40 kg), which corresponded to 60.10±4.32% of their body mass. Bourgois *et al.* [1] found the muscle mass of 168 male junior world championship competitors to be 50.16 kg and 62.38% of the whole body mass. Thus, the muscle mass of our heavyweight rowers was relatively high as well. The lightweight rowers had significantly smaller muscle mass in comparison with heavyweight rowers (42.63±4.27 kg), but there were no significant differences in the percentage of muscle mass (58.27±4.08%) between the studied groups of rowers. According to these results we may say that the lightweight subjects also have relatively high muscle mass and the amount of muscle mass plays an important role in rowing success.

In rowing, maximal oxygen consumption is known to be a good predictor of competition success [12, 15], although its predictive influence varies in different analyses [12, 15, 16]. Although $\dot{V}O_{2max}$ ($l\cdot min^{-1}$) in heavyweight rowers was significantly higher than in lightweight rowers (5.21±0.46 vs. 4.31±0.62 $l\cdot min^{-1}$), the relative $\dot{V}O_{2max}$ ($ml\cdot min^{-1}\cdot kg^{-1}$) showed no statistical differences (58.89±4.51 vs. 58.70±7.68 $ml\cdot min^{-1}kg^{-1}$). According to these results, the relative $\dot{V}O_{2max}$ does not have a high value in predicting the competitional success of rowers. Muscle mass was significantly related to $\dot{V}O_{2max}$ in heavyweight rowers ($r = 0.80$). In lightweight rowers, statistically significant correlations were found between $\dot{V}O_{2max}$ and body fat percentage ($r = -0.87$) and lean body mass ($r = 0.80$).

Energy expenditure on 2000 metre single scull distance is high [10, 13, 15]. According to Roth *et al.* [10], the energy for the 2000 metre rowing distance is provided 67% aerobically and 33% anaerobically, 21% alactic and 12% lactic. This means that a rower needs both high aerobic and anaerobic capacity. In our study, we used five maximal strokes (P5) on a rowing ergometer to determine the anaerobic alactic power and 20 maximal strokes (P20) to determine the anaerobic lactic power. P5 and P20 results were significantly higher in heavyweight rowers in comparison with lightweight rowers. Statistically significant correlations were found between P5 and lean body mass ($r = 0.71$), muscle mass ($r = 0.83$) and skeletal mass ($r = 0.68$) for heavyweight rowers. No statistically significant correlations were found between the anthropometric parameters of lightweight rowers and P5 results. These results are in accordance with a review article by Shephard [13], who reported that maximal anaerobic as well as aerobic parameters differ radically between lightweight and heavyweight rowers.

The heavyweight rowers showed significantly ($p<0.05$) shorter 2500 metre time than the lightweight rowers (500.62±16.49 vs. 535.85±20.24 sec.). Statistically significant relationships were found between the 2500 "all-out" test and muscle mass ($r = -0.81$) and CSA thigh ($r = -0.88$) for heavyweight rowers and between lean body mass ($r = -0.91$) for lightweight rowers. This means that rowers' body mass should contain a high amount of lean body mass both in lightweight and heavyweight rowers.

In conclusion, the results of the study indicate that the anthropometric profile of lightweight male rowers differs radically from that of the heavyweight rowers. The results of the investigation suggest that for heavyweight rowers the best anthropometrical parameters to predict competition success are muscle mass and CSA thigh. For lightweight rowers, the best anthropometrical parameter to predict competitional success is lean body mass.

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INTER-POPULATION DIFFERENCES ON LINEAR ENAMEL HYPOPLASIAS IN TWO LITHUANIAN AND DANISH MEDIEVAL AND EARLY MODERN SAMPLES

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ABSTRACT

The aim of the study was to investigate the epidemiology of non-specific stress markers — Linear Enamel Hypoplasias (LEH) — in two medieval populations. Analysis was performed on 88 adult individuals from Subačiaus St sample (Lithuania) and 126 adult individuals from Tirup (Denmark). Statistically significant population differences in general incidence of LEH (in Subačiaus St 100% individuals were affected, in Tirup — 90,5%), number of stress episodes per person (3.31 and 2.66 in average correspondingly) and severity of enamel hypoplasias (average grade correspondingly 1.78 and 1.37) were found. In general, Subačiaus St sample adults had more marked LEH and greater number of stress episodes. We argue that differences in LEH expression reveal different stress level in both populations due to different life conditions. Possible causes of such differences and problems of interpretation of the results are discussed in the text.

Key Words: enamel hypoplasia, medieval population, Lithuania, Denmark

INTRODUCTION

Multidisciplinary approach to morbidity of paleopopulations enables to elucidate various aspects of history and population dynamics. However, influence of pathogens and individual respond to them is often unspecific. Thus, recently more and more scientific research focuses on the analysis of non-specific stress indicators, especially on the epidemiology of Linear Enamel Hypoplasias (LEH). LEH are defined as horizontal lines of decreased enamel thickness on the external surface of the tooth crown due to disturbance of the enamel formation during tooth crown development [17]. Such disturbances can be caused by various factors that affect child's growth: inherited and infectious disease, changes in dietary habits, malnutrition, intoxication and others [14]. These factors can affect the activity of ameloblasts and interrupt enamel formation. When individual recovers after the insult, formation of tooth crown continues, leaving a line of thinner enamel — a trace of experienced stress.

Population analysis is based on the assumption that differences in LEH frequency, severity and age at formation reflect differences in stress level of population. Thus LEH are widely used for evaluation of the health status of certain population and for interpopulation comparisons [3, 6, 22, 23, 26]. However, there is no agreement on the interpretation of the results. Some authors argue that the more severe and frequent LEH, the greater stress people experienced during their childhood and thus, the less favourable life conditions they had [3, 6, 8, 20, 25]. According to others [1], stress markers on human teeth mean that the individual managed to get through the disease and recovered, so his/her living conditions or individual resistance must have been better than those who had died in childhood and, thus, don't show any traces of stress on the teeth. The latter opinion is in concert with the so-called "osteological paradox" [24].

Finally, there is a radically sceptical view [12] that LEH are fairly poor indicator of population stress level, because they can be conditioned also by mechanical, ceremonial trauma, ingestion of toxic substance or genetic factors, so they cannot reflect the level of systemic stress in certain population. Even if individual really have experienced dietary stress or disease, it is hard to predict if hypoplasia will occur because it depends on properties of the individual immune system.

In purpose to evaluate such contradictory views we decided to compare frequency and severity of stress markers, expressed in LEH, in two populations and to analyse the possible causes of differences. At first we had to evaluate if there are differences in number of affected individuals in populations living in different geographical and cultural conditions, and if there are differences in LEH frequency and severity per individual.

MATERIALS AND METHODS

Analysis was performed on two medieval populations. Subačiaus St in Vilnius (Lithuania) is an urban orthodox cemetery dated 17th century, excavated in 1998 by A.Vaicekauskas. Tirup (Denmark) is rural parish cemetery dated 12–14th centuries, excavated in 1984 by J. Kieffer-Olsen, investigated by the first author during stay at Odense University.

Only adult individuals of known sex and age (they were estimated by other investigators using conventional morphological criteria) were taken for the study. Both series were investigated by the same individual, this way eliminating the possible bias of interobserver error. Our earlier study [13] revealed that there are differences in LEH expression on upper and lower dentition, thus, only individuals with complete upper and lower teeth of left or right side were included into analysis. LEH were recorded on all permanent teeth of the left side of the dentition (in case of missing tooth, the antimere from right side was used).

Severity of hypoplasias was recorded according to Schultz [16]: 1 degree — mild, 2 degree — moderate, 3 degree — severe. Number of stress episodes per individual was defined according to the age at which hypoplasia formed. If LEH on several teeth of the same individual match the same age at formation they were defined as one stress episode. Age at LEH formation was determined according to Massler *et al.* [9].

In total, there were 88 individuals from Subačiaus St and 126 individuals from Tirup that could provide reliable information and were included into analysis.

RESULTS

The general incidence of LEH was high in both samples: 90.5% individuals of Tirup population had one or more hypoplasias, while in Subačiaus St, 100% of individuals had traces of stress expressed in LEH ($t=3.64$; $p<0.05$).

There are also differences in severity and number of LEH in both populations. Average severity of hypoplasias was statistically higher in Subačiaus St population than in Tirup (1.78 and 1.37 degree correspondingly; t = 3.86; p<0.05). Majority of individuals in both samples had hypoplasias of moderate degree — 44.3% in Subačiaus St and 49.2% in Tirup. Percent of mild injuries also was similar in both populations — correspondingly 38.6% and 35.7%. Severe hypoplasias were more common in Subačiaus St — 17% of all affected individuals, while in Tirup — only 5.6% (t = 2.40; p<0.05) (Table 1).

Table 1. Severity of LEH in two populations

Population	LEH degree			Total	Mean	SD
	1	2	3			
Subačiaus St	34(38.6)*	39(44.3)	15(17.0)	88(100)	1.78	0.72
Tirup	45(35.7)	62(49.2)	7(5.6)	113(90.5)	1.37	0.82

* — number and percent (in parentheses) of affected individuals.

Statistically significant (t = 3.67; p<0.05) difference was also found in the average number of stress episodes per individual — 3.31 in Subačiaus St and 2.66 in Tirup (Table 2). Majority of people in Subačiaus St population had 2–4 stress episodes, in Tirup — 2–3 stress episodes. Only 3.4% of Subačiaus St individuals and 2.6% of Tirup individuals expressed the highest number (6) of stress episodes. The greatest and statistically significant population differences were between groups of people with 1 stress episode (t = 3.86; p<0.05) and between groups of people with 4 and 5 stress episodes (t = 2.16; p<0.05 and t=2.25; p<0.05). It means, that in Subačiaus St sample higher number of individuals had multiple stress episodes.

Table 2. Number of stress episodes expressed in LEH per individual in two populations

Population	Number of stress episodes						Mean	SD
	1	2	3	4	5	6		
Subačiaus St	4(4.5)*	24(27.3)	19(21.6)	26(29.5)	12(13.6)	3(3.4)	3.31	1.24
Tirup	20(17.7)	34(30.1)	32(28.3)	19(16.8)	5(4.4)	3(2.7)	2.66	1.25
t	**3.26**	0.45	1.13	**2.16**	**2.25**	0.29		

* — number and percentage (in parentheses) of affected individuals.

DISCUSSION

Our analysis revealed significant population differences in frequency and severity of stress indicators expressed in LEH. In general, Subačiaus St sample adults had more marked LEH and greater number of stress episodes. Do those differences really reflect different stress level? Incidence of LEH is fairly high in both samples. According to literature such situation is not uncommon in Medieval populations [3, 8, 21]. But evaluation of LEH incidence in population usually come across the problem of precise determination of hypoplasias. As LEH of mild degree are not very clear, there is possibility to take as hypoplasia more prominent perikymata, lines that define the normal enamel growth. This must be taken into consideration when one wants to compare individuals with hypoplasias of mild or unspecified degree.

In our case, main population difference was expressed by hypoplasias of moderate and severe degree, that reliably can be considered as stress markers. If more severe LEH means greater stress in childhood, we could consider people from Subačiaus St population being more stressed than people from Tirup. Actually, interpretation of the severity of LEH is more complicated, because it depends not only on severity of stress, but also on individual features of immune system [12]. Two different people exposed to the same stress can develop hypoplasias of different degree. This was supported by experimental studies that failed to confirm correlation between severity of stress and manifestation of LEH [19]. Despite that we think that differences detected by us are fairly large to express differences on population level.

The same problems can also affect the number of stress episodes, because not everyone who was stressed will necessarily develop LEH and, in opposite, LEH can appear on teeth of unaffected individual because of mechanical damages or genetic causes [12]. Other studies at the same time, however, reveal relation between stress and LEH. According to May *et al.* [10], children who received less than 34.25 kcal/day in supplement had more LEH then those who received more supplement. Our analysis revealed statistical differences of the number of stress episodes. Major population differences were between groups of mildly stressed people and groups of highly stressed people of both populations. We think, such differences can be attributed to differences in stress level. And results also reveal the same tendency — individuals with 4 and 5 stress episodes were more frequent in Subačiaus St population.

Thus our study revealed that LEH do show objective differences between populations. It was found that people from Subačiaus St population have more and greater hypoplasias than people from Tirup. There can be two totally different interpretations of this phenomenon. High number and severity of LEH can indicate, that individuals of that population had hard and poor living conditions and were exposed to greater stress during childhood [3, 6, 8, 20, 25]. Or, in opposite, this could mean that those individuals had fairly wealthy life and this enabled them to survive stress and develop stress markers while poorer and less stronger individuals died [1]. In order to define which explanation is more reliable in our case, we should discuss factors that can cause differences between groups of people.

When one has to compare populations from different geographical regions, geographical-climatic factors should be taken into consideration. In our case both populations were from the same geographical latitude. Despite slight climatic differences — climate in Lithuanian is more continental and in Denmark is more maritime — other conditions are similar. Obviously, climatic differences are too slight to cause great differences in people's life conditions.

Another factor — population-genetic differences. There are cases when enamel defects are inherited, but frequency of such defects are fairly low (1 of 14000–16000 of people in USA) [14]. As was mentioned before, LEH can also be caused by mechanical trauma or cultural treatment and thus, cannot reflect systemic stress [12]. But again, such damages are not very frequent and that fact, that hypoplasias were recorded on all, not on a few separated teeth allow us to minimise the possibility of random damages.

We think we can also minimise the importance of slightly different chronology. Although Tirup is dated 12–14th centuries and Subačiaus St — 17th century in both cases that were Middle Ages according to historical and economical processes that took places in those centuries. But population differences are of importance. Tirup was a small medieval village, subsistence of inhabitants being based on agriculture, while Subačiaus St population belonged to the city. People from villages were more isolated from other communities due to their settled life style. In towns and cities migrations of people because of crafts and trades often took place. Such migrations could cause mixing of people and genetic changes. This implies that additional studies concerning changes in the same population during time and differences in different populations of the same time should be taken in order to evaluate the real influence of the population-genetic factors to the epidemiology of LEH.

The third group of factors that can cause differences in epidemiology of LEH — ecological and cultural. We suppose that those causes were the most important in determining different people life conditions and different stress level in different populations. Ordinary citizens in Middle Ages had worse life conditions than peasants. Various infectious diseases were wide and easily spread in towns because of great number of people and high density [5, 11, 18]. Ordinary citizens were often malnourished [2, 4, 7, 15]. Such situation was really stressful for children who were born in town. According to this, it is not surprisingly that people from Subačiaus St had more frequent and severe hypoplasias, because they had to experience more stresses in their childhood. According to historical data (A. Ragauskas, pers. comm.), the orthodox community of Vilnius, although experienced periods of political discrimination, was quite influential in 17th century. Many of its members reached high social and political status. However, it was quite stratified society with own rich and penniless individuals. Nor historical, nor archaeological data at the moment do not provide reliable information about social status of those individuals which constituted the sample of present study. Taking into account these facts, conclusion about less beneficial life conditions of people from Subačiaus St population than in Tirup could be made, but at the moment the effect of the "osteological paradox" cannot be rejected.

However, we argue that LEH are an objective indicator of life condition and can be used in comparative purposes. But one should take into consideration conditions of recording and, especially, interpretation of obtained results. Further analysis of better documented samples possibly will solve the contradiction of the above discussed hypothesis. It is also important to define if stress experienced in childhood affect people life later in adulthood. We think it would be advisable to look at selective morbidity and elucidate influence of childhood stress to life longevity of adults.

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STAGES OF BIOLOGICAL MATURATION IN THE SLOVAK POPULATION: TIMING AND SEQUENCES

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ABSTRACT

Data on stages of maturation were collected by specially instructed paediatricians and youth specialists from 3584 Slovak boys and girls in 43 districts in 1962. Axillary and pubic hair were studied in both sexes, mammae in girls, mammillae and genitalia in boys and menarche ("yes" or "no" at the time of investigation) in girls. The method used was that of Tanner, described in his book *Foetus into Man*, 1981. The four stages of maturation of secondary sex characteristics were:

- 0 — infantile stage,
- 1 — onset of pubertal development,
- 2 — quantitatively more advanced stage than 1 but not mature yet,
- 3 — just attained mature stage of development,
- 4 — fully mature stage of development (which sometimes need not be present even in a normal adult).

The results are presented in a table and eight figures. Due to the long-lasting stagnation in maturation (more than 30 years) in Czech girls, we may presume that the same stagnation in the development of secondary sex characteristics occurred in Slovak girls and boys as well, and that the results are still valid at present. The first sign of maturation comes in girls at the age of 11.1 years when stage 1 in mamma occurs in 50 per cent of girls. Next come the pubes (at 11.6 years) and axilla (at 12.6 years). The median age of menarche is 13.2 years.

In 50 per cent of boys puberty starts at the age of 11.6 years with stage 1 in genitalia development. It is followed by stage 1 in pubes (at 12.7 years), stage 1 in the mamilla (13.4 years) and finally the stage 1 in the axilla at 13.6 years. Boys are delayed in comparison with girls in axillary hair by a year at stages 1 and 2, by 11 months at stage 3 and by 6 months at stage 4. Stage 1 occurs in the axilla in boys at 13.6 years and in girls at 12.6 years. The first stiff dark pubic hair occurs in 50 per cent of girls at the age of 11.6 years and in boys at 12.7 years. Girls attain stage 2 at 13.7 years and boys at 14.6 years (being belated by 11 months). Girls are ahead of boys in pubic hair at stage 3 by 5 months and at stage 4 by 6 months. The results show that at the age of 14 years fully mature "men" in terms of pubes and genitalia development sit in the same classroom at school next to their mates who have not attained even the 1st stage of development of the same characteristics yet. A similar picture can be seen in girls at the age of 13 years in the development of the mamma and pubes: A fully mature "woman" sits next to a girl-child in one classroom. These findings are important for teachers, school health officers and sport instructors. For psychological reasons, boys and girls themselves should be aware of the broad variability in the occurrence of various stages of maturation. They tend to compare themselves with their contemporaries and some of them may get worried that they are not "normal".

Key words: biological maturation, age of menarche, stages of maturation

INTRODUCTION

There is no doubt that one of the most interesting phenomena in human biology in the 20th century has been the secular trend of increase in the mean stature of humans in industrialised countries.

A nearly converse relation to the increase in stature was found in the decreasing age of sexual maturation as represented by the age of menarche in girls. From 1895 to 1962 the onset of menarche in Czech girls shifted to an approximately 2 years earlier time (from 15 to 13 years of age). Then it came to a halt, although stature continued to increase [1]. We suppose that a similar picture occurred in Slovak girls whose history of menarche does not reach so far back as that of the Czech girls. Anyhow, they were a part of both statewide anthropological surveys performed in 1951 and 1961 in former Czechoslovakia and were also involved in a special investigation of the stages of sexual development in 1962 [2]. Their data were analysed separately from the Czech girls. On the whole, the Slovak girls were slightly smaller than the Czech ones, and their age of menarche was by 0.1 year higher (13.2 years). More details on growth and maturation in Czech and Slovak youths were provided by Prokopec in his doctoral thesis [3], which also gives an overview of publications on somatic maturation. Though the onset of menarche does not necessarily correlate with secondary sex characteristics in girls, we may expect that their relation to age has remained unchanged from the early seventies to the present. We may also expect that maturation of boys has also come to a halt similarly to girls. Thus, the stages of sexual maturation of Slovak children and youths from 9 to 18 years of age, investigated in 1962, are likely to have not only historical significance but also current validity.

MATERIAL AND METHODS

With the voluntary aid of 18 paediatricians and 25 medical specialists for adolescents (practically a half of all registered in the Slovak regions) who were specially instructed, data were collected for a representative sample from 43 districts amounting to 3564 Slovak boys and girls from 9 to 18 years of age (1798 boys and 1766 girls). The children were divided into 5 groups (0–4) according to the development stages of secondary sex characteristics. These included: axillary and pubic hair in both sexes, mammae in girls, mamillae and genitalia in boys and menarche in girls (noted only by the status quo method: "yes" or "no" at the time of investigation). The five stages of maturation of secondary sex characteristics were the same as in Tanner [4], but rated 0–4 instead of 1–5:

- 0 — infantile stage,
- 1 — onset of pubertal development,
- 2 — quantitatively more advanced than 1 but not mature yet,
- 3 — mature stage of development (just attained),
- 4 — fully mature stage of development (which sometimes does not have to be present even in the normal adult).

At first a simple percentage distribution of each developmental stage in every age group (attained year ± 6 months), separately for boys and girls, was computed. The method of cumulative frequencies was used for analysing the incidence of individual stages of maturation in each age group of the children. Theoretical values (standards) were obtained by plotting the cumulative data on a probability paper and by drawing the best fitting line. The 10th, 50th and 90th centiles were put into a table (Table 1). The age of menarche (the age at which 50 per cent of girls attain their physiological maturity) was also calculated in the same way.

Table 1. Age distribution of developmental stages of secondary sex characteristics in Slovak boys and girls from 9 to 18 years of age (in years)

BOYS				GIRLS			
AXILLA	10%	50%	90%	AXILLA	10%	50%	90%
0	(8.2)	10.8	13.4	0	(7.9)	9.9	11.9
1	11.1	13.6	16.1	1	10.3	12.6	15.0
2	13.7	15.7	17.8	2	12.0	14.7	17.4
3	14.6	16.5	(18.4)	3	13.3	15.6	17.0
4	15.2	17.0	(18.9)	4	14.2	16.6	(18.9)
MAMILLA	10%	50%	90%	MAMMA	10%	50%	90%
0	9.0	10.6	13.5	0	(7.4)	9.1	10.8
1	10.5	13.4	16.3	1	9.0	11.1	13.2
2	12.8	15.0	16.3	2	10.6	13.7	16.9
3	14.0	16.2	(18.3)	3	12.4	15.1	17.8
4	14.8	16.9	(19.0)	4	13.1	15.8	(18.6)
PUBES	10%	50%	90%	PUBES	10%	50%	90%
0	(8.2)	10.3	12.4	0	(7.8)	9.5	11.3
1	10.7	12.7	14.8	1	9.6	11.6	13.6
2	12.8	14.6	16.4	2	11.3	13.7	16.2
3	13.7	15.7	17.7	3	12.7	15.2	17.8
4	14.6	16.6	(18.5)	4	13.4	16.0	(18.6)
GENITALIA	10%	50%	90%		10%	50%	90%
0	(7.5)	9.7	12.0				
1	9.6	11.6	13.6				
2	12.0	14.3	16.7	MENARCHE	11.7	13.2	14.8
3	13.2	15.4	17.6				
4	14.1	16.7	(19.2)				

Sequence
50% stages of development

Boys	(years)	Girls	(years)
1 — genitalia	(11.6)	1 — mamma	(11.1)
2 — pubes	(12.7)	2 — pubes	(11.6)
3 — mammilla	(13.4)	3 — axilla	(12.6)
4 — axilla	(13.6)		

Menarche occurs in girls between stages 1 and 2 in the axilla, mamma and pubes.

RESULTS

The ages by which 10, 50 and 90 percent of boys and girls had attained a certain stage of maturation in secondary sex characteristics, are given in Table 1. Maturation in 50 per cent of boys started with changes in the genitalia (stage 1) at the age of 11.6 years. The first pubic hair occurred 1.1 year later (at 12.7 years) and at the age of 13.4 years a turgescent mamilla was observed in 50 per cent of boys. Axillary hair stage 1 occurred in 50 percent of boys at the age of 13.6 years. In genitalia, 50 per cent of boys reached stage 2 at the age of 14.3 years, stage 3 at 15.4 and stage 4 at 16.7 years. In pubes stage 2 appeared in 50 per cent of boys at the age of 14.6 years, stage 3 at 15.7 and stage 4 at 16.6 years. Further ages of attainment of individual stages of maturation may be read from Table 1. There is a time period of 4 to 5 years between the 10 and 90 per cent ranges in the occurrence of the described stages of secondary sex characteristics in boys.

