Papers on Anthropology

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PREFACE

Our consecutive, tenth collection has appeared in print. The collection of anthropological studies, initiated by Juhan Aul in 1964, has reached its first jubilee. We have realised two of our goals: first, to develop the research into the anthropometric structure of human body build as an integrated whole and, second, to relate body build characteristics to health care, medicine and physical education.

All this has become possible thanks to the friendly cooperation between the researchers from Tallinn and Tartu, and between the various faculties and institutes of the University of Tartu. We have been joined in our efforts by colleagues from Lithuania, Latvia, Poland, Bulgaria and Germany.

We express our gratitude to all the authors, reviewers and Tartu University Press.

We wish everyone a lot of success in all their endeavours.

Prof. Helje Kaarma

CONTENTS

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RADIATION EFFECT IN THE REMNANT RAT KIDNEY

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ABSTRACT

The segmental sclerotic lesions, which develop in remnant glomeruli of rats following ablative injury, resemble those seen in a variety of human renal diseases. In the present study we investigated the effect of low-dose irradiation of experimental nephrectomized rats. Attention was focused on the morphological and ultrastructural changes in the renal corpuscles after 5/6 nephrectomy. Morphological study demonstrated degeneration of the tubular epithelium, development of focal-segmental glomerulosclerosis and interstitial fibrosis. Electron microscopic study demonstrated thickened glomerular basement membrane after nephrectomy.

Key words: Experimental glomerulosclerosis, rats, kidney, irradiation, glomerular basement membrane

INTRODUCTION

Kidney diseases have always been topical. Many renal diseases progress to the end stage via focal and segmental glomerular sclerosis, independent of the initial pathogenetic mechanism [12]. Ablation of renal mass produces a higher increase in blood pressure and morphological changes [8, 14, 16, 17], in the first place glomerular hypertrophy and glomerular sclerosis [4]. Tubulointerstitial fibrosis accompanies experimental and human glomerulopathies. The segmental sclerotic lesions and interstitial sclerosis, which develop in remnant glomeruli of rats following ablative injury resemble those seen in a variety of human renal diseases. The remnant kidney model in rats is a model for the analysis of glomerulosclerosis [3]. The progressive renal disease develops within two weeks after 5/6 nephrectomy [20]. In the literature proliferation of mesangial cells [6] and proliferation of glomerular cells with fibrinogen deposits have been described [18]. Glomerular capillary loops dilatation is associated with a number of ultrastructural abnormalities in endothelial cells, mesangial cells and podocytes [13]. Tubulointerstitial injury with tubular dilation and atrophy, infiltration of mononuclear cells [10]. The effect of radiation of low-dose to remnant kidney has not been investigated previously [1, 2].

MATERIAL AND METHODS

The experiments were performed on 30 male Wistar rats (Kuopio, Finland) whose age was 70–80 days, weight 250–279 g and who had normal systolic blood pressure of 102–135 mmHg. Systolic blood pressure was measured on the tail (Harvard Rat Tail BP. Monitor) during the 2nd and 4th weeks after surgery. The rats were divided into three groups:

3 Grey group (10 rats) — irradiation one day after surgery;
control group (10 rats) — rats without irradiation;
healthy controls (10 rats) — rats without surgery.

In experimental groups, the rats underwent five-sixths renal ablation under methohexital anesthesia (Brietal, 50 mg/100g, intraperitoneally, LILLY Deutschland GmbH, Germany). Normal Wistar rats (without surgery) were studied as healthy controls. Left kidney of rats (group 1) was irradiated (Cobalt-60) 24 hours after operation in anaesthetized (Brietal) animals with 3 Grey in a single dose. The rats were kept in a room with constant temperature and a 12-hour light-dark cycle. The rats were allowed free access to normal rat show (R 70, Lactamin, Sweden) and water. The rats were killed 4 weeks after surgery.

For light microscopy kidneys were fixed in 10% formalin, embedded in paraffin, cut in 2–4 μm thick sections and stained with H&E, PAS, Congo, Masson Trichrome, T-PAS, periodic acid-methenamine silver (PAMS). For TEM kidneys were fixed in cold (4°) glutaraldehyde solution (2,5%) buffered with sodium cacodylate buffer at pH=7,4 for 2 hours, postfixed for 1 hour in 1% osmium tetroxide solution at the same temperature and pH, dehydrated in alcohol and embedded in Epon-812. Semithin sections stained according to Richardson were examined using an Olympus BX-50 microscope. Ultrathin (70 nm) sections were stained with uranyl acetate and lead citrate. TEM Philips Tecnai-10 with camera Mega View II was used for viewing and photographing. Values are presented as mean ± SEM.

RESULTS

Macroscopically the kidneys of the 1st and 2nd groups of animals was hypertrophied and the kidneys' weight ranged from 1,0g to 2,2g. Systolic blood pressure of the animals was measured using special devices in a 2-weeks interval (Table 1).

Table 1

Group	Animals weight (g) I wk	Animals weight (g) IV wk	Systolic blood pressure (mmHg) IV wk
Control	260,0 ± 3,9	321,0 ± 4,3 *	155,3 ± 0,25 *
3 Grey	260,9 ± 6,2	312,4 ± 6,1 *#	141,0 ± 0,19 *#
Healthy control	266,1 ± 3,4	332,5 ± 4,6	128,3 ± 0,17

p<0,05 vs.H. controls, # p<0,05 vs. Controls

Morphological study

On light microscopy of 1 and 2 groups animals showed that renal corpuscle was focal-segmental glomerulosclerosis of many glomeruli. One hundred glomeruli per kidney were examined for sclerotic evaluation (Table 2). The renal corpuscles of the healthy control group were spherical structures with normal average diameter (93,5 ± 3,90 μm) and glomerular urinary space.

Table 2. Kidney morphology

Group	FSGS	IF
3 Grey	34,3 ± 6,9 *#	1,0 ± 0,4 *#
Control	50,9 ± 5,4 *	2,2 ± 0,3 *
Healthy control	8,0 ± 6,3	0 ± 0

p < 0,05 vs.H. controls, # p < 0,05 vs. Controls

Many glomeruli and tubules of the control group showed interstitial fibrosis with positive fibrin deposits by Masson Trichrome staining (Fig. 1, 2).The renal corpuscles of control group were plump, collapsed and sclerotic. The Bowman's capsules of control group rats were thick. The average diameter of this group's renal corpuscles was 94,5 ± 2,05 μm. Glomerular urinary space (Fig. 3) was contracted (1,95 ± 0,10 μm) and many glomeruli included hyalin (Fig. 5). This group of rats had significantly thickened, wrinkled glomerular basement membrane. Glomerular capillary-loops were large and wide, the amount of capillaries was decreased. Podocytes had very many electron-dense granules in their cytoplasm. There was a great number of mitochondrions; they were large and wide. The cells of proximal convoluted tubules had detriment and short brushborder (2,60 ± 0,12 μm), tubules contained hyalin. The epithelial cells of proximal and distal convoluted tubules were irregular. Histological examination showed atrophy of the tubules. Congo blue was negative for amyloid and positive for fibrin by the Masson Trichrome stain. Mesangial areas revealed intense staining with PAMS. The mesangial matrix was increased without deposits of FSGS and the mesangial cells nucleus was irregular (Fig. 7).

The renal corpuscles of 3 Grey animal group were spherical and large (Fig. 4), the average diameter of renal corpuscles was 109,5 ± 2,48 μm. Glomerular urinary space was 2,95 ± 0,17 μm. There were collapsed renal corpuscles in this group. Transmission electron microscopy in 3 Grey group demonstrated irregularly thickened glomerular basement membrane (Fig. 8) and large glomerular capillary loops. Podocytes had electron-dense granules in their cytoplasm. The mesangial areas revealed intense staining with PAMS. The loops of tubules were contracted and epithelial cells were elongated and irregular. Congo blue was negative for amyloid and positive for fibrin by the Masson Trichrome stain (Fig. 6).