The mean sequences of events in girls were as follows: Changes on the areola mammae came first (in 50 per cent of girls) at 11.1 years. The first pubic hair appeared 5 months later (at 11.6 years) and after a year (at 12.6 years) stage 1 of axillary hair occurred. Stage 2 occurred in the mammae in 50 per cent of girls at the age of 13.7 years, stage 3 at 15.1, and stage 4 at 15.8 years. Stage 2 in pubes came in girls at the same age as in mamma (13.7 years), and stages 3 and 4 occurred in pubes in comparison with mamma with the difference of only 1 and 2 months (stage 3 at 15.2 years and stage 4 at 16.0 years). In axillary hair, stage 2 appeared in 50 per cent of girls at the age of 14.7 years (a year earlier than in boys), stage 3 at 15.6 years (11 months earlier than in boys), and stage 4 at 16.6 years (six months before boys). In girls the age span between the 10th and 90th per cent ranges is about 4 to 6 years in the mamma, pubes and axilla. The 50th percentile of menarche in girls corresponds with the age of 13.2 years (the 10th percentile being 11.7 and the 90th percentile 14.8 years). Menarche occurs in 50 per cent of Slovak girls between stages 1 and 2 of the axilla, mamma and pubes. The time sequences of the secondary sex characteristics as given here for the given centiles need not be true in individual cases. We observed boys and girls in whom axillary hair occurred before their pubic hair or breasts started to develop. Girls are more advanced in maturation than boys of the same age. The onset of maturation comes in axillary hair and pubes about a year earlier in girls than in boys. Percentages of stages of maturation (0–4) in the given age groups from 9 to 18 years are given in Figures 1–4 for boys and 5–8 for girls. The maturation rate of girls is very rapid until the age of 14 years and slower afterwards, whereas in boys a steady increases in stages 3 and 4 in successive age groups after the age of 14 years may be observed year by year up to the age of 18 years. Although some cases of fully mature stages of development in pubes and genitalia occur in boys as early as at 13 years, they constitute only about 50 per cent in 18-year-olds.

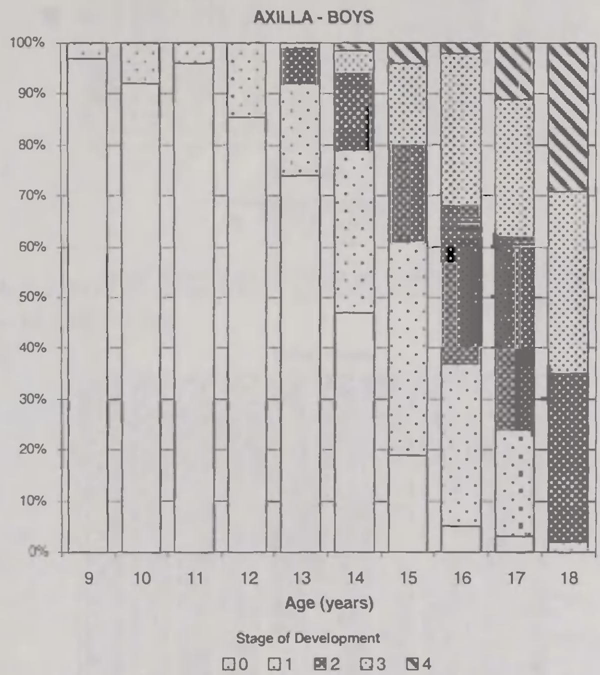

Figure 1. Stages of development of axillary hair in Slovak boys from 9 to 18 years of age.

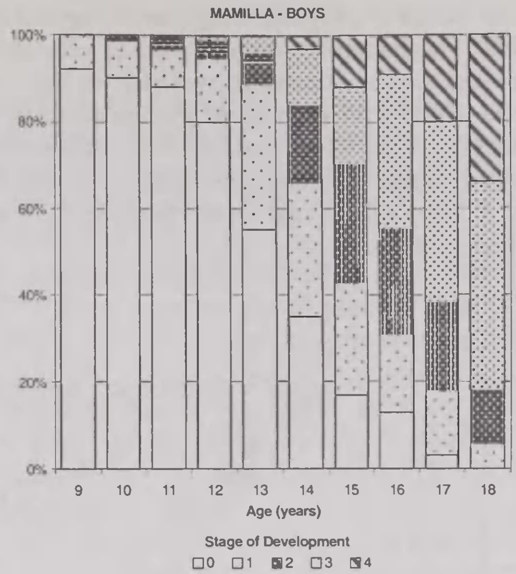

Figure 2. Stages of development of mamilla in Slovak boys from 9 to 18 years of age.

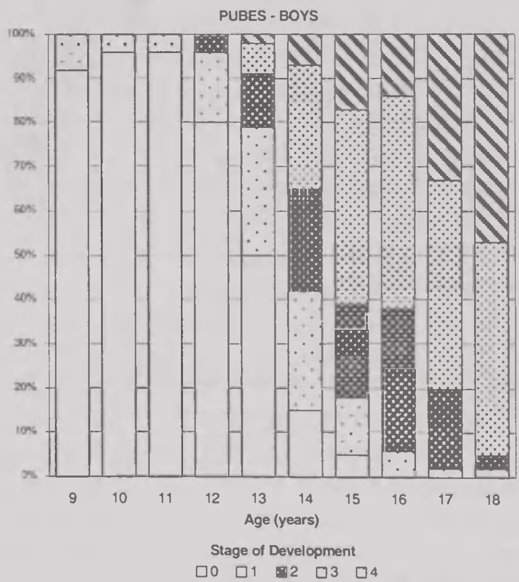

Figure 3. Stages of development in pubic hair in Slovak boys from 9 to 18 years of age.

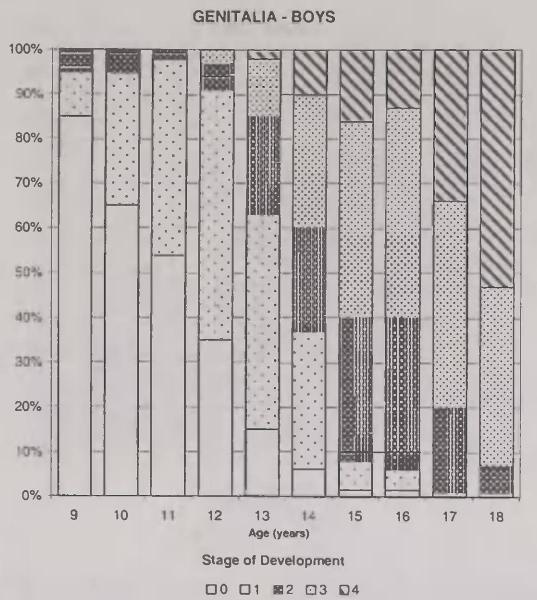

Figure 4. Stages of development in genitalia in Slovak boys from 9 to 18 years of age.

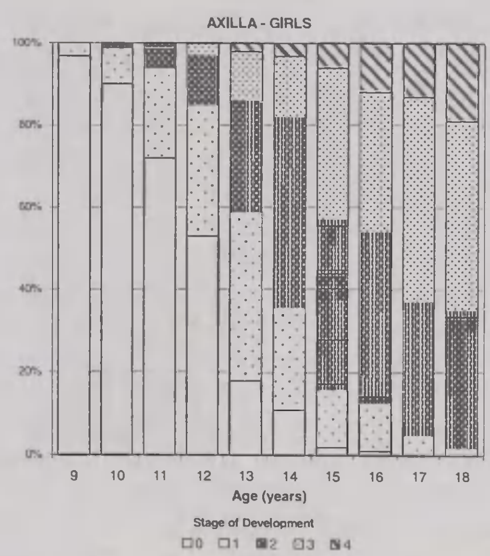

Figure 5. Stages of development of axillary hair in Slovak girls from 9 to 18 years of age.

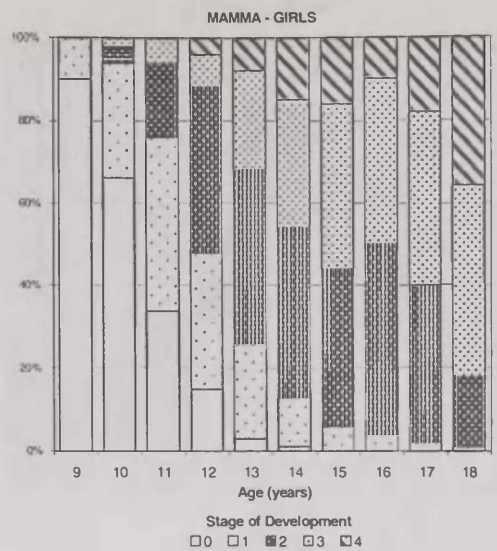

Figure 6. Stages of development of mamma in Slovak girls from 9 to 18 years of age.

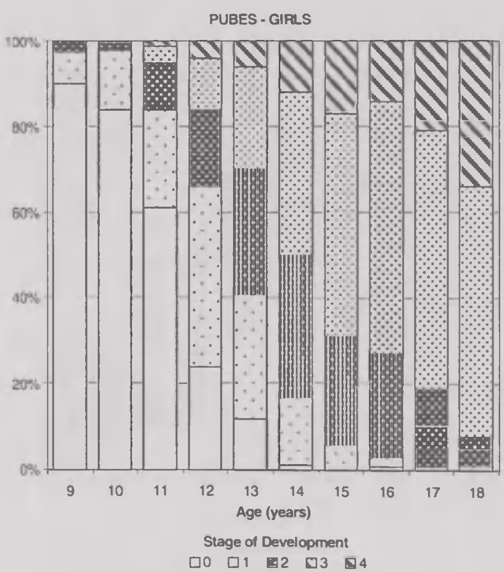

Figure 7. Stages of development in pubic hair in Slovak girls from 9 to 18 years of age.

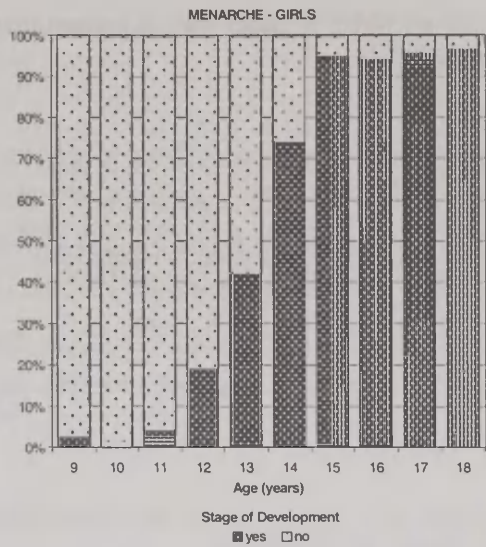

Figure 8. Percentage of Slovak girls from 9 to 18 years of age with menarche.

DISCUSSION

The distribution of maturation stages in 14-year-old boys is similar to that in 13-year-old girls. At the age of 14 years in girls and 15 years in boys there were some children without the slightest sign of maturation (infantile stage of development) as well as those with signs of full maturity (Fig. 3, 4, 6 and 7). These children sit in the same classroom at school and are graded according to the same criteria in maths and in gymnastics. Our findings may contribute to a more exact assessment of children and youths (according to biological, not chronological age) in the second decade of life and may be thus useful for teachers, school medical officers and in physical education. They shows that obligatory sex education should be given earlier and perhaps on a selective basis according to the stage of development (maturation) of individual children. According to the stagnation of the trend of maturation in Czech girls (menarche) which has lasted for more than 30 years already, we may expect that a similar stagnation occurred in Slovak girls and that the above standards are still valid for the present Slovak children and youths of both sexes. No similar survey has been undertaken (as far as the author knows) in recent years in Slovakia. A joint European survey which is under way at present may answer this question in the near future.

ACKNOWLEDGMENT

The author is indebted to all participating paediatricians and youth specialists and to Dr. Pavel Chyle, CSc for the revision of the English text and to Marcela Havlinova for the art work.

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KNEE EXTENSION ISOMETRIC FORCE PRODUCTION CAPACITY IN RELATION TO BODY MASS IN PRE- AND POSTPUBERTAL BOYS

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ABSTRACT

This study compared the absolute and body mass-related knee extension isometric strength characteristics between 14 prepubertal (11-year-old) and postpubertal (16-year-old) boys. During the measurement of knee extension maximal isometric force and rate of force development the subjects were seated in a specially designed dynamometric chair with the knee and hip angles equal to 90° and 110°, respectively. The subject was instructed to react to the light signal (ignition of the signal lamp) as quickly and strongly as possible by extending the leg against a cuff fixed to a strain gauge system, and to maintain the maximal effort as long as the signal was on (2 s). Postpubertal boys had greater ($P<0.05$) absolute values of knee extension maximal isometric force and rate of force development than prepubertal boys. However, no significant differences ($P>0.05$) were observed between the groups in the knee extension maximal isometric force and rate of force development in relation to body mass. It was concluded that puberty is characterised by: (a) increased voluntary maximal and explosive isometric force-generating capacity of the knee extension muscles; (b) unchanged knee extension isometric strength characteristics in relation to body mass.

Key words: puberty, knee extensor muscles, isometric strength, body mass.

INTRODUCTION

Muscle strength is an important characteristic of neuromuscular performance, which changes throughout the years of growth, particularly during puberty. Numerous studies in this field have focused to measure the maximal isometric or isokinetic strength, which gives information about the maximal voluntary force-generating capacity of muscle groups. Significant increase in maximal isometric strength [4, 13, 21] during puberty is well documentated. However, a smaller number of studies have assessed the associations between maximal and body mass-related strength characteristics of the muscles during puberty. There are only few studies that report the rate of voluntary isometric force development of the muscles in pre- and postpubertal children [9, 13].

The increase in maximal strength of the muscles during puberty is often associated with increase in muscle mass [16] or cross-sectional area [15]. Some investigations demonstrate a significant increase in muscle strength in relation to body mass between 8-year-old and 13–14-year-old children [7, 21]. However, the studies which have used anthropometric measurements [6] or ultrasonic techniques [14] have reported that isometric strength expressed per unit of cross-sectional area of the muscles appears to remain unchanged throughout puberty. Thus, the changes in maximal isometric muscle strength in relation to body mass during puberty need further investigation.

The knee extensor muscles play an important role in many movement activities. These muscles have a great importance in the function and stability of the knee joint as well as in prevention of knee injuries.

The purpose of this study was to compare the absolute and body mass-related values of maximal isometric force and rate of force development of the knee extensor muscles in prepubertal (11-year-old) and postpubertal (16-year-old) boys.

MATERIAL AND METHODS

Subjects

Twenty eight boys aged from 11 to 16 years participated in the study. The subjects were distributed into two groups: prepubertal (11-year-old, n = 14) and postpubertal (16-year-old, n = 14) boys (Table 1).

Pubertal stages were determined according to the criteria of Tanner [22]. All 11-year-old boys were in Tanner stage 1, and they were classified prepubertal as for pubic hair and genitalia. Informed parental consent was obtained prior to the children's participation in the experiment. All 16-year-old boys were in Tanner stage 5 and they were classified as postpubertal. Their written informed consent was obtained. The study was approved by the University Ethics Committee.

Table 1. Physical characteristics of subject groups (mean±SE).

Variable	Age groups	
	11-year-old (*n*=14)	16-year-old (*n*=14)
Age (years)	11.4±0.1	16.4±0.1
Height (cm)	152.8±2.9	176.5±1.7
Body mass (kg)	40.3±2.8	67.8±2.5
Body mass index ($kg \cdot m^{-2}$)	17.3±0.5	21.8±0.6

Note. All characteristics differed significantly ($P<0.05$) between groups.

Twenty-four to 48 hours before collecting the data the subjects were given instructions and the strength testing procedures were demonstrated. This was followed by a practice session to familiarize the subjects with the procedures. The subject's dominant leg was determinated based on kicking preference.

Prior to testing, each subject underwent a ten-minute warming-up period. Postpubertal boys and adults performed five-minute submaximal ergometer cycling followed by stretch exercises of the knee extensor and plantarflexor muscles. Prepubertal boys performed running and stretching exercises.

Isometric dynamometry

During the measurement of knee extension maximal isometric force and rate of isometric force development (RFD) the subjects were seated in a specially designed dynamometric chair with the knee and hip angles equal to 90° and 110°, respectively. The body position of the subjects was secured by three Velcro belts placed over the chest, hip and thigh. The isometric knee extension force was recorded by a standard strain-gauge transducer mounted inside a metal frame. It was placed around the distal part of the ankle of the dominant leg above the malleoli using a Velcro belt. The electrical signals from the strain-gauge transducer were digitized on-line (sampling frequency 1 kHz) using a personal computer. The digitized signals were stored on hard disk for further analysis. During the testing the subject was instructed to react to the light signal (ignition of the signal lamp, placed 1.5 m from the subject) as quickly and strongly as possible by extending the leg against a cuff fixed to a strain gauge system, to maintain the maximal effort as long as the signal was on (2 s). Three attemps were carried out, and the best result was used for further analysis. A rest period of 1 min was allowed between the attemps. The force-time curve and light signal were analysed by personal computer. Knee extension maximal isometric force and RFD as the force in relation to time period of 0.2 s from onset of the force production were calculated.

Statistical analysis

The data are means and standard errors (±SE). One-way analysis of variance (ANOVA) following by Tukey post hoc comparisons were used to test for differences between the age groups. A level of $P<0.05$ was selected to indicate statistical significance.

RESULTS

Postpubertal boys had bigger ($P<0.05$) height, body mass and body mass index than prepubertal boys (Table 1). Knee extension maximal isometric force was greater ($P<0.001$) in postpubertal boys as compared with prepubertal boys (Fig. 1A). No significant difference ($P>0.05$) was observed in knee extension maximal isometric force in relation to body mass between the groups (Fig. 1B). Postpubertal boys had greater ($P<0.001$) knee extension isometric RFD than prepubertal boys (Fig. 2A). However, no significant difference ($P>0.05$) was observed in knee extension isometric RFD in relation to body mass between the groups (Fig. 2B).

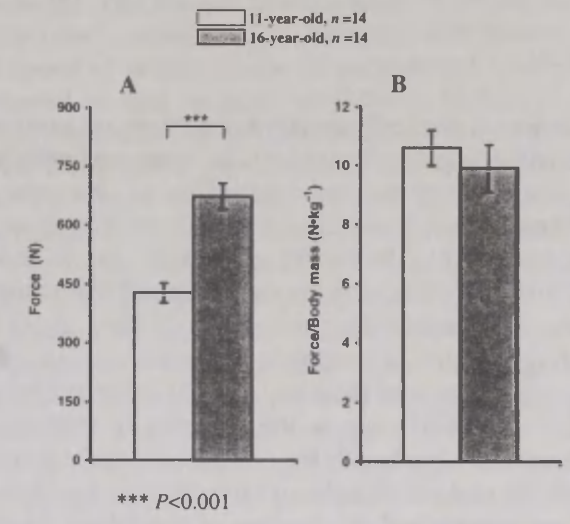

Figure 1. Mean (±SE) absolute (A) and body mass-related (B) values of knee extension maximal isometric force in pre- and postpubertal boys.

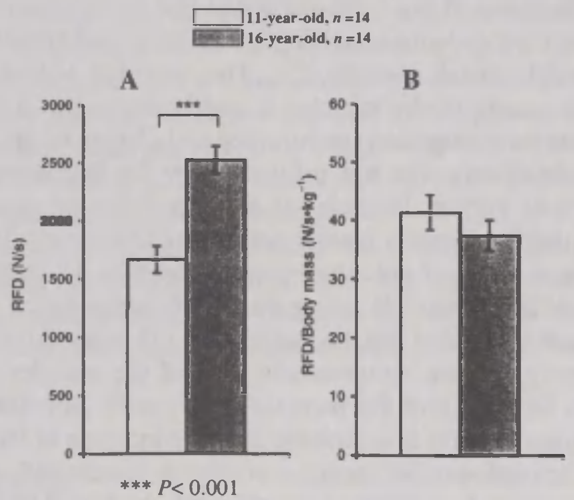

Figure 2. Mean (±SE) absolute(A) and body mass-related (B) values of rate of knee extension isometric force development (RFD) in pre- and postpubertal boys.

DISCUSSION

The study indicated markedly greater knee extension maximal isometric force (36.6%) in postpubertal boys as compared with prepubertal boys. The increase in the absolute value of maximal voluntary strength of knee extensor muscles in boys over puberty is consistent with earlier findings [1, 19, 20]. This is mainly due to an increase in muscle size and body dimension as well as neural maturation. There is a rapid increase in muscle strength in male children at approximately 13 years of age, which corresponds to an increase in muscle mass [16], cross-sectional area of muscles [15] and to the attainment of sexual maturity [4]. The increase in the secretion of testosterone at puberty has been associated with the increase in skeletal muscle mass [17]. Growth in skeletal muscles occurs through an increase in the number of sarcomeres and the number of myofibrils, both of which increase muscle strength [18]. Hypertrophy of muscle fibres in children increases linearly with age from birth to adolescence [16]. It is possible that neural maturation contributes to the age effect for maximal isometric force. It has been suggested that the expression of muscle strength is dependent on myelination of the motor nerves, which is complete until sexual maturity [5]. The maximal voluntary force-generation capacity of the muscles is highly dependent upon the degree of motor unit activation (recruitment and change of the firing rate of the muscle fibres), which is influenced by the development of the central nervous system. Blimkie [4] has found that 16-year-old boys could voluntarily activate a greater percentage of their available motor units during a maximal voluntary contraction than 11-year-old boys. Belanger and McComas [3], using the twitch interpolation technique, have suggested that 2 of the 10 prepubertal (11-year-old) boys could not voluntarily activate motoneurone pool of the muscles optimally. These facts indicate that the increase in isometric voluntary muscle strength during puberty is associated with the increase in the ability of motor unit activation under maximal voluntary muscle action.

The present study indicated a significantly higher (34%) isometric RFD of the knee extensor muscles in postpubertal boys as compared with prepubertal boys. The RFD in isometric contractions is related to contractile speed. The maximum shortening speed determined from the force-velocity curve is closely related to the shortening speed of sarcomeres, which correlates with myosin-ATPase activity [2]. The activity of this enzyme in infants and prepubertal children is lower than in adults [8]. The number of sarcomeres increases, and as a necessary consequence, muscle length increases with growth. Thus, the contractile speed of whole muscle in postpubertal boys seems to be faster compared to that in prepubertal boys. Moreover, contractile speed is highly dependent upon motor unit activation: recruitment and change of the firing rate of slow and fast twitch motor units in voluntary contraction. These two mechanisms are influenced by such factors, as the development of the nervous system and the differentiation of muscle fibre types. Hence, the effects of the above mentioned factors gradually increase with growth [10].

The reports on the changes in maximal voluntary isometric and isokinetic muscle force per unit of body mass during puberty are contradictory. Several authors have observed a significantly higher knee extensor isokinetic peak torque in relation to body mass in postpubertal children as compared with prepubertal children [7, 21]. Others [11], however, have reported an age-related increase in knee extension isokinetic peak torque that could not be accounted for by changes in body mass. The relationship between muscle size and maximal voluntary isometric force seems to remain unchanged over puberty across various muscle groups [4]. It has been hypothesized that the increase in muscle mass per unit of fat-free weight, neural maturation, or both contribute to the increase in strength across age [12]. However, our data clearly indicated that maximal voluntary isometric force and rate of force development expressed per unit of body mass appeared to remain unchanged through puberty. It is possible that these differences could be attributed to differing motor unit activation patterns between isometric and dynamis muscle contractions.

In conclusion, this study indicated that puberty is characterised by: (a) increased voluntary maximal and explosive isometric force-generating capacity of the knee extensor muscles; (b) unchanged knee extension isometric strength characteristics in relation to body mass.

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MAXIMAL AND BODY MASS-RELATED KNEE EXTENSION ISOMETRIC STRENGTH IN WOMEN OF INCREASING AGE

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ABSTRACT

This study compared the absolute and body mass-related knee extension isometric strength characteristics in five age groups of women: 20–29-year-old (3rd decade group), 30–39-year-old (4th decade group), 40–49-year-old (5th decade group), 50–59-year-old (6th decade group) and 70–77-year-old (8th decade group). Knee extension maximal isometric force (MF) was greater ($P<0.01$) in the 3rd, 4th and 5th decade groups than in the older groups, although the differences between the three younger groups were not significant ($P>0.05$). The 6th decade group produced greater ($P<0.001$) knee extension isometric MF than the 8th decade group. Knee extension isometric MF in relation to body mass was greater ($P<0.05$) in the 3rd decade group as compared with the other groups. The 4th and 5th decade groups had greater ($P<0.01$) isometric MF in relation to body mass than the two older groups, although the difference between the two younger groups were not significant ($P>0.05$). The 6th decade group had greater ($P<0.01$) isometric MF in relation to body mass than the 8th decade group. The 3rd, 4th and 5th decade groups had greater ($P<0.01$) knee extension rate of isometric force development (RFD) than the older groups. No significant differences ($P>0.05$) in isometric RFD between the three younger and two older groups was found. It was concluded that in women a significant age-related decrease in knee extension voluntary isometric force production capacity begins from the 6th decade, however, a decrease in maximal isometric force in relation to body mass begins earlier, i.e. from the 4th decade.

Key words: aging, knee extensor muscles, isometric strength, body mass

INTRODUCTION

Muscle strength is an important characteristic of neuromuscular performance, which decreases with increasing age. Numerous studies have focused on measuring the age-related differences in maximal isometric or isokinetic strength, which gives information about the changes in maximal voluntary force-generating capacity of the muscles. Some authors have suggested a relative constant annual loss of maximal muscle strength with increasing age. However, most authors agree that there apparently is a plateau of maximal muscle strength until the mid-40s, after which there is an accelerated loss of muscle strength [10, 12, 16, 18]. Age-related decline in human muscle strength takes place rapidly after the age of 60 years [9, 13].

Age-related decrease in maximal isometric muscle strength has been attributed to the reduction in muscle mass which is related to alteration in hormone balance [12] and decline in physical activity [19]. It has been suggested that the decline in muscle mass is most likely mediated by a reduction in the number and size of muscle fibres, especially of fast-twitch fibres [17, 22].

Less attention has been paid to studying age-related changes in the rate of isometric force development, which is an indicator of explosive muscle strength. However, it has been shown that the rate of isometric force development may decline with increasing age even more than maximal isometric force [6, 13, 15, 26]. Muscle strength and especially the ability of leg extensor muscles to develop force rapidly are important performance characteristics which have been shown to contribute to several tasks of daily life such as climbing stairs, walking or even prevention of falls and trips [3].

The purpose of this study was to compare the absolute and body mass-related values of maximal isometric force and rate of force development of the knee extensor muscles in women of increased age.

MATERIAL AND METHODS

Subjects

Twenty eight female subjects aged from 20 to 77 years participated in this study after written informed consent. The subjects were distributed into five age groups: 20–29-year-old (3rd decade group, $n = 13$), 30–39-year-old (4th decade group, n = 13), 40–49-year-old (5th decade group, n = 11), 50–59-year-old (6th decade group, n = 12) and 70–77-year-old (8th decade group, n = 13). The subjects were screened by a questinnaire to exclude those with diagnosed neuromuscular disorders. The physical characteristics of the subjects are presented in Table 1. The study was carried out on the approval of the University Ethics Committee.

Table 1. Physical characteristics of subject groups (mean±SE)

Variables	Age groups				
	3rd decade (20–29 yr)	4th decade (30–39 yr)	5th decade (40–49 yr)	6th decade (50–59 yr)	8th decade (66–77 yr)
n	13	13	11	12	13
Age (years)	20.7±0.2	35.5±0.7	44.3±0.9	54.8±0.9	70.8±0.8
Height (cm)	169.3±1.3*	167.6±1.6*	163.7±1.4	163.6±1.8	158.8±1.4
Body mass (kg)	60.8±1.8	65.5±2.7	64.6±3.3	67.9±1.8#	65.6±2.1#

Note. * P<0.05 compared to the 5th, 6th and 8th decade groups;
# P<0.05 compared to the 3rd decade group.

Twenty-four to 48 hours before data collections the subjects were given instructions and the strength testing procedures were demonstrated. This was followed by a practice session to familiarize the subjects with the procedures. The subject's dominant leg was determinated based on kicking preference. Prior to testing, each subject underwent a ten-minute warming-up period which consisted in running and stretching exercises.

Isometric dynamometry

During the measurement of knee extension maximal isometric force (MF) and rate of force development (RFD) the subjects were seated in a specially designed dynamometric chair with knee and hip angles equal to 90° and 110°, respectively. The body position of the subjects was secured by three Velcro belts placed over the chest, hip and thigh. Knee extension isometric force was recorded by a standard strain-gauge transducer mounted inside a metal frame. It was placed around the distal part of the ankle of the dominant leg above the malleoli using a Velcro belt. The electrical signals from the strain-gauge transducer were digitized on-line (sampling frequency 1 kHz) using a personal computer. The digitized signals were stored on the hard disk for further analysis. During the testing the subject was instructed to react to the light signal (ignition of the signal lamp, placed 1.5 m from the subject) as quickly and strongly as possible by extending the leg against a cuff fixed to a strain gauge system, and to maintain the maximal effort as long as the signal was on (2 s). Three attempts were carried out and the best result was used for further analysis. A rest period of 1 min was allowed between the attempts. The force-time curve and light signal were analysed by personal computer. Knee extension isometric MF and RFD as the force in relation to time period of 0.2 s from the onset of force production were calculated.

Statistical analysis

The data are means and standard errors (±SE). One-way analysis of variance (ANOVA) followed by Tukey post hoc comparisons were used to find the differences between age groups. A level of $P<0.05$ was selected to indicate statistical significance.

RESULTS

The 3rd and 4th decade groups had greater ($P<0.05$) height than the other groups (Table 1). No significant differences ($P>0.05$) in height were noted between the 3rd and 4th decade groups as well as between the older groups. The 3rd decade group had smaller ($P<0.05$) body mass than the 6th and 8th decade groups.

Knee extension isometric MF was greater ($P<0.01$) in the 3rd, 4th and 5th decade groups than in the older groups, although the differences between the three younger groups were not significant ($P>0.05$) (Fig. 1A). The 6th decade group produced greater ($P<0.001$) knee extension isometric MF than the 8th decade group.

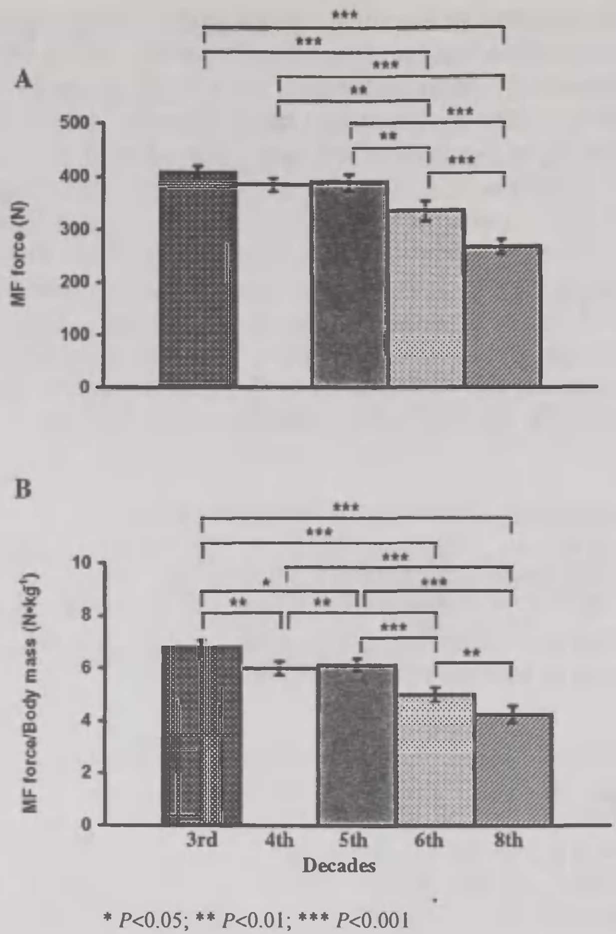
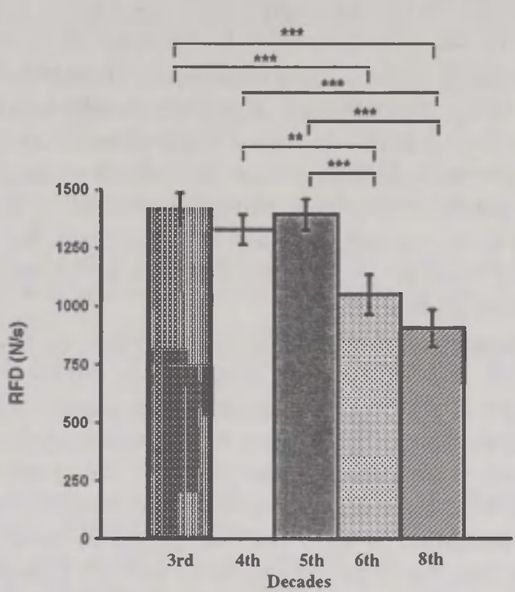


Figure 1. Mean (±SE) absolute (A) and body mass-related (B) values of knee extension maximal isometric force (MF) in women of increasing age.

Knee extension isometric MF in relation to body mass was greater (*P*<0.05) in the 3rd decade group as compared with the other groups (Fig. 1B). The 4th and 5th decade groups had greater (*P*<0.01) isometric MF in relation to body mass than the two older groups, although the difference between the two younger groups was not significant (*P*>0.05). The 6th decade group had greater (*P*<0.01) isometric MF in relation to body mass than the 8th decade group.

The 3rd, 4th and 5th decade groups had greater ($P<0.01$) knee extension isometric RFD than the older groups (Fig. 2). No significant differences ($P>0.05$) in isometric RFD between the three younger and the two older groups were found.



** $P<0.01$; *** $P<0.001$

Figure 2. Mean (±SE) values of knee extension rate of force development (RFD) in women of increasing age.

DISCUSSION

The present study indicated clear age-related differences in voluntary force production capacity of the knee extensor muscles in women. It was found that a significant decrease in knee extension isometric MF and RFD takes place after the age of 50 years. Thus, this study supported the previous findings that there is a plateau of maximal voluntary muscle strength until 40–50 years, after which an accelerated loss of muscle strength begins [10, 12, 16, 18]. Age-related decrease in maximal muscle strength is due to reduced muscle mass in elderly women, which is associated with the decreased number of both slow- and fast-twitch muscle fibres [1, 22], atrophy of existing muscle fibres [1, 2, 8], a decrease in the number of cross-bridges formed during activation, and/or a reduction in the force developed by each cross-bridge [4]. It has been found that the decrease in maximal muscle strength in older women is consistent with the loss of motor units [5, 7]. Denervation of fast-twitch muscle fibres and reinnervation by axonal sprouting from slow motor units can also contribute to reduction in force production capacity of the muscles [11]. The underlying mechanisms of ageing that cause changes in the morphology of muscles are unknown but appear to be an intrinsic time-dependent process [25]. In addition to changes in muscle morphology, a decline in maximal muscle strength in ageing may be accompanied in part by a decrease in voluntary neural drive to muscles [13, 14]. A possible decrease in the capacity for rapid neural activation of the muscles may explain the great age-related decrease in rate of force development [15].

Our data suggested that significant reduction in knee extension isometric MF in relation to body mass begins earlier than absolute values of MF, i.e. after the age of 30 years. It is known that the loss of muscle mass with increasing age may be replaced by increased fat and connective tissue within the muscles [20, 23]. The present study indicated that the 6th and 8th decade groups had a significantly greater body mass as compared to the 3rd decade group. A number of studies have shown an increase in superficial body fat with ageing [21, 24].

In conclusion, the present study indicated that a significant age-related decrease in knee extension voluntary isometric force production capacity takes place in women after the age of 50 years, however, a decrease in maximal isometric force in relation to body mass after the age of 30 years.

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PERCEIVED AND ACTUAL PHYSICAL COMPETENCE AND BODY ATTRACTIVENESS IN YOUNG FEMALES

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ABSTRACT

The purpose of the study was to examine the relationship between perceived and actual physical competence and body attractiveness in young females. Twenty-two young females (mean age 22.1±3.7 yrs) were subjects of the study. Perceived physical competence and body attractiveness were measured by Physical Self-Perception Profile. To measure the subjects' actual physical competence a 2-km walking test was administered. Anthropometrical variables included body height, mass, and sum of five skinfolds (triceps, subscapular, abdominal, supraspinal, medial calf). The results showed a positive relationship between perceived and actual physical competence ($r = 0.44$ to 0.65). Perception of body attractiveness, however, was not related to walking time and body fatness in young females.

Key words: perceived competence, body attractiveness, walking, young females

INTRODUCTION

The body provides the vehicle through which we interface with life. Through the body we explore and present ourselves, express our sexuality; and through its state of health, its capabilities and its appearance, the physical self becomes a central element of the whole personality. Our perceptions of our physical selves therefore provide a key to understanding the constitution of our identities, the basis of our self-esteem, and many of our behaviour patterns [5].

Since the early 1980s there has been a resurgence of interest in the study of self-perception [8]. There is good reason for this renewed interest because people's self-perceptions are clearly linked to their mental well-being and to their motivational states [14]. Thus, self-perceptions have obvious relevance to life in general, and in this particular case to body perception and physical competence.

The construct of perceived competence or ability has been highlighted in both psychological and sport psychological literature as one that is intimately related to motivational indicators such as choosing to participate, sustaining effort, and continuing interest in tasks or activities [2, 10, 13]. According to Harter's [6] competence motivation theory, perceived competence is viewed as a domain-specific indicant of self-esteem that is responsive to a number of antecedent variables and that influences affective and motivational outcomes. In short, perceived competence and perceptions of performance control are viewed as correlates, and both are influenced by perceptions of success, feedback from significant others, and one's motivational orientation. Self-perceptions of competence and control, in their turn, influence, affect and continue motivation [6, 7, 8].

The quantity of sport-related research testing Harter's theory has increased substantially over the last decade [1, 13]. Despite the interest in the role of perceptions of ability in future motivated behaviour, little attention has been directed to the accuracy with which perceptions of competence relate to more objective measures of competence. In the Physical Self-Perception Profile, developed by Harter [6], body attractiveness is included as one important component of general physical self-perception. However, previous research on this topic, especially concerning young females, has been clearly insufficient. Thus, the purpose of the present study was to examine the relationship between perceived and actual physical competence and body attractiveness in young females.

MATERIAL AND METHODS

Subjects

Twenty two young females (mean age 22.1±3.7 yrs) volunteered to participate in the study. The subjects were not regularly participating in training groups or sport clubs. The measurements were taken during one day in November 1998.

Perceived physical competence and body attractiveness

The instrument used in this study was a Physical Self-Perception Profile (PSPP) [3]. It incorporates four 6-item subdomain subscales to assess sport competence, physical strength, physical conditioning, and body attractiveness. A fifth subscale, assessing physical self-worth, was also included in the instrument. Each subscale contained 12 questions which were scored on a 4-point ordinal scale: a score of 1 indicated low perceived competence, and a score of 4 indicated high perceived competence. The validity and reliability of this instrument have been demonstrated earlier [4].

Actual physical competence and anthropometry

To measure the subjects' actual physical competence, a 2-km walking test was administered [9]. The walking test was conducted in indoor conditions on a 150 m track. The subjects walked alone with at least 30 second starting intervals between participants. The oral instruction given was: "Walk the distance as fast as you can." Walking time was recorded to the nearest second.

Anthropometry

Body height (Martin metal anthropometer) and weight (medical balance scale) of the subjects were measured and body mass index (BMI) was calculated. Sum of five skinfolds (triceps, subscapular, abdominal, supraspinal, medial calf) was measured (Holtain skinfold calliper, UK).

Statistical analysis

Descriptive statistics (mean ±SD) for each of the dependent variables were determined. Pearson correlations between perceived and actual physical competence and body attractiveness were calculated. Cronbach alphas were calculated to measure internal reliability of the PSPP scores. Statistical significance was set at $p<0.05$.

RESULTS

Descriptive statistics and internal consistencies for PSPP scores, 2-km walking test and anthropometry are presented in Table 1. Cronbach alphas based on whole sample were satisfactory for subscales (alphas ranging from 0.75 to 0.83).

Table 1. Descriptive statistics and internal consistencies for PSPP scores, 2-km walking test and anthropometrical measurements

Variables	α	Mean	SD
Sport competence	0.77	2.87	0.4
Physical strength	0.83	2.58	0.6
Physical conditioning	0.79	2.74	0.5
Body attractiveness	0.75	3.02	0.6
Physical self-worth	0.80	2.94	0.5
2-km walking (min)	–	16,3	1.1
Height (cm)	–	171.4	4.3
Weight (kg)	–	61.7	3.5
BMI (kg/m^2)	–	21.3	1.8
Sum of 5 skinfolds (mm)	–	67.6	6.9

Table 2. presents Pearson correlations between PSPP scores, 2-km walking time and somatic measures. Physical self-worth was related with all measures of physical self-perception. 2-km walking time was related with sport competence, physical conditioning and general physical self-worth as well as with body fatness. However, the sum of skinfolds was not related with physical self-perception indices.

Table 2. Zero-order correlations between PSPP scores, 2-km walking test and somatic measurements

Variables							
Sport competence	X						
Physical strength	0.45*	X					
Physical conditioning	0.34	0.56**	X				
Body attractiveness	0.34	0.22	0.36*	X			
Physical self-worth	0.57**	0.47*	0.67**	0.38*	X		
2 km walking	–0.65**	–0.31	–0.52**	–0.19	–0.44*	X	
Sum of 5 skinfolds	–0.17	–0.08	0.11	–0.16	–0.24	–0.58**	X

* p<0.05 ** p<0.01

DISCUSSION

The overall intent of this study was to investigate the associations between actual and perceived physical competence and body attractiveness in young females. The cumulative results indicate that actual physical competence, as assessed by 2 km walking test, was related to body fatness, sport competence and general physical self-worth, but not to perception of body attractiveness in young females.

Recent research of self-concept and self-esteem has focused both on identifying areas of specific content within the individual's overall perceptual perspective and on the multifaceted structural organisation of those components. Several studies have been related to the development of instrumentation to be used for further research in the area [6, 12]. In the Physical Self-Perception Profile (PSPP), developed by Harter [6], body attractiveness is included as one important component of general physical self-worth. As obvious prerequisite for the validity of PSPP is evidence of its reliability. In this study, good internal consistency of the PSPP scales was evident. Therefore, our results are in accordance with previous research findings [4, 5, 12].

The 2-km walking test used in our study has been demonstrated to be a valid and feasible fitness test for the healthy adult population [9]. Harter's [6] competence motivation theory holds that an individual's perception of his or her competence influences performance in achievement settings; individuals act in ways consistent with their perception of self. In addition, Sonstroem [11] has developed a model in which he indicated a relation between perceived competence and actual participation level. Therefore, it was hypothesised that there exists a positive relationship between actual and perceived physical competence in young females. The results generally support our hypothesis as well as the earlier theoretical work by Harter [6] and Sonstroem [11] indicating moderate positive association between actual physical fitness and indices of physical self perception (perception of physical strength, physical conditioning and physical self-worth).

Perception of body attractiveness is identified as distinct subarea of PSPP which is shown to be subordinate to global physical self-esteem and global general self-esteem in a hierarchical organisation [4]. However, no research data are available indicating an association between body attractiveness, physical fitness and body fatness in young females. Our results clearly demonstrated that actual physical competence, as assessed by the 2-km walking test, and subcutaneous fatness are not related with perception of body attractiveness in young females. It may be speculated that the perception of body attractiveness in young females is more closely related to the cosmetic aspects of appearance and perception of physical self than to the perception of physique. Further experimental studies on this research direction are clearly needed to identify the correlates of perception of more fitness-related body attractiveness in different age and sex groups.

In conclusion, the results of this study suggest that there exists a positive association between perceived and actual physical competence in young females. The 2-km walking test, as an indicator of physical competence, was related with several indices of physical self-perception (physical strength and conditioning, physical self-worth). However, perception of body attractiveness by young females was not related to fitness and body fatness.

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ANTHROPOMETRIC DATA, THEIR CORRELATION TO PLASMA LIPIDS AND BLOOD PRESSURE IN SCHOOLCHILDREN OF TALLINN (1998–1999)

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ABSTRACT

In the study some anthropometric parameters, plasma lipids and blood pressure were measured in 471 schoolchildren at the age of 14.0±0.75 years in two Estonian and two Russian schools of Tallinn Northern District.

Some ethnic differences were found: the Estonian schoolchildren were taller and heavier than the Russian ones. The mean of body mass index (BMI) did not differ between sexes and ethnic groups. Overweight by the proposed criterion (BMI≥22 kg/m²) was found in 13.8% of schoolchildren. Underweight (BMI≤16 kg/m²) was established in 2.4% of Estonians and 5.4% of Russians. Dynamometric data showed that hand muscles strength was greater in Estonians than in Russians of the same sex group.

Measuring of blood plasma lipids' levels showed that the values of total cholesterol (TC) were lower in boys than in girls, and the values of high density lipoproteins cholesterol (HDL-C) were also lower in boys than in girls. HDL-C correlated to anthropometric parameters (height, weight, BMI, upper arm and thorax circumferences, triceps and subscapular skinfolds T+S) negatively only in boys.

Correlations between anthropometric data and blood pressure (BP) showed that height correlated positively with BP only in boys. Other physical parameters that reflect body mass had positive correlations to arterial BP both in boys and girls.

Key words: anthropometry, plasma lipids, blood pressure, schoolchildren, epidemiology

The materials used in this paper are a part of an epidemiological investigation of atherosclerosis main risk factors in schoolchildren of Tallinn in 1998–1999. The aim was to find out the prevalence of main risk factors, associations of some anthropometric parameters with blood lipids and blood pressure. Analogical studies in the same population of schoolchildren were carried out ten and fourteen years ago [1, 3]. Comparing the present data with the previous ones shows the trends of risk factors and their interaction.

MATERIAL AND METHODS

A total of 471 schoolchildren aged 14.0±0.75 years from four secondary schools of Tallinn Northern district participated in the study. By their ethnic origin 211 (44.8%) of the subjects examined were Estonians and 260 (55.2%) were Russians, 48% of them boys (100 Estonians, 126 Russians) and 52% girls (111 Estonians, 134 Russians).

The study included examination and an interview by standardised questionnaires [1], clinical-physiological investigation of anthropometry, blood pressure (BP) measurement after a 5-minutes rest on the right arm with a mercury sphygmomanometer, hands muscle strength measurement with dynamometer (±0.2 kg) and venous blood samples from the antecubital vein after a fast of 12 hours.

Anthropometric measurements were made with the following exactness: height (H, ±0.5 cm), weight (W, ±0.1 kg), upper arm circumference of the right arm (UAC, ±0.1 cm), thorax circumference in the phase of inspirium (ThC, ±0.1 cm) and skinfold thicknesses measured twice on the right upper arm over the triceps and subscapular (T and S, ±0.2 mm). In the study the mean of these two measurements was used. The body mass index was calculated as $BMI = W, kg/(H,m)^2$. Systolic blood pressure (SBP) was recorded for Korotkoff's first phase and diastolic pressure both for Korotkoff's fourth (DBPIV) and fifth (DBPV) phases. Measurements were made twice, the mean of the two measurements was used in the analysis (±2mmHg).

Biochemical analyses of total cholesterol (TC, mmol/l), high density lipoprotein cholesterol (HDL-C, mmol/l) and triglycerides (TG, mmol/l) were performed in EDTA-plasma by enzymatic methods at the Diagnostic Centre of Tallinn on the KONE-Dynamic analyser. The data were computed using the SAS statistical package [4].

RESULTS AND DISCUSSION

Means of anthropometric and dynamometric data, plasma lipids and arterial blood pressure by sex and ethnic origin are presented in Table 1. Ethnic differences appeared in height and weight: the Estonian pupils, both boys and girls, were taller and heavier than the Russian ones. Boys were taller and heavier than girls, both in Estonian and Russian ethnic groups. In the previous studies 14-year-old boys' height also exceeded girls' height. The mean values of BMI did not differ noticeably between boys and girls, while in the previous data of 10 and 14 years ago the mean value of BMI in 14-year-old girls was greater than in boys of the same age.

Table 1. Anthropometric variables, plasma lipids and blood pressure by sex and ethnic origin of schoolchildren (Estonians — Est; Russians — Rus)

Variable	Est Boys		Rus Boys		Est Girls		Rus Girls	
	M	SD	M	SD	M	SD	M	SD
Height, cm	171.1	8.00	167.3	9.29	164.5	6.27	162.3	6.24
Weight, kg	58.5	12.13	55.7	10.12	53.7	8.82	51.4	7.94
BMI, kg/m^2	19.9	3.31	19.8	2.67	19.8	2.61	19.5	2.57
UAC, cm	25.6	3.21	25. 0	2.68	24.4	2.58	23.5	2.45
ThC, cm	85.8	6.43	84.9	6.15	86.9	5.43	84.9	6.12
T, mm	12.1	8.49	10.3	5.69	16.0	5.92	14.9	5.88
S, mm	9.8	8.51	8.8	6.04	11.4	5.42	11.6	6.45
Right hand, kg	34.4	9.10	33.3	9.03	23.5	5.28	22.6	4.98
Left hand, kg	32.2	7.83	30.0	8.64	21.1	4.99	20.4	5.84
TC, mmol/l	4.00	0.69	4.04	0.73	4.10	0.71	4.16	0.78
HDL-C, mmol/l	1.28	0.31	1.26	0.27	1.34	0.28	1.36	0.36
TG, mmol/l	1.41	0.64	1.12	0.57	1.58	0.91	1.11	0.55
SBP, mmHg	119.3	12.36	115.4	10.84	114.2	7.97	114.4	9.32
DBPIV, mmHg	73.7	8.12	74.4	7.63	73.7	7.58	74.8	8.15
DBPV, mmHg	64.3	10.0	64.0	8.78	66.3	8.58	65.6	9.89

Means and medians of BMI together with 85th percentile are presented in Table 2. BMI values at the 85th percentile are accepted as the criterion of over-weight in epidemiological studies. In our previous cooperative studies [1, 3] the proposed criterion for estimation of overweight for the age of 14 was BMI≥22 kg/m^2. In the present study the values of the 85th percentile and the proposed criterion coincide well. Overweight (BMI≥22 kg/m^3) appeared in 13.8% of schoolchildren (12.3% of them Estonians and 15.1% Russians), equally among boys (13.7%) and girls (13.9). Ten years ago the incidence of overweight was almost twice higher (25.5%), and then girls were more often overweight (27.7%) than boys (17.9%). Opposite to the previous studies this time underweight (BMI≤16 kg/m^2) was established in 2.4% of Estonians and 5.4% of Russians, at that underweight girls were observed more often (4.9%) than boys (3.1%). In this study obesity (BMI≥25 kg/m^2) appeared as often as underweight (4% of all), while in Russian girls underweight was found three times more often than obesity. Upper arm circumference was greater in boys than in girls and in Estonians greater than in Russians, both in boys and girls. Thorax circumference was the greatest in Estonian girls, skinfold thicknesses were greater in girls than in boys in both ethnic groups.

Table 2. Body mass index (BMI) and incidence of over- and underweight

Sex	Ethnic origin	Body mass index (BMI, kg/m^2)					BMI ≥ 22	BMI ≥ 25	BMI ≤ 16
		n	Mean	SD	Median	85%	%	%	%
Boys	Estonians	100	19.9	3.31	19.0	21.8	11.0	7.0	2.0
	Russians	126	19.8	2.67	19.2	22.0	15.9	4.0	4.0
	Total	226	19.8	2.96	19.0	21.9	13.7	5.3	3.1
Girls	Estonians	111	19.8	2.61	19.4	21.6	13.5	3.6	2.7
	Russians	133	19.5	2.57	19.3	22.0	14.3	2.3	6.8
	Total	244	19.6	2.59	19.3	21.8	13.9	2.9	4.9
Both sexes	Estonians	211	19.8	2.95	19.2	21.7	12.3	5.2	2.4
	Russians	259	19.6	2.62	19.2	22.0	15.1	3.1	5.4
	Total	470	19.7	2.77	19.2	21.9	13.8	4.0	4.0

Dynamometric measurement showed that boys' hands muscle strength was greater than of that of girls, and the right hand was stronger than the left in all subgroups. Estonians (both girls and boys) had greater hands muscle strength than Russians.

Comparison of the data of blood plasma lipids showed that the mean level of TC in 14-year-old boys was lower than in girls of that age, and in Estonians lower than in Russians. Sex difference was found in the relationship of cholesterol antiatherogenic subfraction both in the present and previous studies: HDL-cholesterol level was lower in boys than in girls, while no ethnic differences were found.

Correlations between blood plasma lipids and anthropometric parameters presented in Table 3 confirmed the sex differences. Total cholesterol had negative correlation to height and low positive correlation to skinfolds only in boys. HDL-cholesterol had negative correlation to anthropometric data only in boys in this and the previous study as well. This means that, to a certain extent, the early beginning of males' atherosclerosis is due to rapid acceleration and sex difference in lipid metabolism that occur already at the pubertal age, as the level of antiatherogenic cholesterol (HDL-C) decreases in boys, not in girls. That argument has been confirmed by adult population studies in Estonia, in which lower HDL-C level in males than in females was

Table 3. Correlation coefficients between anthropometric data and plasma lipids and blood pressure in boys and girls (r — is presented with the significance $p \leq 0.01$)

Variable	Sex	TC	HDL-C	TG	SBP	DBPIV	DBPV
Height	Boys	–0.31	–0.20	–	0.36	0.28	0.19
	Girls	–	–	–	–	–	–
Weight	Boys	–	–0.31	0.21	0.47	0.44	0.27
	Girls	–	–	–	0.28	0.32	0.30
BMI	Boys	–	–0.28	0.31	0.37	0.37	0.22
	Girls	–	–	–	0.28	0.28	0.25
Upper arm	Boys	–	–0.28	0.27	0.46	0.40	0.23
circumference	Girls	–	–	–	0.30	0.31	0.26
Skinfolds	Boys	0.26	–0.19	0.34	0.33	0.33	0.24
T + S	Girls	–	–	–	0.26	0.33	0.29
Thorax	Boys		–0.29	0.20	0.45	0.33	–
circumference	Girls	–	–	–	0.20	0.31	0.32

established [5]. In the present study the level of TG had positive correlations to anthropometric data in boys but not in girls. In the previous study, when girls were more overweight, positive correlations between TG and anthropometric data were found both in girls and boys. As TG in girls characterises body fat mass (estimated by W, BMI, T+S, UAC) the missing correlations to TG level can be explained by too strict weightwatching.

In the previous studies the criterion of hypertension for 14-year-old children was established at SBP/DBP≥140/80mmHg. By this criterion in the present study of the population of 14-year-old schoolchildren hypertension does not pose a particular risk, and, compared with the previous studies, has stayed at a relatively low level (elevated SBP in 2.3% and elevated DBP in 7.8% of pupils). Correlations presented in Table 3 showed that height correlated positively with blood pressure only in boys. Other physical variable had positive correlation to arterial blood pressure both in boys and girls: SBP had the greater positive correlation in boys and DBPV in girls.

In conclusion, physical development parameters together with sexual maturation at that age period have a certain impact on blood plasma lipids and arterial blood pressure and some sex and ethnic differences exist. As compared with previous investigations when 27.7% of girls were overweight the occurrence of overweight (especially in girls) has decreased remarkably. At present underweight is becoming a problem; it is connected with the changed nutrition situation. That is why blood total cholesterol level is decreasing while the level of antiatherogenic HDL-cholesterol concentration has remained at a similar level, being lower in boys.

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EXPERIENCE OF APPLICATION OF ADAPTIVE POTENTIAL FOR ESTIMATION OF SOME CONSTITUTIONAL FEATURES OF REACTIVITY OF THE GROWING ORGANISM IN A HIGHLY URBAN ENVIRONMENT

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ABSTRACT

The analysis of variability of the index of adaptive potential (AP) obtained on the basis of investigated signs of morphological development and parameters of functioning of cardiovascular system has allowed us to establish the dynamics of adaptive processes in time (on the example of Minsk pupils) and to observe the nature of territorial variability of an investigated parameter of reactivity (on the example of pupils of Gomel). The text provides the formula for the index of AP.

An increase in the frequency of cases of AP describing the stress on adaptation mechanisms among all age groups of Minsk in 1999 in comparison with 1993–1994 reflects the rising ecological pressure on a growing organism in the conditions of a modern megalopolis. The high frequency of cases among all age groups of pupils when the AP index exceeds the threshold value testifies to ecological hazards in Volotova housing estate in comparison with the centre of Gomel. The higher percentage of such cases in Minsk and Gomel among boys, especially in the older age groups, is a consequence of chronic urban ecological pressure on the more reactive male organism. The hyperreactivity of boys and girls of the endomorphic somatic type on environmental troubles is particularly noticeable.

The outcomes of the research demonstrate the efficiency of usage of AP as an indicator of ecological hazards.

INTRODUCTION

Intensively increasing industrial pollution of urban environment has caused a number of acute problems of urban ecology. Development of new technologies directed at the protection of environment and the organisms living in it as well as perfection of biomedical methods of diagnostics and correction of adaptation processes for urban population at personal and population levels attract the constant attention of scientists. A developing organism is particularly sensitive to the effects of both favourable and unfavourable factors. Therefore, systematic following of dynamics of morpho-functional parameters of children in pre-school establishments and schools reveals the tension in adaptive processes in time and enables us to prevent their failure, i.e. transition from norm to pathology [2].

It is known that a change in the level of functioning of systems or their elements is always connected with strengthening of metabolic and power processes. This, however, leads to the violation of homeostasis only when the regulator mechanisms are overstressed and their functional reserve exhausted. Therefore the status of an organism can be defined by estimating the level of its functioning as a system, by the degree of strain on its regulatory mechanisms and functional reserve.

There is a number of methods, which define the transition from norm to pathology and allow us to receive simultaneous information on the status of several regulatory mechanisms and are sensitive enough to changes at miscellaneous levels of structural-functional organisation of a living system. For estimating the degree of strain of regulatory mechanisms, the biochemical methods for determining the contents of corticosteroids and catecholamins in a blood and urine are the most reliable. As these techniques are very labour-consuming and need steady conditions, the opportunities of using them are essentially limited.

While estimating the level of operation of an organism an essential role belongs to the parameters of the cardiovascular system, as the metabolic rate depends on the level of blood supply. Therefore, the system of blood circulation is an indicator of the organism's adaptive reactions. For the first time the concept of the blood circulation system as an indicator of adaptation-accommodation activity of the organism was formulated in the monograph *Space cardiology* [1]. The parameters of the functional status of the cardiovascular system reflect "the price of adapting".

"The transition from health to illness, from norm to pathology represents a process of gradual decrease of the degree of adaptation of an organism to environmental conditions (reduction of the adaptive potential — AP), which may result in various borderline conditions, including the prenosological and the premorbid" [3, p. 6]. The AP is a reserve of the adaptation-accommodation capabilities of an organism, which ensures the development and flow of protective-adaptation reactions. R. M. Bayevsky and his co-workers [3] have devised a 4-grade classification of functional statuses (levels of health): the status of **satisfactory adaptation** to environmental conditions at high or sufficient functional capabilities of the organism; a condition of **stress of adaptation** mechanisms, at which sufficient functional capabilities are provided at the expense of mobilisation of functional reserves; **unsatisfactory adaptation** denotes a decrease in the functional capabilities of the organism; and the **failure of adaptation** is accompanied by the fall-off of the organism's functional capabilities.

MATERIAL AND METHODS

In order to define sex and age variability of the main morphofunctional parameters of physical development of children and adolescents in the conditions of increasing urban environmental hazards which present heightened requirements to the mechanisms of adaptation, a cross-sectional research of three most ecosensitive age groups among the pupils of Minsk (8, 13 and 17 years) was conducted in 1993–1994 and in 1999. Similar age groups of pupils were investigated in 1998–1999 at the schools of Gomel; this category of data was clustered into two territorial samplings in view of probable distinctions between the ecological conditions in downtown (Gm–D) and in Volotova housing estate (Gm–V). Gomel is a region centre, a large industrial city located in the zone of radiation control. The analysis of variability of AP has enabled us to establish the dynamics of adaptive processes in time (on the example of Minsk pupils) and to observe the nature of territorial variability of a studied parameter of reactivity (on the example of the Gomel pupils).

For the definition of AP the formula [3] is offered, which can be utilised at mass researches populations with different sex and age structure.

AP (in points) = 0.011 (PR) + 0.014 (SP) + 0.008 (DP) + 0.014 (A) – 0.009 (W) – 0.009 (L) – 0.27,

where SP and DP are the value of systolic and diastolic pressure (in mm Hg),

PR — pulse rate per minute,
A — age (in years),
W — body weight (kg),
L — body height (cm).

The threshold value for satisfactory adaptation is **2.1 points**, i.e. all the values below this parameter describe normal adaptation; the AP values **from 2.11 to 3.2 points** testify to the stress of adaptive mechanisms; the range **from 3.21 to 4.3 points** is characteristic of unsatisfactory adaptation; **4.31 points and more** show the failure of adaptation.

This formula has been successfully applied for a dynamic overview of the health of first-year pupils in the Far North. Changes in the compensatory accommodation capabilities of their organisms during the study have been shown [4].

Using the above-mentioned formula, we have defined the personal parameters of AP for estimating the functional capabilities of the cardiovascular system as an indicator of adaptive reserves of the organisms of the pupils of three age groups investigated by us in 1990 in Minsk and Gomel. On the basis of these initial data the average parameters of AP and reliability of differences between the compared territorial, sex and age groups were computed.

RESULTS AND DISCUSSION

The analysis of the obtained data has shown (Tables 1–2) a highly significant ($p<0.001$) increase of AP in 8-year-old pupils of both sexes in Minsk in 1999 in comparison with their coevals in 1993–1994. The 8- and 13-year-old boys and girls in Gm–D differ significantly ($p<0.01$) from their coevals in Gm–V by the smaller values of the parameter. The same age groups of boys ($p<0.001$) and 8-year-old girls ($p<0.01$) of Gm–D are characterised by smaller values of AP in comparison with their Minsk coevals in the 1999 research.

Table 1. Comparative characteristics of AP index (points) in the male groups studied

Age, years	N	Min	Max	x	m(x)	s	N	Min	Max	x	m(x)	s	p ≤
	Minsk 1993–1994						**Minsk 1999**						
8	**257**	0.87	2.39	**1.57**	0.02	0.26	**50**	1.44	2.24	**1.78**	0.02	0.17	**0.001**
13	**98**	0.98	2.55	**1.82**	0.03	0.28	**68**	1.12	2.44	**1.87**	0.04	0.29	
17	**65**	1.48	2.76	**2.14**	0.03	0.26	**54**	1.72	3.11	**2.19**	0.03	0.25	
	Gomel (downtown) 1998–1999						**Gomel (Volotova) 1998–1999**						
8	**101**	1.03	2.28	**1.63**	0.03	0.26	**69**	1.18	2.34	**1.73**	0.03	0.22	**0.01**
13	**101**	1.13	2.58	**1.77**	0.03	0.27	**69**	1.38	2.51	**1.91**	0.03	0.26	**0.001**
17	**100**	1.39	3.30	**2.10**	0.04	0.36	**45**	1.64	3.18	**2.18**	0.04	0.30	
	Minsk 1993–1994						**Gomel (downtown) 1998–1999**						
8	**257**	0.87	2.39	**1.57**	0.02	0.26	**101**	1.03	2.28	**1.63**	0.03	0.26	
13	**98**	0.98	2.55	**1.82**	0.03	0.28	**101**	1.13	2.58	**1.77**	0.03	0.27	
17	**65**	1.48	2.76	**2.14**	0.03	0.26	**100**	1.39	3.30	**2.10**	0.04	0.36	
	Minsk 1999						**Gomel (downtown) 1998–1999**						
8	**50**	1.44	2.24	**1.78**	0.02	0.17	101	1.03	2.28	1.63	0.03	0.26	0.001
13	**68**	1.12	2.44	**1.87**	0.04	0.29	101	1.13	2.58	1.77	0.03	0.27	0.05
17	**54**	1.72	3.11	**2.19**	0.03	0.25	**100**	1.39	3.30	**2.10**	0.04	0.36	
	Minsk 1993–1994						**Gomel (Volotova) 1998–1999**						
8	**257**	0.87	2.39	**1.57**	0.02	0.26	**69**	1.18	2.34	**1.73**	0.03	0.22	**0.001**
13	**98**	0.98	2.55	**1.82**	0.03	0.28	**69**	1.38	2.51	**1.91**	0.03	0.26	**0.05**
17	**65**	1.48	2.76	**2.14**	0.03	0.26	**45**	1.64	3.18	**2.18**	0.04	0.30	
	Minsk 1999						**Gomel (Volotova) 1998–1999**						
8	**50**	1.44	2.24	**1.78**	0.02	0.17	**69**	1.18	2.34	**1.73**	0.03	0.22	
13	**68**	1.12	2.44	**1.87**	0.04	0.29	**69**	1.38	2.51	**1.91**	0.03	0.26	
17	**54**	1.72	3.11	**2.19**	0.03	0.25	**45**	1.64	3.18	**2.18**	0.04	0.30	

The average parameter of AP exceeding 2.1 points testifies to tensions in the adaptation mechanism of 17-year-old boys in Minsk in 1993–1994 and 1999, and also in Gm–V. In the remaining cases the average parameters of AP belong to a satisfactory category, i. e. normal adaptation. The average level of AP in all sex and age groups of Minsk shows a tendency of increase from 1993–1994 to 1999 (see Tables 1–2) as the ecological load on the organisms of the pupils has increased. As to Gomel, the higher parameters of the index in Gm–V as contrasted to Gm–D are indirect indicators of greater ecological hazards in Volotova housing estate.

Table 2. Comparative characteristics of AP index (points) in the female groups studied

Age, years	N	Min	Max	x	m(x)	s	N	Min	Max	x	m(x)	s	p ≤
	Minsk 1993–1994						**Minsk 1999**						
8	**247**	0.66	2.44	**1.49**	0.02	0.24	**55**	1.23	2.19	**1.71**	0.03	0.23	**0.001**
13	**80**	1.22	2.43	**1.80**	0.03	0.28	**70**	1.36	2.85	**1.90**	0.03	0.27	**0.05**
17	**89**	1.51	2.98	**2.00**	0.03	0.25	**63**	1.55	2.69	**2.01**	0.03	0.25	
	Gomel (downtown) 1998–1999						**Gomel (Volotova) 1998–1999**						
8	**103**	0.96	2.18	**1.57**	0.02	0.23	67	1.25	2.36	**1.75**	0.03	0.21	**0.001**
13	**104**	0.68	2.54	**1.83**	0.03	0.28	69	1.39	2.84	**2.02**	0.04	0.30	**0.001**
17	**100**	1.37	2.70	**2.00**	0.03	0.27	69	1.58	2.70	**2.07**	0.03	0.24	
	Minsk 1993–1994						**Gomel (downtown) 1998–1999**						
8	**247**	0.66	2.44	**1.49**	0.02	0.24	**103**	0.96	2.18	**1.57**	0.02	0.23	**0.01**
13	**80**	1.22	2.43	**1.80**	0.03	0.28	**104**	0.68	2.54	**1.83**	0.03	0.28	
17	**89**	1.51	2.98	**2.00**	0.03	0.25	**100**	1.37	2.70	**2.00**	0.03	0.27	
	Minsk 1999						**Gomel (downtown) 1998–1999**						
8	**55**	1.23	2.19	**1.71**	0.03	0.23	**103**	0.96	2.18	**1.57**	0.02	0.23	**0.001**
13	**70**	1.36	2.85	**1.90**	0.03	0.27	**104**	0.68	2.54	**1.83**	0.03	0.28	
17	**63**	1.55	2.69	**2.01**	0.03	0.25	**100**	1.37	2.70	**2.00**	0.03	0.27	
	Minsk 1993–1994						**Gomel (Volotova) 1998–1999**						
8	**247**	0.66	2.44	**1.49**	0.02	0.24	67	1.25	2.36	**1.75**	0.03	0.21	**0.001**
13	**80**	1.22	2.43	**1.80**	0.03	0.28	69	1.39	2.84	**2.02**	0.04	0.30	**0.001**
17	**89**	1.51	2.98	**2.00**	0.03	0.25	69	1.58	2.70	**2.07**	0.03	0.24	
	Minsk 1999						**Gomel (Volotova) 1998–1999**						
8	**55**	1.23	2.19	**1.71**	0.03	0.23	67	1.25	2.36	**1.75**	0.03	0.21	
13	**70**	1.36	2.85	**1.90**	0.03	0.27	69	1.39	2.84	**2.02**	0.04	0.30	**0.02**
17	**63**	1.55	2.69	**2.01**	0.03	0.25	69	1.58	2.70	**2.07**	0.03	0.24	

Distribution of individuals with heightened AP (2.11–3.2 points) has revealed the following regularities (Table 3). In all the groups compared, the proportion of AP exceeding 2.11 points increases considerably with age, describing the stress in the mechanism of adaptation. In 8-year-old children such values are rather rare (from 1.4% in Gm–V to 5.9% for Gm–D among boys, and from 0.9% in Minsk in 1993–1994 to 5.5% in Minsk in 1999 among girls). To the period of puberty at 13 the frequency of AP of the given category has increased and

Table 3. Age distribution of AP indexes depending on the status of adaptation mechanisms

Age, years	Boys					Girls				
		up to 2.1 points		2.11–3.2 points			up to 2.1 points		2.11–3.2 points	
	N	n	%	n	%	N	n	%	n	%
					Minsk 1993–1994					
8	238	230	96.6	8	3.4	231	229	99.1	2	0.9
13	98	86	87.8	12	12.2	80	66	82.5	14	17.5
17	65	33	50.8	32	49.2	89	63	70.8	26	29.2
					Minsk 1999					
8	50	48	96.0	2	4.0	55	52	94.5	3	5.5
13	68	52	76.5	16	23.5	70	58	82.9	12	17.1
17	54	21	38.9	33	61.1	63	48	76.2	15	23.8
					Gomel (downtown) 1998–1999					
8	101	95	94.1	6	5.9	103	101	98.1	2	1.9
13	101	90	89.1	11	10.9	104	83	79.8	21	20.2
17	100	55	55.0	45	45.0	100	68	68.0	32	32.0
					Gomel (Volotova) 1998–1999					
8	71	70	98.6	1	1.4	67	64	95.5	3	4.5
13	69	57	82.6	12	17.4	69	46	66.7	23	33.3
17	45	18	40.0	27	60.0	69	41	59.4	28	40.6

ranges in boys from 10.9% in Gm–D to 23.5% in Minsk 1999, and among girls from 17% in Minsk 1993–94 and 1999 to 33% in Gm–D. At the age of 17 the percentage of parameters of AP testifying to the tension in the adaptation mechanism is even higher: its frequency varies from 45% among the young men in Gm–D to 60–61% among the pupils from Minsk 1999 and Gm–V, and among girls from 23.8% (in Minsk 1999) to 40.6% (among the girls of Gm–V). Thus among Minsk schoolboys an obvious increase in the frequency of adaptation stress from 1993–94 by 1999 can be observed. In Gomel in 1998–1999 the pupils of both sexes in Gm–V are characterised by higher frequency in comparison with Gm–D. Among the schoolgirls of Minsk no definite dynamics in the frequency of heightened AP was observed.

Thus, the rather high percentage of individuals with stress of adaptive mechanisms among the pupils studied in 1998–1999 in Minsk and Gomel testifies to considerable environment hazards (natural and social), in which the present generation grows up. According to the general principles of ontogenesis, the pressure of negative environmental factors renders a stronger effect on the male organism, which was revealed to a greater extent in Minsk. As for the distribution of AP categories in Gomel, the Volotova housing estate is more severely harmed in ecological aspects.

To define the constitutional features of distribution of AP parameters in the investigated sex and age samples of urban schoolchildren, the material was clustered according to somatotypes (Tables 4–5).

As one can see from the tables, in Minsk in 1999 the average parameter of AP exceeding 2.1 points, which testifies to the stress of adaptive mechanisms, has been detected in 13-year-old boys only among the endomorphic type. At the age of 17 years the stress on adaptive mechanisms appears among Minsk young men of ectomorphic (1999) and mesomorphic (increases from 1993–1994 to 1999) types as well. The maximum frequency of heightened AP level occurs among the young men of the endomorphic type.

In Gomel the similar nature of distribution of the given category of AP among young men resembles those parameters for pupils of Minsk only in the 17 years age group. In Gm–D the AP parameters are higher in young men of endomorphic and uncertain types and in Gm–V in meso- and endomorphic types. Thus AP is somewhat higher in mesomorphic young men in Volotova and in endomorphic ones in downtown.

Among the schoolgirls, AP exceeding 2.1 points occurs more often among 13-year-old endomorphic girls in Minsk in 1999 and in both samples of Gomel. Among 17-year-old girls, the endomorphic type is characterised by the stress of adaptive mechanisms in Minsk (1993–1994) and in Gm–D.

Table 4. Age dynamics of AP index (points) for urban boys of different somatotypes

Somatotype	8 years					13 years					17 years				
	n	x	m(x)	s	v	n	x	m(x)	s	v	n	x	m(x)	s	v
	Minsk 1993–1994														
ectomorphic	106	**1.54**	0.03	0.26	17.15	40	**1.72**	0.05	0.29	16.73	17	**2.04**	0.07	0.29	14.30
mesomorphic	94	**1.56**	0.03	0.26	16.40	41	**1.87**	0.04	0.26	13.89	44	**2.17**	0.04	0.24	11.04
endomorphic	16	**1.66**	0.06	0.26	15.44	13	**1.97**	0.07	0.24	12.40	4	**2.28**	0.11	0.22	9.77
uncertain	22	**1.60**	0.05	0.25	15.41	4	**1.91**	0.12	0.24	12.41					
	Minsk 1999														
ectomorphic	16	**1.73**	0.04	0.15	8.74	20	**1.80**	0.07	0.31	17.40	16	**2.12**	0.05	0.21	9.88
mesomorphic	23	**1.77**	0.03	0.16	8.95	37	**1.88**	0.05	0.28	14.67	35	**2.23**	0.05	0.27	11.99
endomorphic	2	**1.87**	0.02	0.03	1.39	5	**2.19**	0.09	0.21	9.47	1				
uncertain	9	**1.90**	0.07	0.20	10.77	6	**1.74**	0.08	0.19	10.81	2	**1.97**	0.04	0.06	3.03
	Gomel (downtown) 1998–1999														
ectomorphic	27	**1.57**	0.04	0.23	14.59	40	**1.73**	0.04	0.27	15.46	32	**1.97**	0.06	0.32	16.39
mesomorphic	44	**1.68**	0.04	0.27	16.24	53	**1.79**	0.04	0.28	15.83	57	**2.10**	0.04	0.31	14.63
endomorphic	17	**1.71**	0.05	0.22	13.04	8	**1.88**	0.06	0.18	9.59	9	**2.52**	0.16	0.48	18.91
uncertain	13	**1.48**	0.06	0.23	15.36	–					2	**2.29**	0.40	0.56	24.42
	Gomel (Volotova) 1998–1999														
ectomorphic	11	**1.68**	0.07	0.24	14.54	26	**1.79**	0.04	0.20	11.08	14	**2.04**	0.06	0.23	11.29
mesomorphic	38	**1.70**	0.03	0.19	11.40	30	**1.94**	0.04	0.23	11.86	23	**2.20**	0.05	0.25	11.55
endomorphic	14	**1.81**	0.06	0.23	12.81	15	**2.08**	0.07	0.26	12.61	6	**2.48**	0.16	0.39	15.59
uncertain	7	**1.76**	0.11	0.29	16.72	2	**1.63**	0.05	0.07	3.99	2	**2.00**	0.36	0.51	25.32

Table 5. Age dynamics of AP index (points) for urban girls of different somatotypes

Somatotype	8 years					13 years					17 years				
	n	x	m(x)	s	v	n	x	m(x)	s	v	n	x	m(x)	s	v
	Minsk 1993–1994														
ectomorphic	113	**1.46**	0.02	0.22	14.97	37	**1.75**	0.05	0.29	16.33	27	**1.90**	0.04	0.20	10.47
mesomorphic	66	**1.48**	0.03	0.27	18.37	34	**1.87**	0.05	0.26	14.08	50	**2.02**	0.04	0.25	12.51
endomorphic	25	**1.59**	0.06	0.32	20.17	7	**1.79**	0.12	0.31	17.14	12	**2.16**	0.07	0.24	11.07
uncertain	27	**1.48**	0.04	0.19	12.94	2	**1.66**	0.01	0.01	0.76	–				
	Minsk 1999														
ectomorphic	22	**1.81**	0.05	0.21	11.81	28	**1.77**	0.04	0.19	10.99	22	**1.96**	0.06	0.27	13.99
mesomorphic	20	**1.65**	0.05	0.21	12.45	33	**1.99**	0.05	0.28	14.05	29	**2.01**	0.04	0.23	11.59
endomorphic	4	**1.83**	0.14	0.29	15.76	6	**2.11**	0.09	0.22	10.54	12	**2.09**	0.07	0.26	12.29
uncertain	9	**1.52**	0.03	0.10	6.55	3	**1.66**	0.14	0.24	14.73					
	Gomel (downtown) 1998–1999														
ectomorphic	37	**1.58**	0.04	0.25	15.96	46	**1.79**	0.03	0.20	10.99	35	**1.88**	0.04	0.25	13.50
mesomorphic	32	**1.52**	0.03	0.18	12.12	43	**1.85**	0.04	0.29	15.52	49	**2.03**	0.03	0.24	11.92
endomorphic	22	**1.65**	0.05	0.24	14.54	9	**2.13**	0.10	0.29	13.62	15	**2.14**	0.07	0.26	11.98
uncertain	12	**1.53**	0.08	0.27	17.49	5	**1.81**	0.07	0.17	9.19	1				
	Gomel (Volotova) 1998–1999														
ectomorphic	18	**1.69**	0.06	0.24	14.49	27	**1.95**	0.05	0.28	14.38	23	**1.98**	0.04	0.20	9.99
mesomorphic	32	**1.74**	0.03	0.19	10.83	26	**1.99**	0.06	0.31	15.44	43	**2.08**	0.04	0.25	12.04
endomorphic	10	**1.84**	0.06	0.20	10.83	15	**2.13**	0.07	0.29	13.50	13	**2.09**	0.05	0.20	9.39
uncertain						7	**2.03**	0.15	0.39	19.34	1				

The constitutional peculiarities of the reactivity of the organism were traced after a grouping of the pupils with stress of adaptive mechanisms in cohorts referred to miscellaneous somatic types (Tables 6–7). Despite the small quantitative saturation of somatotype cohorts, it is possible to observe a definite tendency in the distribution of AP parameters exceeding 2.1 points. The greatest percentage of this AP level found in all territorial groups of schoolboys and schoolgirls falls on the mesomorphic type, such parameter can be somewhat more often seen in the boys of the ectomorphic type (Minsk) and the girls of the endomorphic type in Minsk (1999) and in Gm–D.

Table 6. Percentage distribution of increased (2.11–3.2 points) indices of adaptation potential for boys depending on somatotypes

Age, years	N	Somatotype							
		ectomorphic		mesomorphic		endomorphic		uncertain	
		n	%	n	%	n	%	n	%
		Minsk 1993–1994							
8	8	4	**50.0**	2	**25.0**	1	**12.5**	1	**12.5**
13	12	2	**16.7**	6	**50.0**	3	**25.0**	1	**8.3**
17	32	5	**15.6**	24	**75.0**	3	**9.4**		
		Minsk 1999							
8	2	–	–	1	**50.0**	–	–	1	**50.0**
13	16	4	**25.0**	8	**50.0**	4	**25.0**	–	–
17	33	10	**30.3**	22	**66.7**	1	**3.0**	–	–
		Gomel (downtown) 1998–1999							
8	6	–	–	5	**83.3**	1	**16.7**	–	–
13	11	4	**36.4**	6	**54.5**	1	**9.1**	–	–
17	45	9	**20.0**	28	**62.2**	7	**15.6**	1	**2.2**
		Gomel (Volotova) 1998–1999							
8	1	–	–	–	–	–	–	1	**100.0**
13	12	1	**8.3**	5	**41.7**	6	**50.0**	–	–
17	27	3	**11.1**	17	**63.0**	6	**22.2**	1	**3.7**

Table 7. Percentage distribution of increased (2.11–3.2 points) indices of adaptation potential for girls depending on somatotypes

Age, years	N	Somatotype							
		ectomorphic		mesomorphic		endomorphic		uncertain	
		n	%	n	%	n	%	n	%
		Minsk 1993–1994							
8	2	–	–	1	**50.0**	1	**50.0**	–	–
13	14	5	**35.7**	8	**57.2**	1	**7.1**	–	–
17	26	4	**15.4**	16	**61.5**	6	**23.1**	–	–
		Minsk 1999							
8	3	3	**100.0**	–	–	–	–	–	–
13	12	1	**8.3**	7	**58.4**	4	**33.3**	–	–
17	15	3	**20.0**	6	**40.0**	6	**40.0**	–	–
		Gomel (downtown) 1998–1999							
8	2	1	**50.0**	–	–	1	**50.0**	–	–
13	21	3	**14.3**	13	**61.9**	5	**23.8**	–	–
17	32	8	**25.0**	14	**43.8**	9	**28.1**	1	**3.1**
		Gomel (Volotova) 1998–1999							
8	3	1	**33.3**	1	**33.3**	1	**33.3**	–	–
13	23	6	**26.1**	8	**34.8**	6	**26.1**	3	**13.0**
17	28	6	**21.4**	17	**60.7**	4	**14.3**	1	**3.6**

Thus, an increase in body weight causes a growing risk of violation of mechanisms of adaptation to extreme conditions of urban environment. This is especially characteristic of girls at the age of 13 years and of boys aged 17 years.

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MORPHO-FUNCTIONAL CHARACTERISTICS OF AGE-RELATED CHANGES IN THE TRIGEMINAL NERVE

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ABSTRACT

The study of how the components of nerve conductors change with age and a morpho-functional evaluation of the process of ageing was performed on a sample of 21 human cadavers, 4 to 75 years old. 126 specimens of the main branches of the trigeminal nerve (CN V) were studied by morphological methods. Reactive changes in the structure of myelinated nerve fibres were documented along the course of postnatal ontogenesis. We report that with age, the relative number of myelinated fibres of greater diameter increases on cross-sections of the CN V. Thus, in children and young adults, the thin myelinated fibres (diameter 1–3.9 μ) make up 88.8% to 62.8% of all visible nerve fibres, correspondingly. In the nerves of older adults, this number decreases to 37.8% in the 31–50 age group, and to 23.4% in the 51–75 age group because of the increase in the number of thicker fibres (diameter 4–5.9 and 6–9.9 μ). The greatest variability in the diameter of myelinated fibres was found in the subjects aged 40–50. Since the increase in the diameter of myelinated fibres leads to greater conduction velocity, we hypothesised that a change in proportions between the myelinated fibres of different diameters may result in increased diversity of information conducted by nerves at older ages at the expense of reliability of this information. We concluded that the myelin sheath is the most labile component of nerve fibres, and that age-related changes (such as increase in diameter) within it start early in life and are sufficiently reliable and informative for estimating the degree of the involution process. Degeneration of nerve conductors was rarely seen in the CN V.

Keywords: age-related changes, trigeminal nerve, neural sheaths, neural fibres, ‘nervi nervorum’

INTRODUCTION

A number of studies on the intratruncal structure of human peripheral nerves have demonstrated their considerable lability, variability and individual changeability [15, 17, 24]. There are fewer data, however, on the quantitative distribution of different types of fibres in peripheral nerves, possibly owing to the large amount of laborious computations required; consequently the number of studies documenting variability in the fine structure of nerve trunks is rather small [21, 23, 26].

Yet the need for such studies is undeniable in the face of at least the following two considerations:

1) Owing to the significant structural lability of neural components during ontogenesis, any detailed information on the quantitative distribution of different myelinated fibres in nerve trunks and on changes in their fine structure throughout life could contribute to our understanding of the age-related involution of nerve conductors; this, in turn, should prove useful in evolving strategies for the treatment of peripheral neuropathies.

2) Due to the known fact that unmyelinated and myelinated fibres of different diameter (thin, middle, and thick) conduct neural impulses at varying velocity, any data on the exact structure of nerve trunks could help to explain various pathological manifestations usually associated with clinical phenomena involving these trunks.

There is a wealth of detailed data on age-related changes in both unmyelinated and myelinated fibres and the myelin sheath of nerves [16, 25], but less is known regarding the interplay of fibres of different diameters and their relative number in peripheral nerve trunks throughout life. In general, as far as the trigeminal nerve is concerned, there are only a few publications on myelinated fibres in the ethmoidal, lingual and inferior alveolar branches of this nerve [5, 10, 14].

The human trigeminal nerve (CN V) is one of the most vulnerable peripheral nerves from the standpoint of frequent neuralgias affecting it, e.g. the *tic douloureux* [2, 8, 11, 30]. However, only few publications make special mention of the myeloarchitectonics of some of the CN V branches [10, 14, 26, 29]. In view of this evident oversight, we deemed it worthwhile to select the CN V as the subject of a study of the myeloarchitectonics of and age-related changes in nerve conductors. We made an attempt also to trace the age-related reactive processes of nerve elements in the sheaths (‘*nervi nervorum*’) and conducting system of the CN V in the course of human ontogenesis.

Moreover, the study of age-related changes in peripheral nerves may serve as an important source of knowledge about more general aspects of human ageing.

MATERIAL AND METHODS

Trigeminal (CN V) nerves were removed from 21 human cadavers aged 4 to 75 years. The material was taken not later than 12 hours post mortem from subjects, who died a sudden death.

After the removal of soft tissues, the main branches of CN V on the right and left sides of the face were exposed and then cut approximately 2–3 mm distal to their exit from the foramina. Care was taken not to stretch and/or damage the nerve trunks. The major branches of CN V were observed, namely the ophthalmic, maxillary, and mandibular nerves. From each of these representative portions, three parts were excised, namely: proximal (immediately at the exit from the foramina), middle, and distal (at the first branchiating). All the collected material was fixed in 10% neutral formalin. To study conductor components, part of the specimens were subjected to Shick staining [22] and part to Weigert-Pal and Marky staining [28] prior to their embedding in paraffin. The three peripheral branches were cut into separate blocks under a dissecting microscope. In all, 126 specimens of the CN V were further sectioned, the sections were coded to prevent bias and examined.

The amount of nerve fibres with stained myelin sheath was determined by a light microscope, using an ocular micrometer. To study the '*nervi nervorum*', the nerve sheaths were impregnated with silver nitrate, according to the classical methods, and stained by Beilschowsky [19], Gross and Kampos technique [28].

Outer myelin diameters were measured for all the myelinated nerve fibres, after which the fibres were categorised into thin (diameter 1–3.9 μ), middle (4–5.9 μ), thick (6–9.9 μ), and very thick (10.0 μ or more) fibres. Proportionalities of these four diameter-based categories were fully determined for each specimen.

The nerves of the neural sheaths ('*nervi nervorum*'), i.e. the proper nerve elements of the CN V sheaths, were studied in 86 of our 126 specimens. In each case, the epineurium, perineurium, and endoneurium were observed.

Statistical analysis

Slides were assessed by the same investigator, to eliminate possible inter-observer error. Descriptive statistics were employed to delineate the quantitative distribution of myelinated fibres in different age groups. Multiple t-tests were used to indicate differences between two consequent age groups.

The methods of information theory [4, 21] were used for evaluation of the morpho-functional status and abilities of the conducting system of CN V during the successive periods of ontogenesis. Bearing in mind that a myelinated fibre is an elementary part of a unit (namely, the conductor system of the nerve), we determined its following characteristics:

a) observed entropy (*H*) — the amount of information per one element of the unit, computed according to Bandarin [4, p. 246];
b) maximal entropy (H_{max}) — expected entropy on assumption that all elements are of equal capability;
c) relative entropy (*h*) — ratio of observed (*H*) to maximal (H_{max}) entropy;
d) coefficient of surplus (*R%*) — degree of reliability of information transmission according to the formula [18; 36]:

$$R\% = \frac{(H_{max} - H)}{H_{max}} \times 100.$$

RESULTS

Figure 1 provides data on the relative number of myelinated nerve fibres of each diameter category during postnatal ontogenesis. Our results suggest that in children (mean age 4 years) the thin myelinated fibres comprise up to 88.8% of all fibres, while the remaining fibres do not exceed 4–5.9 μ in diameter. In the nerves of young adults (18–30 years of age), the number of thin fibres decreases to 62.8%, with a concurrent increase in the percentage of middle fibres and a first appearance of thick myelinated fibres. In the next age group (31–75 years of age) there is a clear tendency to a relative decrease in thin and middle fibres, along with an increase in the number of thick and thickest fibres. The greatest variability in the diameter of myelinated fibres was encountered in subjects who were at 40–50 years of age.

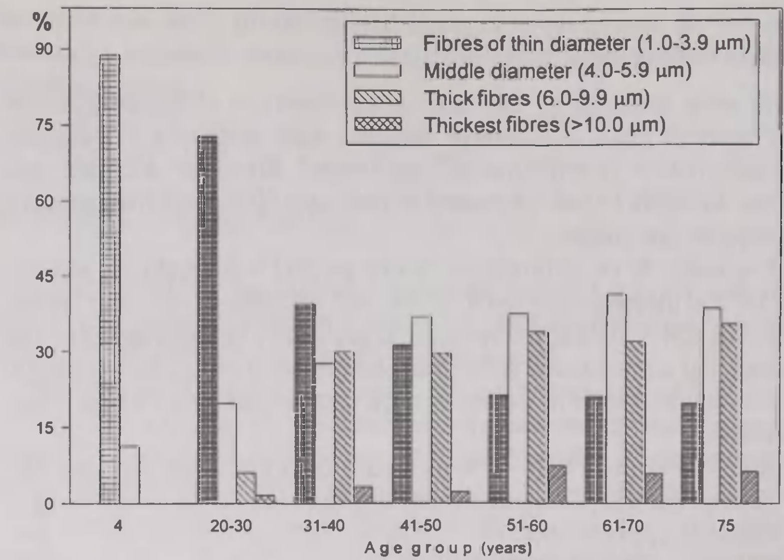
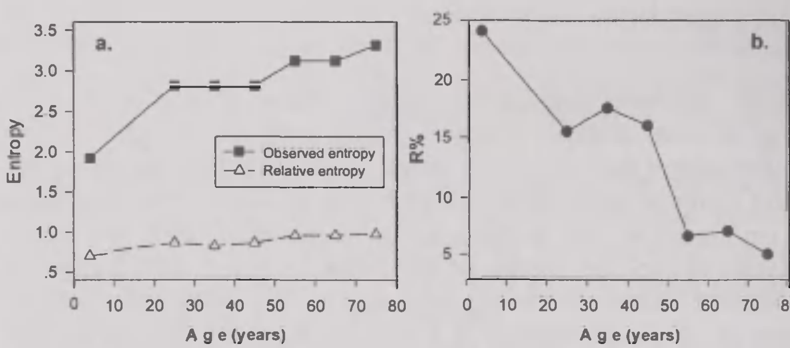


Figure 1. Myelinated fibres content in different age groups.

When analysing the myeloarchitectonics of peripheral nerves by the methodology of information theory, the values of entropy (both observed and relative, H and h, respectively) seem to increase with age, whereas the coefficient of surplus ($R\%$) was inversely correlated to age (Fig. 2).



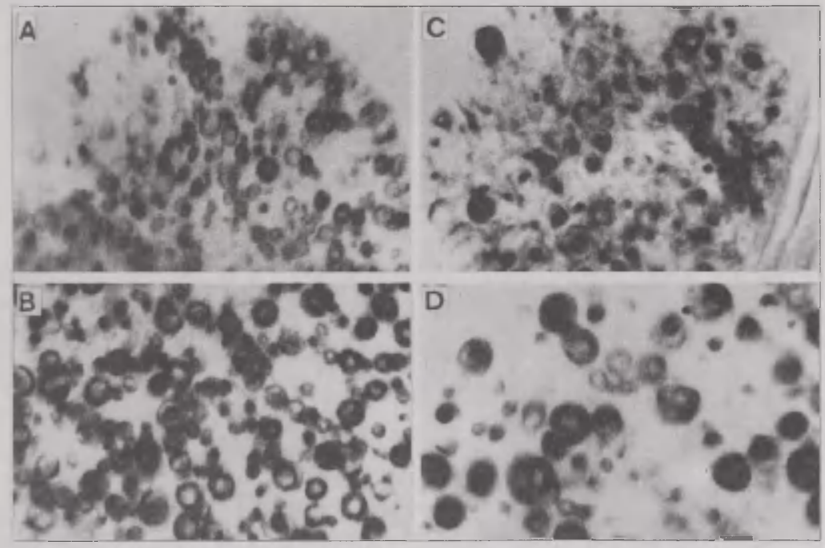
a. Entropy, **b.** Coefficient of surplus.

Figure 2. Results of information theory calculations in the conductor system of CN V according to age groups.

The morphological manifestations of the reactive process involve all parts of the trigeminal nerve and their number increases with increasing age. For description purposes, they are conveniently presented herein according to the anatomical structures involved:

Nerve conductors

The reactive changes here are similar in character and differ only quantitatively throughout the stages of ontogenesis. Thus, even in the nerves of children, it is possible to distinguish nerve fibres with small, but sharply demarcated loci of thickening at the axial cylinders (Fig. 3). The number of these changes is the higher the older people get.



a. 4-year-old. b. 21-year-old. c. 37-year-old. d. 75-year-old. Ophthalmic nerve. Weigert-Pal. ×400.

Figure 3. Age-related changes in myelinated fibres composition.

In the axial cylinders, the ageing process manifests itself in several changes, namely: dyschromia (uneven colouring of the fibres by silver nitrate, indicative of their altered tinctorial behaviour); varicosities, enlargements, and round to oval outgrowths of neuroplasma (Fig. 4, 5).

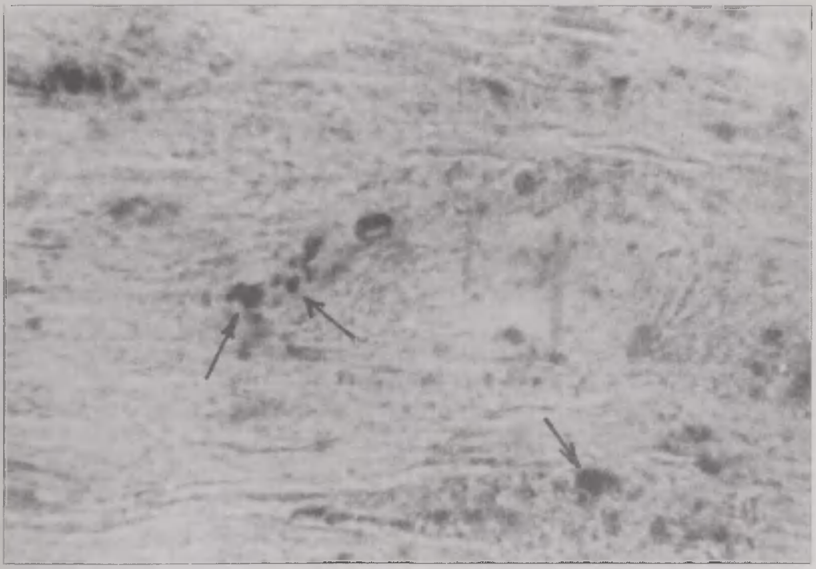
Figure 4. Outgrowth of perineural sheath (arrow) and thickening of nerve fibres in epineurium. Ophthalmic nerve, female, 64 years. Silver nitrate. ×400.

Figure 5. Single myelinated fibre inside of epineurium. Mandibular nerve, male, 71 years. Silver nitrate. ×400.

Degeneration of axial nerve conductors is rather infrequently observed in the CN V throughout the ageing process. When it does appear, it mostly indicates the coexistence of other age-related conditions, such as atherosclerosis, hypertonic disease, or disturbance of the brain-blood circulation.

Myelinated sheaths

Myelin ages by its disintegration (Fig. 6). Initial appearance of fibres with disintegrated myelin occurs in nerves of people 30–35 years of age, and with subsequent ageing, there is an ever increasing number of myelinated fibres showing the products of disintegrating myelin in them.



Arrow points to derivates of myelin. Maxillar nerve, female, 42 years. Marky. ×400.

Figure 6. Destruction of myelin in a person who died from acute heart insufficiency.

Neural sheaths

With ageing, moderately-sized vesicular protrusions appear on the walls of the perineural sheath of the fascicula (Fig. 4). Concurrently, there is an increasing disruption of the tinctorial properties of the Schwann cells, and even a proliferation of these cells at several points.

We should note that frequently, despite the mentioned transformations in the myelinated sheaths and perineural walls, the axial cylinders remain intact or show only slight varicose thickenings.

The age-related changes in the CN V neural conductors and the myelinated sheaths of this nerve are compared in Table 1.

Table 1. Number of degenerative nerve fibres by age groups (mean ± SD), in percentage.

	Children (4 yr. old)	**Young adults** (18–40 yr. old)		**Older adults** (41–75 yr. old)	
Site	mean ± SD	mean ± SD	P*	mean ± SD	P
Nerve sheaths	11.40±1.53	16.00±1.30	<0.001	25.50±2.43	<0.001
Conductors	7.30±0.60	10.10±2.10	<0.001	12.50±1.53	0.001

* Significance of comparison with the previous age group.

From this Table can be gleaned that the number of nerve conductors showing reactive changes is always higher in nerve sheaths than in conductor components *per se*. In *nervi nervorum*, as well, there is an increasing number of fibres that undergo degenerative changes with increasing age. Thus, in the nerves of people aged 41–50 years, we encountered 18.5±2.3% of such fibres, in people aged 51–60 years — 24.6±1.4% (a statistically significant increase, $p<0.001$), and in people aged 61–75 years — 34.4±3.3% ($p<0.001$). Clearly, the initial manifestations of involution in CN V are periaxonal alterations involving both the myelinated envelope and the perineural sheaths.

The reactively altered fibres in the nerve sheaths of different branches of the CN V are compared in Table 2. From this Table we learn that the number of fibres showing reactive changes is always higher in the perineural than in the epineural envelope. We should mention that these involutive regressive changes were prominent mostly in the maxillar and mandibular nerves of all age groups.

Table 2. Number of reactively changed nerve fibres in nerve sheaths of different parts of CN V (mean ± SD), in percentage

		Age group		
		Children (4 yr. old) N = 3	**Young adults** (18–40 yr. old) N = 9	**Older adults** (41–75 yr. old) N = 9
Nerve	Site	mean ± SD	mean ± SD	mean ± SD
ophthalmic	epineurium	4.10±2.20	12.20±1.56**	18.50±3.20^{NS}
	perineurium	10.00±3.10	21.00±0.84**	23.60±1.30^{NS}
maxillar	epineurium	11.30±1.10	15.00±0.72**	22.70±2.30*
	perineurium	12.00±2.00	10.50±0.31*	20.70±3.78*
mandibular	epineurium	11.70±1.13	13.70±0.99*	22.20±1.76*
	perineurium	14.10±0.80	23.50±2.60**	28.60±4.40^{NS}
Total	epineurium	10.80±1.60	15.00±1.08*	21.13±2.42*
	perineurium	13.30±0.91	17.00±4.68*	25.96±3.16**

Significance of comparison with the previous age group:
** — $p<0.001$, * — $p<0.05$, NS — $p>0.5$.

DISCUSSION

The findings of the present study point to the occurrence of significant remodelling in CN V structure with age. As known, nerve conductors contain both unmyelinated and thin myelinated fibres. The myelinated fibres have a relatively uniform diameter during the first decade of life. However, with increasing age, they undergo a process of myelin accumulation within their envelope, which leads to increasing diversity in their diameters and thickness.

The increase in the number of thick myelinated fibres comes at the expense of the thin fibres, which leads us to speculate that such a change in the proportions of myelinated fibres of different diameter may exert an effect on the amount of information conducted by nerves. The myeloarchitectonics of CN V were therefore analysed by information analysis methodology [27, 31, 36], employed here to evaluate the morpho-functional state of the nerve in the course of age-related remodelling. Indeed, the values of entropy, both absolute and relative, have been found to increase with age (i.e., there is increasing diversity in the amount of information which passes through each nerve conductor), whereas their coefficient of surplus *R%* decreases (thus suggesting diminished reliability of information transmission).

With increasing age, there is growing evidence of the reactive process, which first of all damages the paraneural structures and the myelinated sheaths. Thus, involution commences here as a periaxonal reaction, with axial parts of the nerves being damaged secondarily. Demyelinization is one of the earliest signs of the CN V involutive process [12] and is a well-known cause of neuralgia [7].

In our previous studies of microcirculatory bed in human CN V, we have demonstrated the compensatory and adaptational abilities of intraneural blood vessels [34, 35]. In fact we found that remodelling of the CN V intraneural blood circulation appears to be correlated in terms of time, degree and place with concurrent changes in the perineural sheaths. This important finding led us to assume that both the myelinated nerve sheaths and the microcirculatory bed function in concerted fashion as a morpho-functional unit [33]. The nerves of the neural sheaths (‘*nervi nervorum*’), which were observed in the epi-, peri-, and endoneurium, are very quick to react and their reactivity level is high. This suggested to us that, in unfavourable conditions, the neural sheaths probably react first, to be followed by reaction of the neural conductors [32, 33].

Many of the investigators of CN V neuralgia have claimed that there is a strong correlation between this condition and old age [1, 6, 9, 37]. In aged persons, there is a high incidence of sporadic pains and paresthesias, with decline in sensitivity [3, 9].

The results of the present study support this claim and further suggest that in old age there are salient indications of a reactive process in the CN V, involving the conductor fibres, the nerves of the CN V sheaths and their blood vessels. The reactive changes associated with this involution occur mostly in the maxillar and mandibular nerves, which are also the most vulnerable to neuralgias [3, 13, 20].

CONCLUSIONS

1) In human trigeminal nerve, the relative number of myelinated fibres of greater diameter increases with age. The highest variability in diameter of the myelinated fibres was encountered in subjects aged 40–50. Since increase in the diameter of myelinated fibres leads to a greater conduction velocity, any such change in the pro-

portionalities of myelinated fibres of different diameters must result in increased variegation of the information conducted by the trigeminal nerve in older people, and this at the expense of reliability of this mode of information transmission.

2) Reactively changed nerve conductors appear during ontogenesis in the epineurium, perineurium, and endoneurium ('*nervi nervorum*') of the human CN V, their number increasing with age. Such involutive reactive changes occur mostly in maxillar and mandibular nerves, which are also frequently subject to neuralgias.
3) The structures in perineurium, e.g. myelinated fibres, axial cylinders, show age-related reactive changes earlier than do epineurial and endoneurial structures. The degree of the '*nervi nervorum*' reactivity in CN V is higher than that of the axial neural conductors.

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BODY MASS AND NUTRITION IN THE MALE POPULATION OF TALLINN

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ABSTRACT

The objective of the study was to investigate the relationship between diet and body mass in the male population of Tallinn, Estonia.

An epidemiological study of the free-living male population of Tallinn aged 20–54 was carried out involving 2477 participants. The screening procedure included standard epidemiological methods. In 908 men their nutritional status was studied by means of the 24-hour recall method; 52 nutrients were calculated. The relationships between diet and body mass index (BMI) were studied by means of quantile analysis, quadratic and multiple regression analyses.

The population was characterised by rather high prevalence of overweight and mean values of BMI, Western dietary pattern and high awareness of healthy lifestyle. The study confirmed positive relationships between BMI and energy intake, SFA, animal protein, starch, and alcohol consumption; negative relationships with vegetable protein, vegetable fat, PUFA, fibre consumption, P/S ratio. The relationships between diet and BMI were non-linear, due to the changes in dietary habits that had taken place in the population. For a part of the population the consumption of many nutrients had a parabolic relationship with both BMI and age. The parabolic character of relationships was connected with the changes of the dietary pattern in a part of overweight people who are strongly motivated to improve their diet. They had decreased the caloric value of their diet, had consumed less animal fat, sugar, starch and more vegetable oil in comparison with the people with the lowest weight. For the rest of the population the relationship between diet and BMI was, obviously, more complex.

The study confirmed the most important relationships between diet and body mass. The relationships between nutrition and body mass were non-linear, due to the changes in diet that had taken place in the population.

Keywords: Body mass, nutrition, cross-sectional study

INTRODUCTION

Excessive body mass is considered to be one of the risk factors for coronary heart disease (CHD) [5], which remains the leading cause of death in most economically advanced countries, including Estonia [17]. It is well known that nutrition is the main factor determining the level of body mass. Nevertheless, numerous relationships between nutrition and body mass which have been proved in animal-experimental and clinical research often fail to be confirmed in cross-sectional epidemiological studies, especially carried out on intra-national level in economically advanced countries with high levels of CHD risk factors and a Western dietary pattern [15].

The aim of the study was to assess the relationships between nutrition and body mass in the male population of Tallinn, Estonia.

MATERIAL AND METHODS

The free-living male population of Tallinn, the capital of Estonia, representing one third of the total population of the country, was studied in a cross-sectional study by means of standard epidemiological methods. 2477 men aged from 20 to 54 years were examined with a response rate of 72.2%. The sample was drawn from the lists of electors.

The screening procedure included standard investigation methods and has been described by us elsewhere [12]. The weight of participants was measured without shoes and heavy garments and recorded to the nearest 100 g; height was recorded to the nearest 0.5 cm. For the assessment of body mass, the body mass index (BMI) was calculated as weight, kg/(height, m)^2. Nutrition status was studied by means of the 24-hour recall method on the day of visit in 50% of the participants. Only people with typical nutrition on the previous day and not keeping a diet were included in the analysis. Thus, dietary analysis was carried out in 908 men (36.6% of the participants).

The data were processed using the SAS [9]. Mean values and standard deviations, as well as the prevalence of overweight (BMI≥29) were calculated by BMI; 52 nutrients were calculated. Relationships between nutrients and BMI were analysed by means of quantile analysis, quadratic and multiple regression analysis. Quantile analysis was performed in different age-ethnic groups: at the age 20–39, 40–54 and 20–54 in Estonians, Russians and in the total population, which included, in addition, people of other ethnic origin. The dietary indices included in quantile analysis were as follows: energy intake (kcal), animal and vegetable protein, saturated (SFA), polyunsaturated (PUFA) fatty acids, vegetable fat, sucrose, starch — in per cent of energy intake (%E), polyunsaturated to saturated fat (P/S) ratio. The prevalence of overweight was analysed in the upper and the lower tertiles and quartiles of each nutrient consumption distribution curve (in the upper and the lower deciles for alcohol). The values of BMI belonging to the upper decile of the distribution were considered as overweight in quantile analysis. The cut-off-points for nutrients and BMI were taken for each age-ethnic group separately. The differences between prevalence rates were calculated by means of the following formula (4) using the Student t-test:

$$t = \frac{p_1 - p_2}{\sqrt{\frac{p_1(100-p_1)}{n_1} + \frac{p_2(100-p_2)}{n_2}}},$$

where p_1 and p_2 are the prevalence rates (%) in the compared groups and n_1 and n_2 are the numbers of subjects in the groups.

Quadratic regression models were set up for two ethnic groups — Estonians and Russians (aged 20–54) — and included BMI and age as independent variables and dietary indices as dependent variables. The dietary indices, included in the models, were the following: energy intake (kcal), animal and vegetable protein, SFA, MUFA, PUFA, sucrose, starch, lactose, alcohol (%E), coffee (g), tocopherol, thiamin, riboflavin, pyridoxine, niacin (as niacin-equivalent), calcium, phosphorus, magnesium, copper, zinc (mg/1000 kcal), hemicellulose, cellulose, pectin, fibre (as the sum of hemicellulose, cellulose, and pectin), dietary cholesterol (g/1000 kcal), P/S and Cu/Zn ratios.

Multiple regression models were set up for Estonians, Russians, people of other ethnic origin and the total population (age 20–39 and 40–54). Some of the nutrients were not included in the models to avoid relationships connected with close relations between some nutrients. Thus, the set of nutrients was the same, except vegetable protein, MUFA, PUFA, tocopherol, pyridoxine, phosphorus, Cu/Zn ratio. The nutrients were included in a squared form, as well.

RESULTS

The mean values of BMI in the population (Table 1) increased from 23.5 at the age 20–29 years to 26.4 at the age of 50–54; the increase from one age group to the other was statistically significant. The prevalence of overweight increased from 3.4% in the 20–29 age group to 26.4% at the age of 50–54; the increase from one age group to the other was also statistically significant.

Table 1. Mean values (X ± SD) of BMI and prevalence (%) of overweight in the male population of Tallinn aged 20–54

Age, years	20–29(I) n=587	30–39(II) n=694	40–49(III) n=759	50–54(IV) n=437	20–54 (age-adjusted) n=2477
BMI	23.5±2.4	25.4±2.6	26.1±2.8	26.4±2.1	25.1±2.5
	$P_{I-II} \le 0.05$	$P_{II-III} \le 0.05$	$P_{III-IV} \le 0.05$		
Overweight	3.4	12.8	17.7	24.2	12.3
(BMI ≥ 29)	$P_{I-II} \le 0.05$	$P_{II-III} \le 0.05$	$P_{III-IV} \le 0.05$		

The relationships found between nutrients and overweight in different age and ethnic groups by quantile analysis are shown in Table 2 (the subgroups where no relationships were observed are omitted). The proportion of people with overweight was compared between the upper and lower quantiles (quartiles and tertiles) of each nutrient distribution curve in different age-ethnic groups. It was found that the prevalence of overweight was higher among people with the lowest energy intake, the lowest percentage of sugar, starch, vegetable protein and vegetable fat in their diet and with the highest percentage of animal protein. These relationships were not found in all the groups but only in some of them. As to P/S ratio and PUFA consumption, the relationships found in different groups were directed diversely. In some age-ethnic groups the prevalence of overweight was higher among people with the lowest P/S ratio and the lowest percentage of PUFA consumption in their diet. In some others it was vice versa: the prevalence of overweight was higher among people with the highest P/S ratio and the highest percentage of PUFA consumption. As before, the relationships were not found in all the groups. No relationships with SFA consumption were found.

Table 2. Significant relationships between some dietary indices and the prevalence of overweight (quantile analysis)

Dietary indices	Age, years	Quantiles	Ethnic origin	Student's T between the upper and the lower quantile
	40–54	tertiles	P	–2.44
Energy intake, kcal	20–54	tertiles	R	–2.41
			P	–3.42
	20–39	tertiles	E	+2.12
		quartiles	P	+2.52
PUFA, % E	40–54	quartiles	R	–2.01
	20–54	tertiles	E	+2.02
		quartiles	E	+2.36
P/S	20–39	quartiles	E	+2.03*
	40–54	tertiles	R	–2.33*
Vegetable fat, % E	20–54	quartiles	P	–3.07
Vegetable protein, % E	20–54	tertiles	E	–2.41
	40–54	quartiles	R	+2.03
Animal protein, % E	20–54	tertiles	E	+2.35
			R	+2.03
		quartiles	R	+2.23
			P	+3.08
	20–39	tertiles	R	–2.21
		quartiles	P	–2.65
Sucrose, % E	20–54	quartiles	E	–2.87
			P	–2.79
Starch, % E	20–54	quartiles	P	–2.25

Notes: E — Estonians; R — Russians; P — population; (+, –) — direction of relationship

SFA, % E no relationships found

Thus, negative relationships were found between BMI and energy intake, sugar, starch, vegetable fat and vegetable protein consumption.

Positive relationships were found with animal protein consumption. For P/S ratio and PUFA consumption both positive and negative relationships were revealed.

The data obtained from quadratic regression analysis with age as an independent variable showed that in Estonians and Russians the relationships between age and the consumption of some nutrients were parabolic. In Estonians there were found parabolic relationships with the minimum point at age from 34 to 42, respectively, for the consumption of fibre, cellulose, pectin, magnesium, copper, riboflavin, pyridoxine, and parabolic relationships with a maximum point at age 41 and 44, respectively, for the consumption of animal protein and coffee. In Russians there were found parabolic relationships with the minimum point at age from 36 to 42, respectively, for the consumption of fibre, cellulose, hemicellulose, pectin, tocopherol, and a parabolic relationship with the maximum point at age 40 for the consumption of lactose.

The data obtained from quadratic regression analysis with BMI as an independent variable showed that both in Estonians and Russians the relationships between BMI and the consumption of some nutrients were parabolic. Parabolic relationships with the maximum points for zinc, niacin, calcium, riboflavin and phosphorus were found in Estonians. A parabolic relationship with the maximum point for SFA was found in Russians. The results of quadratic regression analysis were published by us previously in greater detail [10].

The set of dietary indices significant for BMI variance is shown in Table 3. Many relationships with BMI were parabolic: for SFA, vegetable protein, starch, alcohol with the maximum point, for niacin with the maximum point dislocated to the right; for animal protein and calcium with the minimum point; for lactose with the minimum point dislocated to the right. Besides, in some age-ethnic groups positive and negative relationships were found with energy intake, positive relationships with animal protein, fibre, thiamin, niacin consumption and negative relationships with P/S ratio, coffee and zinc consumption. The input of nutrients in BMI variance varied in different age-ethnic groups, nutrition explained from 0 to 33.7% of the variance.

Table 3. Set of significant variables for BMI variance (multiple regression analysis)

Age, years	20–39				40–54		
Variables	β-coefficient	p	R^2	Variables	β-coefficient	p	R^2
	Estonians (n=184)				Estonians (n=170)		
Intercept	18.91	–	–	Intercept	27.98	–	–
Age	0.141	<0.01	0.052	Vegetable protein, squared	–0.108	<0.001	0.030
Animal protein	0.198	<0.01	0.089	Thiamin	3.244	<0.05	0.055
				Energy	–0.169	<0.05	0.076
				Alcohol, squared	–0.011	<0.05	0.098
	Russians (n=233)				Russians (n=187)		
Intercept	22.06	–	–	Intercept	25.24	–	–
Age	0.076	<0.05	0.018	Coffee	–0.140	<0.05	0.022
				Animal protein, squared	0.007	<0.05	0.042
	Other ethnic origin (n=59)				Other ethnic origin (n=75)		
Intercept	21.63	–	–	Intercept	17.53	–	–
SFA, squared	–0.006	<0.01	0.102	Niacin	1.674	<0.01	0.095
Age	0.148	<0.05	0.177	Lactose, squared	0.198	<0.001	0.150
				Lactose	–1.263	<0.01	0.214
				Niacin, squared	–0.035	<0.05	0.257
				P/S	–5.171	<0.01	0.301
				Zinc	–0.967	<0.05	0.337
	Total population (n=476)				Total population (n=432)		
Intercept	20.50	–	–	Intercept	27.33	–	–
Age	0.131	0.0001	0.043	Starch, squared	–0.003	0.0001	0.027
Lactose, squared	0.018	<0.05	0.052	Fibre	0.197	<0.01	0.045
				Energy	0.103	<0.05	0.057
				Calcium, squared	0.000003	<0.05	0.066

DISCUSSION

The mean values of BMI and the prevalence of overweight in the male population of Tallinn aged from 20 to 54 in the mid-1980s were rather high, although they were lower than those in Northern European countries [16].

The nutrition of the population was described by us previously [12]. It was characterised by high energy intake, high consumption of animal protein, fat, dietary cholesterol, low P/S ratio, low intake of carbohydrates, starch, fibres, high coffee intake, deficiency of all micronutrients, except niacin.

As the population is ethnically heterogeneous and there are significant differences between BMI mean values, as well as dietary patterns in Estonians and Russians [12, 13], the data were analysed in ethnic subgroups.

Most relationships found by quantile analysis contradict the relationships found in animal-experimental and clinical research [1, 7]: negative relationships between BMI and energy intake, sugar, starch consumption, positive relationships with P/S ratio and PUFA consumption. In most groups no relationships were found at all. This finding coincides with the fact that well-known relationships between nutrition and body mass often fail to be confirmed in cross-sectional epidemiological studies, especially carried out on intra-national level in economically advanced countries with a high prevalence of overweight and a Western food consumption pattern [3, 8]. Usually it has been explained by both the inaccuracies of the methods and close relations between many nutrients [1, 3, 6, 8]. Trying to understand the relationships found, we classified them into 3 groups:

1. Relationships corresponding with those found in experimental studies.
2. Relationships contradicting those found in experimental studies.
3. Relationships with the same nutrient, diversely directed in different age-ethnic groups.

Group 1 includes the negative relationships with vegetable fat in the population aged 20–54, with vegetable protein in Estonians aged 20–54 and the positive relationship with animal protein found in Estonians, Russians and in the population aged 20–54 [1, 7]. Group 2 comprises the negative relationships with energy, sucrose and starch intake, found in different age-ethnic groups [1]. Group 3 involves relationships found with P/S ratio and PUFA consumption. The relationship with P/S ratio is negative in Russians aged 40–54, which corresponds to experimental data [1, 7], and positive in Estonians aged 20–39. The relationship with PUFA ratio is negative in the total population aged 40–54, which agrees with experimental data [1, 7], and positive in Estonians aged 20–39 and 20–54, and in the total population aged 20–39.

Taking into account that these relationships were obtained comparing the proportion of people with overweight in the upper and lower quantiles of nutrients distribution curves, it is logical to hypothesise that the obtained contradictions depend on the changes in nutrition that have taken place. It seems to be logical because the people with overweight are usually the main target for healthy lifestyle counselling. In comparison with the rest of the population, people with overweight are strongly motivated to improve their dietary habits [14]. It is known that usually some of them decrease the caloric value of their diet, consume less animal fat (this means a decrease in SFA consumption), sugar, bakery products (this means a decrease in starch consumption) and more vegetable oil (this means an increase in PUFA consumption), but they rarely achieve a normal weight. When analysed from this point of view, the obtained relationships seem to correspond to the real situation. In the population a part of people with overweight has changed their diet, but not all of them, and this explains the relationships in groups 1 and 2. This explains not only why the relationships are not found in all groups but also the lack of any relationship with SFA consumption: it depends on the degree of changes in the diet.

Some conclusions can be made about the degree of changes in dietary patterns by people with overweight of various age and ethnic origin: the overweight individuals aged 40–54 of both ethnic groups are more conservative, Estonians aged 20–39 seem to be the most flexible. Obviously, it depends on the traditional dietary pattern, motivation, and awareness of healthy lifestyle. The information concerning healthy nutrition is now widely available. Elsewhere we have shown the high awareness of healthy lifestyle in our population [14].

Hence, an assumption was made that the relationships between nutrition and BMI and between nutrition and age in the population are not linear but parabolic. The data obtained by regression analysis confirmed our hypothesis about the parabolic relationships between BMI and the consumption of some nutrients both in Estonians and Russians. They also confirmed the existence of parabolic relationships between age and the consumption of some nutrients with minimum and maximum points around the age of 40. This is logical as, in comparison with the entire population, the people of older age are more motivated to improve their diet.

Thus, the relationships between BMI and nutrition, between age and nutrition in the population are parabolic, and reflect not only the real relationships but also the changes in diet depending on people's awareness of healthy lifestyle and their motivation to improve their diet.

In order to avoid quadratic regression analysis in many small groups, multiple regression analysis was performed, including nutrients and age also in a squared form. The obtained data confirmed the parabolic nature of the relationships between BMI and nutrition in the population. The input of diet as a whole in the variance of BMI is rather small and varies in different groups. As parabolic relationships are not revealed in all the groups (a linear relationship is considered as a particular case of a parabolic relationship), it is logical to suppose that the changes in the diet of the rest of the population are more complex. Our data show that a part of the population at the age around 40 and older has changed their dietary patterns as well. Besides, a positive relationship with sugar consumption was not revealed in our population. Obviously, it could be explained by the fact that changes in sugar consumption are often observed in people of younger age and with normal weight.

Thus, our hypothesis concerning nutrition changes in a part of the population was confirmed by the data of quadratic regression analysis. Therefore, discussing the results of multiple regression analysis, the coincidence of the obtained relationships with experimental data was the main criterion for deciding whether a relationship is real or it reflects the changes in nutrition. If an obtained relationship was not confirmed by experimental data, we left the question open, as this relationship could depend on mutual relations between some nutrients [7] or reflect the changes in nutrition.

The positive relationships with BMI found for energy intake, SFA, starch, animal protein, alcohol, negative relationship for vegetable protein and P/S ratio are confirmed by experimental data [1, 7].

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ANTHROPOMETRIC METHOD IN EVALUATION OF INDIVIDUAL PHYSICAL ABILITIES IN YOUNG FEMALE VOLLEYBALL PLAYERS

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ABSTRACT

The anthropometric variables had statistically significant correlations between themselves and with height and weight. The latter were the leading characteristics of the system, determining, together with age, 17–90% of the variability of all the other characteristics. As for the tests of physical ability, 6 out of 8 were also in significant mutual correlation. As the tests of physical abilities were also connected with a many anthropometric variables, it proved possible to predict from age and anthropometric characteristics the results of tests PA_1–PA_4, PA_7 and PA_8 within the range of 64–97%.

Anthropometric variables as well as the results of physical ability tests can be classified into five SD classes whereas a distinction can be made between height-weight concordance classes (1 — small, 2 — medium, 3 — big) and disconcordance classes (small height, big weight — pycnomorphous; big height, small weight — leptomorphous). The terms pycnomorphous and leptomorphous were used because these classes also include the pure somatotypes, and, according to our data, the body build of pure somatotypes is also based on different relations between height and weight.

Key words: body structure of young female volleyballers, physical ability tests, anthropometric measurements.

INTRODUCTION

There is no doubt that girls' technical skills in volleyball are essentially determined by their age, body build and physical ability [1, 2, 4, 5, 11, 13, 15, 21]. Still, until now, the studies of the players' body build have laid emphasis on a few most essential measurements and characteristics of body composition only. Thus, height and weight [14], height, weight and lean body mass [6], fat skinfolds [19], weight, thigh and arm circumferences and estimation of body fat content on the basis of skinfolds [7] have been applied.

However, there are no references to extensive application of individual anthropometric measurements, indices and body composition characteristics in this kind of studies. It is not clear either which system of somatotyping should be used for systematising the data of girls' body build. Only the Heath-Carter scheme has been used [3, 22].

Considering what has been said above, the authors of the present paper try to analyse the results of detailed anthropometric measuring of girl volleyballers and to develop a method for applying and systematising all kinds of body measurements in investigations of girls' physical abilities.

MATERIAL AND METHODS

The sample consisted of members of five volleyball teams from different regions of Estonia. The total number of players was 49. All of them practised regularly and participated in annual all-Estonian competitions. The age of the subjects ranged from 13 to 16 years; the average age was 14.43 years. All of them were practically healthy and their sexual development was in concordance with their age.

All the girls underwent detailed anthropometric measuring according to the classical method of Martin [16]. Thirty basic measurements and 12 skinfolds were taken. On the basis of these we calculated 65 indices and characteristics of body composition. While analysing the anthropometric data, we relied on the results of body structure studies carried out at the Centre for Physical Anthropology at the University of Tartu [8, 9, 12, 17, 18].

In order to evaluate the girls' general physical fitness, the following generally recognised tests were used: highest reach of the player's outstretched hand (PA_1), test of standing vertical jump and reach (PA_2) and test of running vertical jump and reach (PA_3). Two Eurofit tests were used — endurance test (PA_4) and stomach muscles strength test (PA_5). We added to these a test of flexibility from a sitting position (PA_6), a test of speed (zigzag run touching medicine balls) (PA_7) and a medicine ball throwing test (PA_8) — a 4-kg medicine ball is thrown from behind one's back in a sitting position with outstretched legs

Statistical analysis of the data by the method of multivariate statistical analysis was carried out by one of the authors of the paper — Säde Koskel, M.Sc. from the Institute of Mathematical Statistics at the University of Tartu.

RESULTS

The mean age of the players was 14.4 years. Their mean height was 166.2±5.9 cm, mean weight 55.7±5.9 kg and mean BMI 20.1±2.5.

The analysis of anthropometric data showed that all single characteristics and indices were in mutual statistically significant correlation having the strongest correlation with height and weight. The leading characteristics were height and weight, and together with age they determined 17–90% of the variability of all the other characteristics.

Out of the eight tests of physical abilities the following six were statistically significantly intercorrelated: highest reach of the player's outstretched hand (PA_1), test of vertical jump and reach (PA_2), test of running vertical jump and reach (PA_3), endurance test (PA_4), speed test (PA_7) and medicine ball throwing test (PA_8).

The tests of physical abilities correlated with a number of anthropometric characteristics. To give a summary evaluation of the influence of all the anthropometric variables on test results, we used linear regression analysis. We predicted test results on the basis of age and several combinations of anthropometric characteristics which were in statistically significant correlation with the tests. It is possible to determine anthropometrically up to 96.6% of the variability of PA_1, 89.6% of PA_2, 87.5% of PA_3, 63.7% of PA_4, 9.9% of PA_5, 71.5% of PA_7, 66.4% of PA_8.

As we have to do with a constitutional system, then, in addition to regression analysis, the connection between body build and physical ability tests can also be demonstrated on the basis of the height-weight

5SD classification introduced by us (see Fig. 1). The classifiation has been described in literature earlier [17, 18]. We distinguish between classes of height-weight concordance — (1) small height and weight, (2) medium height and weight, (3) big height and weight — and classes with height-weight disconcordance — (4) small height, big weight (pycnomorphous) and (5) big height, small weight (leptomorphous girls). We used the terms 'pycnomorphous' and 'leptomorphous' because these groups also include pure somatotypes, and, according to our data, the body build of pure somatotypes is also based on relations between height and weight.

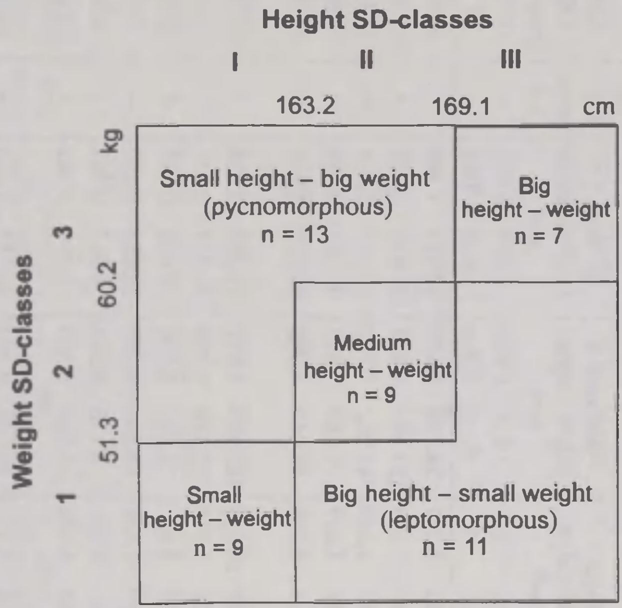

Figure 1. Classification of girls volleyballers according to 5 height/weight classes (n = 49).
Middle row and column are one SD wide (mean ±SD), other ones contain values outside those SD limits.

For height-weight classes we calculated the mean values and SD of the anthropometric data and test results of the 49 girls (see Table 1). The most essential anthropometric data have been presented in Table 2. The significance of differences was calculated by Scheffe test.

Table 1. Anthropometric measurements, body composition indices and physical performance tests of young female volleyball players in height-weight classification (n=49)

No	Variable	1 Small height-weight n=9		2 Medium height-weigth n=9		3 Big height-weight n=6		Sig-nifi-cance 1–3	4 Small height-big weight (pycnomorphous) n=13		5 Big height-small weight (leptomorphous) n=12		Sig-nifi-cance 4–5
		x̄	SD	x̄	SD	x̄	SD		x̄	SD	x̄	SD	
1.	Weight (kg)	42.522	3.765	54.089	2.486	68.575	7.160	+	60.869	7.413	53.525	5.015	+
2.	Height (cm)	158.46	3.107	167.144	1.209	174.517	3.622	+	163.754	3.155	169.617	4.666	+
3.	Trunk length	45.533	1.380	49.622	1.782	52.167	2.339	+	52.169	7.181	50.517	6.302	–
4.	Upper limb length	68.956	3.839	73.389	3.032	76.183	4.031	+	71.108	2.808	74.450	3.393	–
5.	Lower limb length	83.544	4.809	89.067	1.980	93.300	1.933	+	84.192	5.636	91.150	4.166	+
6.	Horizontal arms spread	161.722	10.832	168.956	3.877	175.500	5.655	+	163.315	6.384	170.425	6.662	+
7.	Biacromial breadth	33.556	1.648	35.389	0.928	36.333	2.338	+	35.615	1.446	35.250	1.390	–
8.	Femur breadth	8.078	0.463	8.644	0.364	9.050	0.677	+	8.900	0.488	8.758	0.425	–
9.	Ankle breadth	6.500	0.436	6.556	0.503	7.033	0.659	–	7.008	0.352	7.042	0.287	–
10.	Humerus breadth	5.967	0.381	6.178	0.282	6.567	0.367	+	6.100	0.406	6.250	0.384	–
11.	Wrist breadth	4.767	0.304	5.000	0.245	5.200	0.283	+	5.100	0.224	5.217	0.208	–
12.	Upper chest circumference	76.178	2.575	80.100	2.397	86.183	3.016	+	85.292	4.501	78.342	2.607	+
13.	Waist circumference	63.211	3.061	65.889	2.419	74.883	6.701	+	70.700	5.041	64.883	2.463	+

No	Variable	1 Small height-weight n=9		2 Medium height-weigth n=9		3 Big height-weight n=6		Sig-nifi-cance 1–3	4 Small height-big weight (pycnomorphous) n=13		5 Big height-small weight (leptomorphous) n=12		Sig-nifi-cance 4–5
		x̄	SD	x̄	SD	x̄	SD		x̄	SD	x̄	SD	
14.	Upper thigh circumference	47.689	4.389	55.067	2.005	59.600	8.003	+	59.031	3.209	53.175	3.619	+
15.	Upper leg circumference	30.689	1.110	33.556	1.853	37.200	2.338	+	35.608	2.122	33.633	1.901	+
16.	Lower leg circumference	19.978	1.053	21.244	0.590	23.950	0.838	+	22.708	1.030	22.433	1.341	–
17.	Arms circumference	21.989	1.692	24.333	1.025	27.133	2.089	+	26.877	1.515	23.708	1.294	+
18.	Forearm circumference	20.300	1.010	21.633	0.671	24.050	1.492	+	23.669	1.069	22.083	0.852	+
19.	Wrist circumference	14.567	0.636	15.289	0.668	16.583	0.776	+	16.215	0.800	15.775	0.645	–
20.	mean skinfold (mm)	8.06	1.74	10.14	1.90	13.75	2.84	+	13.26	2.77	8.59	1.99	+
21.	Body density (g/cm^3)	1.060	0.010	1.054	0.008	1.054	0.009	–	1.054	0.008	1.062	0.005	+
22.	Mass of subcutaneous adipose tissue (kg)	10.41	2.21	13.54	2.55	18.44	3.60	+	18.92	4.06	11.60	3.52	+
23.	Body mass index	17.72	1.20	19.36	0.87	22.47	1.50	+	22.66	2.36	18.57	1.13	+
24.	Relat. femur breadth	5.10	0.28	5.17	0.240	5.19	0.39	–	5.44	0.31	5.17	0.25	+
25.	Relat. ankle breadth	4.10	0.25	3.92	0.31	4.03	0.35	–	4.28	0.20	4.15	0.127	–
26.	Relat. wrist breadth	3.01	0.18	2.99	0.16	2.98	0.19	–	3.12	0.13	3.08	0.14	–

Table 2. Physical ability tests

No	Variable	1 Small height-weight n=9		2 Medium height-weigth n=9		3 Big height-weight n=6		Significance 1–2–3	4 Small height-big weight (pycnomorphous) n=13		5 Big height-small weight (leptomorphous) n=12		Significance 4–5
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
1.	Highest reach of player's outstretched hand (cm) PA_1	211.42	8.22	218.63	4.03	229.40	4.39	+	214.00	5.48	220.55	7.13	+
2.	Standing vertical jump and reach (cm) PA_2	246.33	9.40	254.00	6.0	2.66	3.32	+	248.27	9.26	258.64	7.51	+
3.	Running vertical jump and reach (cm) PA_3	251.08	10.04	257.25	7.09	270.00	8.22	+	253.27	9.24	261.18	7.22	+
4.	Endurance shuttle run (sec) PA_4	427.08	68.94	356.63	78.03	337.40	129.22	–	369.27	87.59	386.55	65.33	–
5.	Stomach muscles strength test (sec) PA_5	154.42	31.49	169.13	60.41	160.60	47.74	–	160.64	79.03	189.73	65.28	–
6.	Flexibility test (cm) PA_6	15.92	6.00	19.50	5.58	16.80	10.69	–	16.91	6.32	13.14	3.96	–
7.	Speed shuttle run (sec) PA_7	28.09	1.03	27.80	1.59	27.94	1.36	–	28.36	1.89	26.97	1.03	+
8.	Medicine ball throwing test (cm) PA_8	272.50	37.45	295.00	35.76	326.00	63.48	–	309.09	38.07	300.46	46.01	–

In classes 1–3 we could observe a gradual increase in all anthropometric data, such as length measurements, breadth-depth measurements, circumferences, bone thicknesses of extremities, all skinfolds, mass of subcutaneous adipose tissue and body mass index. A decrease occurred in body density. The proportions of parts of skeleton to height did not change.

Classes 4 and 5 demonstrated the differences between pycnomorphous and leptomorphous subjects that are well known in anthropology.

As compared to leptomorphous girls, pycnomorphous girls had bigger body mass index, smaller body density, bigger mean skinfold, bigger mass of subcutaneous adipose tissue and relatively bigger breadth-depth measurements and circumferences.

The results of physical ability tests were placed into the same classification.

In physical ability tests there were essential differences between classes 1–3 and 4–5 in highest reach of the player's outstretched hand (PA_1), in jump tests (PA_2 and PA_3). Essential differences also appeared between classes 4 and 5 in the speed test (PA_7).

The results of the medicine ball throwing test also differed between classes 1–3, but these differences were statistically insignificant.

DISCUSSION

The conclusions of our present and previous [20] studies as well as the results of several other authors [2, 6, 7, 13] show that the results of a great number of physical ability tests are in correlation with body build. According to our findings, it is possible to predict on the basis of single anthropometric variables and body composition characteristics the results of the tests to a significant extent.

The results of our study indicate that in the future we should apply anthropometric data to a greater degree than before for the comparison of girls' physical abilities.

Due to the regularities of body build structure it is possible to use different anthropometric characteristics. However, if we want to assess the whole body status together with a great number of anthropometric data, we could base our study on a five-class system of height and weight. As far as we have no generally accepted classification of constitutional types, this kind of system enables us to differentiate objectively between the most essential aspects of body build.

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MULTIPLE ORGAN DISSEMINATION OF BACTERIA IN EXPERIMENTAL SEPSIS

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ABSTRACT

The focus of sepsis is often difficult to identify. To find possible microscopical foci of sepsis, dissemination of bacteria into different tissues was assessed in a rat model of intraperitoneal sepsis. 20 Wistar rats were inoculated intraperitoneally with a suspension of *E. coli* together with 2.5 cm^3 of hemolysed human red blood cells: group 1 (5 rats): 2.5 cm^3, group 2 (10 rats): 1 cm^3, group 3 (control) 2.5 cm^3. The rats died or were executed. Blood cultures and tissue sections from different organs were semiquantitatively assessed for the presence and count of bacteria.

All the tissues of septic rats were contaminated with large numbers of bacteria. The amount of bacteria in the tissues was larger than that in the blood. Nonsurvivors had significantly higher count of bacteria than survivors.

Conclusions: Experimental sepsis presents itself with disseminated bacterial microfoci in all organs. The rates of bacterial multiplication or clearance are different in the blood and tissues in survivors. The larger amount of bacteria in tissues is associated with adverse outcome.

Key words: bacteraemia, morphology, rat, septic shock, SIRS.

INTRODUCTION

Despite extensive experimental and clinical research, the mortality of severe sepsis and septic shock still remains between 20 and 46% [1]. Sepsis is defined as systemic inflammatory response syndrome (SIRS) due to infection [2]. A new theory of sepsis in addition to the well-known SIRS incorporates compensatory anti-inflammatory response and immunologic imbalance [3, 4]. In the conditions of inadequate host defences infection control might become determinative of the course and outcome of sepsis. Despite adequate antibiotics and supportive measures sepsis often fails to respond to therapy. The reasons of this are not very clearly understood. It is known that in about 30% of bacteraemic patients no focus of infection can be identified [5]. The presence of bacteraemia has been used as an indicator of generalised infection. Still, blood cultures are often negative in septic patients. In a recent multicentre study bacteraemia was found in only 28% of patients with a sepsis syndrome [6]. The question of septic focus arises again. Where do the bacteria reside and multiply if no macroscopic focus can be identified? In literature there are few data about the spread of bacteria and their possible invasion into different tissues of the host.

The aim of the study was to investigate invasion of bacteria into different tissues in severe experimental sepsis with bacteraemia. To assess more exactly the location of bacteria in the tissues, histological methods were used.

MATERIALS AND METHODS

Experimental animals

Twenty white Wistar rats, weighing 220–270 g were divided into 3 groups:

To group 1 (5 rats) 2.5 cm^3 of live E. coli suspension (approximately 1.5×10^8 bacteria per cm^3) together with 2.5 cm^3 of hemolysed human red blood cells was injected intraperitoneally. All the rats of this group died during the first 24 hours.

Group 2 (10 rats) received intraperitoneally 1 cm^3 of the same suspension together with 2.5 cm^3 of hemolysed human red blood cells. The group was divided into 2 subgroups: 2^A (4 rats) were sacrificed by decapitation on the second day of the experiment, and 2^B (5 rats) were sacrificed on the fifth day of the experiment. One of the rats of group 2^A died on the second day of the experiment.

Group 3 (5 rats) received intraperitoneally 2.5 cm^3 of hemolysed human red blood cells and served as controls. The rats of this group were sacrificed on the second day of the experiment.

Microbiological methods

The bacterial strain was isolated from the urine of patients with acute pyelonephritis. To reach maximal bacterial virulence, the following procedure was used: the strain was isolated from a single colony grown on McConkey agar plate and identified by means of conventional methods for Enterobacteriaceae [7]. A suspension of 3×10^9 bacteria per cm^3 (10 McFarland turbidity standard) was prepared and together with 2 cm^3 of hemolysed human erythrocytes injected intraperitoneally to a healthy rat. On the fifth day the rat was sacrificed by decapitation, blood from the heart was taken using the aseptical technique, and spread on Endo agar plates. The culture was obtained after 24 hours of incubation at 37 °C. A suspension of 1.5×10^8 bacteria per cm^3 was prepared and injected to rats as described above.

Morphological methods

Autopsy of the dead and sacrificed animals was performed immediately after death, using the aseptical technique. Cultures of peritoneal fluid and blood from the hearts of the rats of the second and third groups in nutrient broth and semiquantitative cultures of blood on Endo agar plates were made. Cultures were not obtained from the rats of the first group. Samples for histological investigation were randomly taken from the lungs, heart, spleen, pancreas, liver, suprarenals, kidneys, stomach, small and large intestine, muscle and brain of all the animals. For histological evaluation the tissue samples were fixed in 10% buffered formalin and embedded into paraffin. Sections of 7 micrometer were cut. Staining of bacteria in tissue samples was carried out according to the method of Gram, modified by Brown and Hopps [8]. All the investigations were carried out with the light microscope from Ceti, model Topic (Belgium), using the oil immersion technique by magnification ×1000.

The amount of bacteria was estimated semiquantitatively, whereas a numerical score, the Contamination Index (CI) was applied:

grade 0 — no bacteria anywhere;
grade 1 — 1–5 bacteria found in any field of view;
grade 2 — 3–10 bacteria found in any field of view, isolated or as a cluster;
grade 3 — 1–2 or more clusters of bacteria found in any field of view, 25 or more bacteria in each.

The histopathological samples were coded and examined blind in order to overcome experimental bias.

For rough estimation of the number of bacteria in a tissue volume the number of bacteria in 20 quadrates ($100\mu m^2$ each) per each field of view was counted. Twenty fields of view (400 quadrates) were counted in every section. The volume of tissue per which the number of bacteria was counted was $7\mu m \times 100\mu m^2 \times 400 = 2{,}8 \times 10^{-7}\ cm^3$. The approximate number of bacteria per tissue cm^3 was calculated according to the following formula:

No. of bacteria / volume of tissue cm^3 = No. of bacteria per tissue cm^3.

Twenty-three slides with different estimated CI were counted.

Statistical methods

Due to the abnormal distribution of data, Kruskall-Wallis test was used for comparisons between multiple groups, and for comparison between two groups Mann-Whitney U-test was used. The relationship between variables was determined by Spearman Rank Order correlation. Statistical significance was defined as $p \leq 0.05$.

The study protocol was approved by the Ethics Committee of the University of Tartu.

RESULTS

All the 5 rats of group 1 died within 24 hours after inoculation. One of the rats of group 2^A died on the second day of the experiment.

On autopsy no macroscopical evidence of peritonitis or abscesses in peritoneal cavity were found in either the control or in the study groups. The blood and peritoneal fluid cultures of the control group were negative. All the cultures were positive in all the animals of the second group, showing growth of E. coli. The quantitative count of bacteria in blood cultures was $>10^2 <10^3$ bacteria per cm^3 of blood in all the sacrificed animals, but 10^8 bacteria per cm^3 in the rat which died on the second day of the experiment.

The results of microscopical investigation are given in Table 1. No bacteria were found in any of the organs of control animals. As can be seen from Table 1, almost all organs of the rats of the experimental groups contained bacteria. The bacteria were located mostly in the capillaries and interstitially but were also found inside macrophages and parenchymal cells (Fig. 1). In several cases a cluster of bacteria was seen in a capillary (Fig. 2).

Table 1. Results of histological examination of tissue samples of rats of groups 1 and 2.

Organ	CI															Mean
	Group 1 (n=5)					Group 2^A (n=5)					Group 2^B (n=5)					
Lung	3	3	2	2	1	2	2	2	2	1	1	2	1	2	0	1.4
Heart	3	na	1	2	na	2	2	2	1	2	2	2	na	2	1	1.3
Spleen	2	3	1	1	2	na	na	2	1	3	1	1	2	0	0	1.1
Pancreas	na	na	3	1	na	2	1	2	2	1	2	na	1	1	1	1.1
Liver	3	2	1	1	3	1	1	1	1	1	1	2	0	2	1	1.1
Adrenals	2	2	na	na	1	1	1	0	1	1	na	na	1	1	0	0.7
Kidney	2	3	2	2	2	3	2	2	1	1	2	1	1	1	1	1.3
Brain	3	3	1	2	3	1	0	1	1	1	0	0	0	1	1	0.9
Stomach	2	2	1	1	2	3	2	1	2	na	1	0	0	na	2	1.1
Ileum	1	2	2	1	2	1	0	1	1	1	0	1	1	1	2	0.9
Caecum	2	2	1	2	1	1	2	2	1	na	2	2	1	1	1	1.1
Muscle	2	2	1	na	2	na	1	2	1	na	1	na	1	1	1	0.9
Mean	**2.2**	**2.4**	**1.5**	**1.5**	**1.9**	**1.7**	**1.3**	**1.5**	**1.3**	**1.3**	**1.2**	**1.2**	**0.8**	**1.2**	**0.9**	

CI – contamination index; M — mean; na — not available.

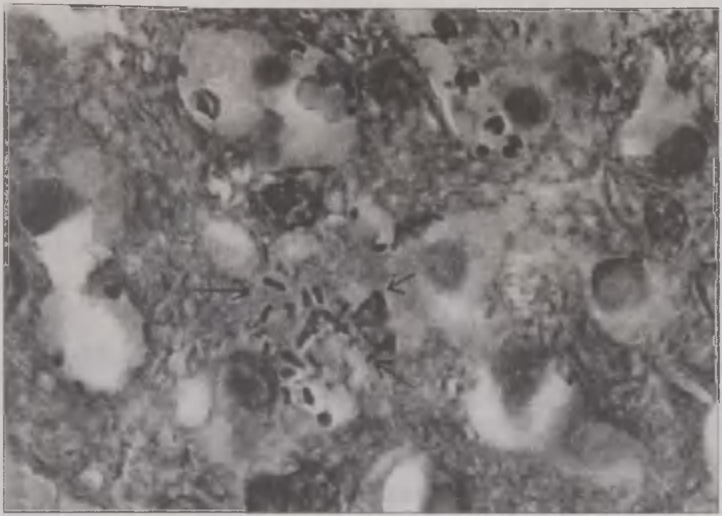

Figure 1. Light micrograph of a liver. A cluster of bacteria in the wall of a sinusoid, in the perivascular space and in a hepatocyte (modified Gram's ×1000).

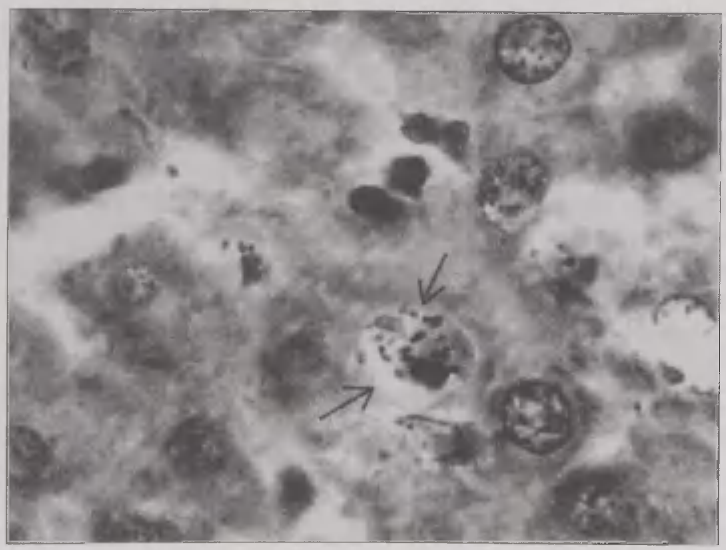

Figure 2. Light micrograph of a liver. A cluster of bacteria almost filling the lumen of a blood vessel (modified Gram's × 1000).

The calculated number of bacteria varied between 1.8×10^8 and 1.8×10^9.

In 14 organs of altogether 7 rats of the second group bacteria were not found. No influx of inflammatory cells was seen in the examined tissues.

The total mean CI of all organs was significantly different between groups ($p<0.05$). The total mean CI of the rats who died was significantly higher than of those, who were executed. ($p<0.01$). Significant negative correlation was found between the total mean CI and duration of sepsis (Fig. 3).

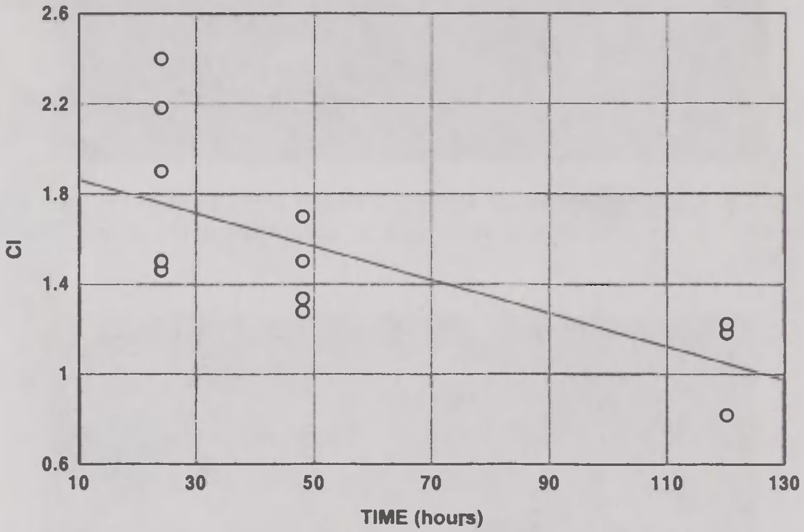

Figure 3. Correlation between the total mean CI and duration of sepsis ($r = -0.88$, $p<0.01$).

The mean CI of the lung, heart and kidney was significantly higher than the mean CI of the suprarenals, brain and ileum.

DISCUSSION

In the study intraperitoneal inoculation of rats with E. coli resulted in contamination of all the investigated organs of the animals with the bacteria. In a previous study [9], when looking for microscopical foci of sepsis in autopsy material, we found invasion of cocci into different organs of two septic patients Bacterial invasion to the brain has also been proposed as a cause of septic encephalopathy [10]. Thus formation of septic microfoci in all tissues is possible in severe sepsis.

The study was designed to ensure maximal generalisation of infection, therefore hemolysed human red blood cells were added to the inoculum of bacteria. Hemoglobin is known to inhibit bacterial clearance from the peritoneal cavity by inhibiting the influx of polymorphonuclear leucocytes into the peritoneal cavity in response to bacterial challenge [11]. Thus the organisms are relieved of the first antibacterial defence and are permitted uncontrollable multiplication and invasion to the circulation. This might also explain the absence of macroscopical evidence of peritonitis and abscesses in the peritoneal cavity.

E. coli were found in all the investigated organs of the experimental animals. No bacteria were found only in occasional organs of five rats of the second group. In our opinion the most probable explanation for this is that due to their small number bacteria could not be seen in the investigated sections.

The bacteria were located mostly intravascularly and in the interstitial space, but also in macrophages, as well as in parenchymal cells. The estimated number of bacteria was very large, suggesting that the bacteria must have multiplied very rapidly in the tissues. A discrepancy between the bacterial count in the blood ($>10^2 <10^3$ bacteria per cm^3) and in the tissues (10^8–10^9 bacteria per cm^3) was seen in survivors, whereas the rats who died had similar values of the blood and tissue bacterial content (10^8 bacteria per cm^3). This suggests different rates of bacterial multiplication or clearance in the blood and in the tissues, which is also dependent on the individual reaction of the host. Other investigators have reached similar results [12]. This difference in the count of bacteria in the blood and in the tissues is most probably caused by disturbances in microcirculation. In severe sepsis due to various reasons capillary vascular stasis and plugging of microvessels with "sludge" occurs [13]. In the sites of obstruction or very slow blood flow, deficiency of phagocytosis and uncontrolled bacterial growth may be present [14]. Our finding of bacterial clusters in capillaries supports this proposal. It must have taken hours of stasis in microcirculation to enable bacteria to multiply to that amount. Besides, there are different mechanisms of bacterial clearance in the blood and in the tissues. In the serum humoral factors, e. g. the complement system, are more important, while in tissues cellular mechanisms, mostly macrophages are responsible for killing of bacteria [15].

In the study the low bacterial clearance rate in tissues might be due to low macrophageal activity, as no macrophageal reaction was seen around the bacteria in tissues. This finding is contradictory to the common idea of generalised and massive activation of macrophages in sepsis [16, 17]. But late evidence has suggested that after an early activation of macrophages a generalised state of macrophage dysfunction or hyporesponsiveness may develop within 24 hours after the septic insult [18].

Differences between the mean CI of different organs are difficult to explain. Increase of blood flow and endothelial permeability in the kidney, liver and heart has been shown to occur in abdominal sepsis [19]. We found higher CI in the heart and kidney but also in the lung. Probably, the conditions of elevated tissue blood content and increased albumin influx that lead to formation of protein rich oedema [19] might be suitable for bacterial invasion and multiplication. Of course, there could be other mechanisms adding to the differences of bacterial content between different organs as well.

Significant negative correlation was found between the duration of sepsis and the total CI of all organs, suggesting that those animals who survive the first acute phase gradually clear the bacteria out of the tissues.

The total mean CI of the first group was not significantly higher of the mean CI of the 2^{A} group, although the inoculum of bacteria was bigger in the first group. In the first group all the rats died, while only one rat died in the second group. This rat's mean values of CI were comparable to the rats of the first group. The size of inoculum is known to influence the outcome [12]. Still, individual reaction seems to play an important role as well. The fact, that the total mean CI of the rats who died was significantly higher than of those who were sacrificed is strongly suggestive of the fact that, despite the size of inoculum, the amount of bacteria in the tissues influences the outcome.

In conclusion: Experimental sepsis presents itself with disseminated bacterial microfoci in all organs. The number of bacteria per tissue volume may be very large, showing rapid invasion and multiplication of the bacteria in the tissues of the host. The rates of bacterial multiplication or clearance are different in the blood and tissues in survivors. The larger amount of bacteria in tissues is associated with adverse outcome.

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BODY MASS INDEX AND ALL-CAUSE MORTALITY: AN 11-YEARS FOLLOW-UP STUDY OF MIDDLE-AGED MEN RESIDING IN TALLINN, ESTONIA

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ABSTRACT

Assessment of the relationship between body mass index (BMI) and all-cause mortality in middle-aged male population of Tallinn, Estonia and identification of BMI values associated with minimum mortality. Two epidemiological studies of CVD risk factors involving independent random samples of the male population of Tallinn aged from 30 to 59 years (n = 4,070) were carried out in 1981/82 and 1984/85. Both cohorts were followed for 11 years on average; pooled data were used in this analysis. During the follow-up period 457 death cases were registered. The significance of the body mass index (BMI) for all-cause mortality was tested by means of quintile analysis, by the Cox proportional hazards regression model and by the Health Index constructed using survival analysis with SAS procedures. Mortality rates according to quintiles of BMI showed a U-shaped curve with a tendency for higher mortality rates in the bottom quintile and a minimum mortality in the range of 26.7–28.9 kg/m^2 (IV quintile). By means of the Cox proportional hazards regression model with BMI and BMI^2 we found that BMI was quadratically related to total mortality with an even higher minimum (at 31.0 kg/m^2). The significance of 20 other variables for prediction of total mortality was also tested and significant ($p<0.05$) variables were included into the constructed Health Index. BMI together with BMI^2 were found statistically significant ($P<0.01$). Other variables selected as statistically significant were: systolic blood pressure, heart rate, coronary heart disease status ($P<0.0001$), total cholesterol (TC), TC^2, education, smoking, alcohol consumption ($P<0.01$), marital status ($P<0.05$). We found a U-shaped relationship between BMI and all-cause mortality with a relatively high BMI associated with minimum mortality. This finding has an implication for public health.

Key words: body mass index, mortality, follow-up study, male population.

INTRODUCTION

Numerous studies have shown a U- or J-shaped association between body mass index (BMI) and all-cause mortality both in men and women [1, 2, 8, 9, 10, 13, 17, 21, 26], while some others have documented a linear relationship, either positive [7, 12, 19] or negative [3, 6, 11].

The inconsistency of these findings has been explained by interactions of BMI with smoking, pre-existing illnesses, ethnicity, education [3, 19]. Other studies have not confirmed this opinion [8, 9, 18].

The aim of this study was to assess the relationship between BMI and all-cause mortality in the middle-aged male population of Tallinn, Estonia, and to identify the BMI values associated with minimum mortality.

MATERIALS AND METHODS

Two independent random samples of the free-living male population of Tallinn aged from 30 to 59 years were drawn from the lists of electors and examined using standard epidemiological methods in 1981/1982 (the first cohort) and in 1984/1985 (the second cohort).

At both surveys the screening procedure included blood pressure, heart rate, weight and height measurements, determination of total cholesterol (TC), triglycerides (Tg) and high density lipoprotein cholesterol (HDLC), ECG at rest classified according to the Minnesota Code. The questionnaire included data on smoking, alcohol consumption, education, occupation, ethnic origin, marital status; the Rose questionnaire was used for the determination of angina on effort [14]. The screening procedure has been described by us in greater detail elsewhere [24, 25]. Measurements were performed by the same team, which underwent a similar training and standardisation procedure at both surveys. Body weight and height were measured according to the protocol of the Countrywide Integrated Non-communicable Disease Intervention Program (CINDI) coordinated by the WHO Regional Office for Europe [4]. BMI was calculated as body weight, kg /(body height, m)^2.

The first cohort of men (2,177 participants, participation rate 70.2%) was followed for 12 years on average (26,292 person-years). The second cohort (1,833 men, participation rate 72.2%) was followed for 9.8 years (18,586 person-years); thus, 4,070 men in total were followed for 11 years on average (44,878 person-years). During the follow-up period the endpoints (all deaths) of men born in the corresponding years were registered at the Registry Office every month, and the death cases of the participants were identified according to these data. The vital status of the rest of the cohort was also verified by the end of the follow-up period at the Address Office and/or by personal contact by mail. 457 death cases were registered, and the causes of death were verified by an expert committee according to death certificates and medical records by means of WHO criteria [20]. Death causes were classified according to ICD-IX criteria. 39.7% of deaths in the first cohort and 47.0% in the second cohort were due to cardiovascular disease, 24.7% and 20.0%, respectively, to oncological diseases, 19.3% and 19.4% to external causes and 16.3% and 21.7% to other causes.

The relationship between the BMI and all-cause mortality was studied by means of quintile analysis: the age-adjusted mortality rates were analysed in five equal parts (quintiles) of the sample distribution according to BMI values (I quintile<23.0 kg/m^2; II quintile 23.0–24.9 kg/m^2; III quintile 25.0–26.6 kg/m^2; IV quintile 26.7–28.9 kg/m^2; V quintile ≥29.0 kg/m^2).

Other variables tested in this analysis were: coronary heart disease (CHD) status at entry, systolic and diastolic blood pressure (SBP, DBP), TC, Tg, HDLC, low density lipoprotein cholesterol, smoking status, number of cigarettes smoked daily, education, occupation, ethnicity, marital status, alcohol consumption habitually and during the last week.

The Cox proportional hazards regression model [5] was used to determine the predictive power of the analysed variables. The entry of the variables into the Cox model is reflected by the Wald Chi Square, which is calculated as:

$$ß_{stand}{}^2 = ß/(SE_ß)^2,$$

where ß is the regression coefficient in the model for a given variable and $SE_ß$ is its standard error.

The preliminary results of this analysis have been published by us previously as well [23].

In addition to the above mentioned statistical methods we also constructed in this study a Health Index using the pooled follow-up data of the above mentioned two cohorts by means of the survival analysis method with SAS [15]. "Primary selection screening procedure" of SAS PROC LIFEREG was implemented, which is a parametric time model, and Weibull survival distribution was used as the basic survival time distribution. The Health Index and its predictive ability has been described by us in greater detail elsewhere [22].

BMI with BMI^2, as well as other continuous variables, were incorporated into this model as they were measured, other variables were categorised.

The smoking status was classified as follows: 0 — has never smoked, 1 — ex-smoker, 2 — smokes regularly 1–15 cigarettes daily, 3 — smokes regularly 16–20 cigarettes daily, 4 — smokes regularly more than 20 cigarettes daily. Alcohol consumption was estimated according to the following classification: 0 — has not consumed alcohol during the last year, 1 — has not consumed alcohol during the last week, 2 — consumed less than 84 g of ethanol last week, 3 — consumed 85–168 g of ethanol last week, 4 — consumed more than 168 g of ethanol last week. Education was classified as low (less than 10 years of school), medium (10–11 years of school or uncompleted university education) and high (university education). The classification of the coronary heart disease (CHD) status was as follows: 0 — no signs of CHD; 1 — possible CHD: Minnesota Code classes 1.2.8 — 1.3; 4.3; 5,3; 4.1,2 and 5.1,2 together with 3.1 or 3.3; 6.1; 7.1; 8.3; history of possible myocardial infarction according to the cardiovascular questionnaire; 2 — definite CHD: Minnesota Code classes 1.1 — 1.2.7; 4.1,2;5.1,2 without 3.1 or 3.3; angina by Rose [27]. Marital status was classified as: 1 — single; 2 — married; 3 — separated; 4 — widowed. A special code (generally 9 or 99) was reserved for missing data status. Age was not included into the model because we had intended to construct the Health Index only on physiological and behavioural variables.

RESULTS

The mortality rates according to quintiles of BMI (M±SE) were as follows: I quintile — 11.81±2.96; II quintile — 8.72±1.80; III quintile — 8.36±1.52; IV quintile — 8.30±2.24; 8.98±1.78, V quintile — 8.98±1.78, showing a slightly U-shaped curve with a tendency for higher mortality rates in the bottom quintile and minimum mortality in the IV quintile (26.7–28.9 kg/m^2).

To adjust not only for age but also for other predictive variables we used the Cox proportional hazards regression model allowing multivariate adjustment.

At the first step we adjusted only for age, and after categorising BMI into quintiles (Q): BMIQI — very low, BMIQII — low, BMIQIII — normal, BMIQIV — high and BMIQV — very high, used consequently the I, III and IV quintiles as reference categories.

In the first model (BMIQI as reference category) the risk ratios (RR) and 95% confidence intervals were as follows: BMIQII — 0.788 (95%CI 0.596–1.041); BMIQIII — 0.741 (95%CI 0.558–0.984); BMIQIV — 0.636 (95%CI 0.475–0.852); BMIQV — 0.802 (95%CI 0.610–1.054).

In the second model (BMIQIII as reference category) the following RR were found: BMIQI — 1.350 (95%CI 1.017–1.792); BMIQII — 1.063 (95%CI 0.788–1.435); BMIQIV — 0.859 (95%CI 0.628–1.174); BMIQV — 1.082 (95%CI 0.806–1.454).

The RR in the third model (BMIQIV as reference category) were: BMIQI — 1.571 (95%CI 1.174–2.104); BMIQII — 1238 (95%CI 0.910–1.6685); BMIQIII — 1.164 (95%CI 0.852–1.591); BMIQV — 1.260 (95%CI 0.931–1.706).

The Cox model after adjustment for all predictive variables is shown in the table. The predictive variables for all-cause mortality were: signs of possible or definite CHD, SBP, smoking status, (direct relationship), mental work (negative relationship), TC (U-shaped relationship). According to this model the minimum mortality was 31.0 kg/m^2.

A similar but even more extended list of significant variables (from the list of 20 variables) for the prediction of total mortality was included into the constructed Health Index. Both BMI and BMI^2 were found statistically significant ($P<0.01$). Other variables selected as predictive were: SBP, heart rate, CHD ($P<0.0001$), TC with TC^2, education, smoking, alcohol consumption (P<0.01), marital status (P<0.05).

Table. Cox proportional hazards model for all-cause mortality

Variable	ß coefficient	SE	Wald Chi-Square	P	RR	95% Confidence interval	
						Lower	Upper
AGE	0.051451	0.00799	41.48479	0.0001	1.053	1.036	1.069
CHD (definite)	0.818956	0.15868	26.63579	0.0001	2.268	1.662	3.096
CHD (possible)	0.695809	0.18979	13.44146	0.0002	2.005	1.382	2.909
SBP	0.010822	0.00206	27.68769	0.0001	1.011	1.007	1.015
Mental work	–0.485388	0.10471	21.48947	0.0001	0.615	0.501	0.756
Ex-smoker	–0.076451	0.20638	0.13723	0.7111	0.926	0.618	1.388
Smoker	0.455463	0.11502	15.68117	0.0001	1.577	1.259	1.976
Smoking status unknown	0.021008	0.02824	0.55346	0.4569	1.021	0.966	1.079
TC	–0.015836	0.00498	10.11473	0.0015	0.984	0.975	0.994
TC^2	0.031856	0.00960	11.02000	0.0009	1.032	1.013	1.052
BMI	–0.022533	0.00863	6.81640	0.0090	0.978	0.961	0.994
BMI^2	0.036311	0.01539	5.56510	0.0183	1.037	1.006	1.069

DISCUSSION

All the three statistical methods used in this study demonstrate the contribution of body mass to all- cause mortality in middle-aged men residing in Tallinn. Quintile analysis showed a U-shaped relationship between BMI and all-cause mortality with a minimum mortality in the range of 26.7–28.9 kg/m^2. When BMI was considered as a continuous variable, the relation to all-cause mortality was also U-shaped revealing even a higher minimum mortality (31.0 kg/m^2). The Health Index confirmed the results of the statistical methods mentioned above. The Health Index can be considered more predictive than the Cox model as more variables were found significant for all-cause mortality.

The non-linear relationship between BMI and all-cause mortality is in accordance with the majority of studies mentioned above, although the BMI values associated with minimum mortality in various studies are different. In comparison to our population lower "optimal" BMI values (24.8 kg/m^2) have been reported for white men in a representative national population sample in the US [8]. A meta-analysis of 19 prospective cohort studies has demonstrated the lowest mortality risk in a wide range of BMI values (23–28 kg/m^2) in men aged 50 [21]. A higher BMI (29.3 kg/m^2) associated with minimum mortality has been found in a large Italian population sample of men aged 45 to 69 [16], as well as in older men in the US (27–30 kg/m^2), in Finland and the Netherlands (30,2 kg/m^2) [2, 9].

The finding of a relatively high BMI associated with minimum risk, if confirmed in other populations and population groups, has an implication for public health and might induce the consideration of changes in clinical recommendations and existing guidelines on healthy values of BMI.

Both models, the Cox regression model as well as the Health Index, can be used for the prediction of all-cause mortality in the middle aged male population of Tallinn.

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AN ATTEMPT TO USE KELLY-REYNOLDS METHOD FOR ASSESSMENT OF SKELETAL AGE IN GIRLS FROM 11 TO 14 YEARS

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ABSTRACT

Skeletal age was assessed with the aid of Kelly-Reynolds method in 65 girls of 11 to 14 years. Planimetry of the skeleton of the left wrist did not show any differences according to age. At the age of 11 and 12 years the mean area of the wrist skeleton corresponded to the skeletal age standards elaborated by Labitzke [9]. At the ages of 13 and 14 years, skeletal age was, respectively, 1 and 1.5 years lower than chronological age. Dividing the girls by breast development stages, again no difference was found between stages 2, 3, 4 and 5 in the area of the wrist skeleton. However, a good accordance appeared between skeletal age corresponding to the mean area of the wrist skeleton and the chronological age in maturation groups. Significant correlations ($r = 0.419$; $p = 0.017$) were found between the area of the wrist skeleton and height. In conclusion, the increase in the area of the wrist skeleton can be associated with growth but not with chronological age. Sexual maturation, obviously, influences skeletal maturation through a growth spurt. Further investigation is necessary to establish whether the lack of differences in skeletal growth between age and maturation groups of girls is related to the low distinctive capacity of the method used.

Key-words: girls, growth, sexual maturation, skeletal maturation

INTRODUCTION

The first method for assessment of skeletal age was the comparison of an x-ray picture of the hand and wrist with a standard picture in corresponding atlases [5, 15]. In order to reduce subjectivity and obtain objective measures, several methods have been proposed [11, 14]. The most profound method for assessment of skeletal age by x-ray pictures has been elaborated by Tanner and co-workers [13, 14]. The validity and reliability of this method (TW2) has been carefully studied and proved [1, 11, 14]. However, this method requires measuring of 20 bones of the hand and the wrist. Therefore the procedure of analysing x-ray pictures is time-consuming.

In 1947 Kelly and Reynolds [8] proposed a method founded on planimetry of the area of the wrist skeleton. In 1970 this method was re-examined by Labitzke [9] with positive results. He elaborated standards for evaluation of the skeletal age of boys and girls in an age range from 7 to 14 years.

The present study aimed to use the Kelly-Reynolds [8] method in girls of circumpubertal age in order to assess the relevance of the method for studies of pubertal girls.

MATERIAL AND METHODS

Subjects

Sixty-five healthy girls aged from 11 to 14 years and their parents gave informed consent for participation in the study. The study design was approved by the Ethics Committee of the Medical Faculty of Tartu University.

Methods

Several anthropometric measurements were recorded, but in this paper only height is used. Height was recorded with a metal anthropometer. Simultaneously with anthropometric measurements, sexual maturation was evaluated by breast development using the scale proposed by Tanner [12].

X-ray pictures of the left hand and wrist were made at Tartu Polyclinic. The obtained x-ray pictures were used for planimetry of the wrist skeleton according to the method of Kelly and Reynolds [8] taking into consideration the suggestions of Labitzke [9]. Skeletal age was calculated according to the standards elaborated by Labitzke [9].

Statistics

The obtained results were grouped by age and sexual maturation stages. The difference in variability of the skeletal age index between the groups was assessed with the aid of one-way ANOVA with post hoc Tuckey-HSD procedure. For testing correlations, Pearson product-moment correlation coefficient was computed. Significance was evaluated by designating the 0.05 probability level as significant.

RESULTS

The planimetry of the area of wrist skeleton showed pronounced variability in each age group. In results there were no significant differences between age groups. In 11- and 12-year-old girls the skeletal age assessed by the standards of Labitzke (1970) was the same as chronological age, but in 13-year-old girls one year and in 14 year-old girls one and half year lower than their chronological age (Table 1). The height of 11-year-old girls differed significantly ($p<0.05$) from that of 13- and 14-year-old girls. Breast development stages showed gradual increase with age, but no statistically significant differences were found between the age groups.

Table 1. Planimetry of wrist skeleton, corresponding skeletal age, height and sexual maturation according to breast development scale in age groups (mean±SD)

Age (years)	n	Planimetry of wrist	Skeletal age (year)	Height	Breast developmental stage*
11	15	16.5±1.9	11.5	152±5	2.5±0.6
12	26	18.1±2.0	12.5	157±8	3.0±0.7
13	16	17.4±1.6	12.0	160±5	3.9±0.8
14	8	17.8±2.5	12.5	162±8	4.5±0.7

* The mean stage was calculated by the sum of stages of every individual divided by the number of subjects

When groups were divided according to breast development stages (Table 2), no significant differences were found in the planimetry of the wrist skeleton. By height the girls in breast developmental stage 2 differed significantly from the girls in stages 3, 4 or 5. By age, significant differences appeared when girls of stage 2 were compared with those in stages 3, 4 or 5, as well as between the girls in stages 3 and 5.

Table 2. Planimetry of wrist skeleton, corresponding skeletal age, height and age in different stages of breast development (mean±SD)

Breast developmental stage	n	Planimetred wrist	Skeletal age (years)	Height	Age
II	19	17.2±2.1	12.0	150±7	11.5±0.9
III	25	17.1±2.2	12.0	157±7	12.3±1.0
IV	16	17.8±1.7	12.5	162±6	12.8±0.9
V	5	18.5±1.3	13.0	160±4	13.6±0.8

A significant correlation ($r = 0.419$; $p = 0.017$) was found between height and wrist skeleton area. Correlations between chronological age, area of the wrist skeleton, and stages of breast development were not statistically significant ($p>0.05$).

Comparison of premenarcheal and postmenarcheal girls did not show any difference in the area of the wrist skeleton.

DISCUSSION

Results obtained with the aid of TW2 evidence good accordance between skeletal maturation and chronological age both in girls and in boys [14]. The same was demonstrated by Labitzke [9] with the aid of wrist planimetry. The present results did not confirm the relationship between chronological and skeletal age in girls from 11 to 14 years. An examination of the results of Labitzke [9] showed a statistically significant difference between 11- and 12-year-old girls in the area of wrist skeleton but not between 12- and 13- as well as between 13- and 14-year-old girls. Thus, the correlation was founded on the differences between the youngest (8–9-year-old) and older (13–14-year-old) girls. During circumpubertal age the results of Labitzke [9] did not distinguish the degree of skeletal maturation between age groups either.

Skeletal age is a better index for prediction of the menarche than chronological age, but the first appearance of breasts or pubic hair is poorly predicted by skeletal age [10]. The same was found in regard of the “take-off” of adolescent growth spurt [4, 6, 7]. Our results did not demonstrate any exact relationship between the increase in the area of wrist skeleton and breast development either. However, we found a correlation between height and increase in wrist skeleton. The results of Beunen et al. [2] confirm that in girls from 6 to 16 years skeletal age is a significant predictor of development of somatic characteristics, first of all of length measures. They found the highest correlation between skeletal age, height and length measures at the ages of 9, 11 and 13 years.

An interesting result of ours was good accordance between skeletal and chronological age in the groups which were formed by stages of breast development. When skeletal age was compared in chronological age groups, the lagging behind of skeletal age appeared in 13- and 14-year-old girls. Obviously, sexual maturation favours skeletal maturation and thereby ensures good accordance between skeletal and chronological age in sexual maturation groups.

Eveleth and Tanner [3] emphasised that the rate of skeletal maturation reflects the interaction of genetic and environmental forces, just like the rate of growth in height. Thus populations differ both in mean skeletal maturity at a given age and in the pattern of increments from age to age. Accordingly differences may exist between Estonian (our study), German (the study of Labitzke) and British girls (the study of Tanner et al.). However, another question arises in regard to the methods used. Planimetry of the area of the wrist skeleton might not have sufficient distinctive capacity to establish age or sexual maturation depending increase in skeletal ossification.

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