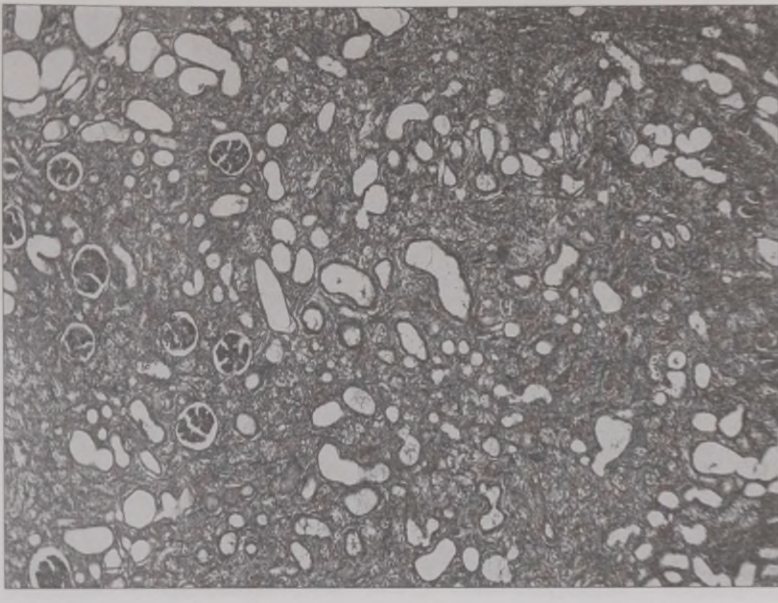

Figure 1. Focal-segmental glomerulosclerosis and interstitial fibrosis. Control group. Masson Trichrome 168×.

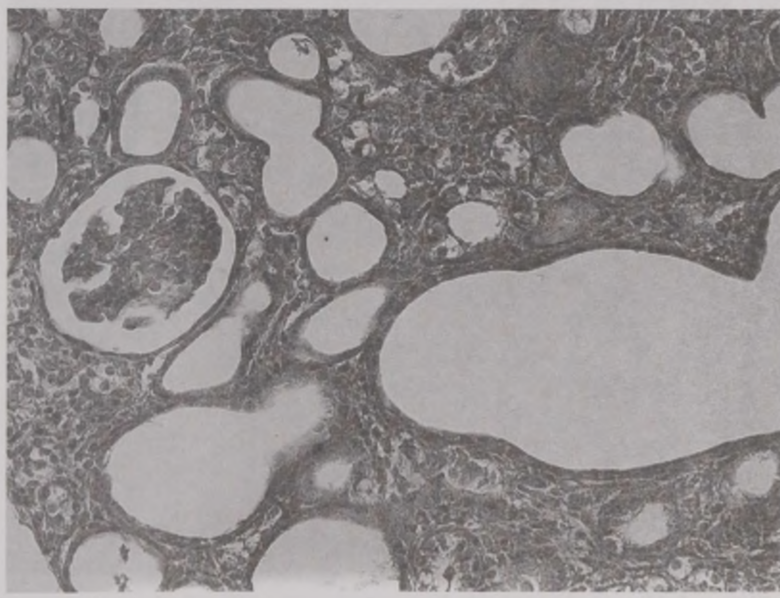

Figure 2. Tubules with atrophic epithelium. Control group. Masson Trichrome 368×.

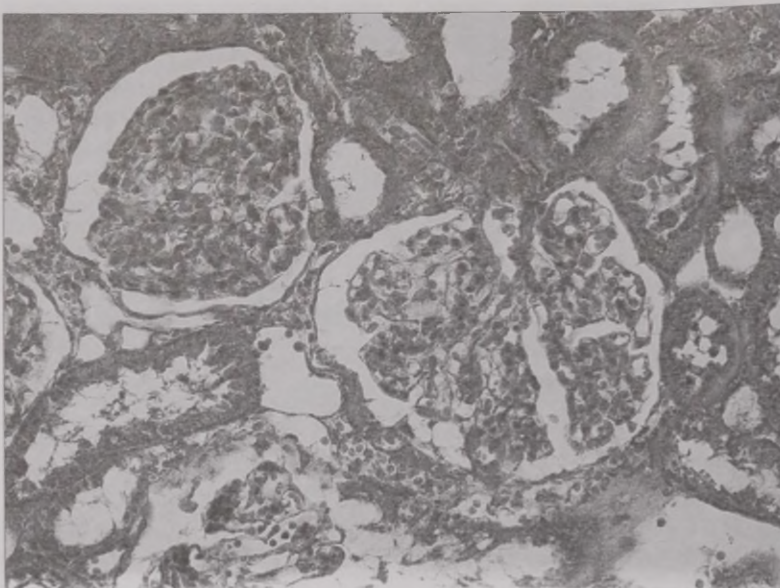

Figure 3. Glomerulus with contracted and irregular urinary space. Control group. Masson Trichrome 368×.

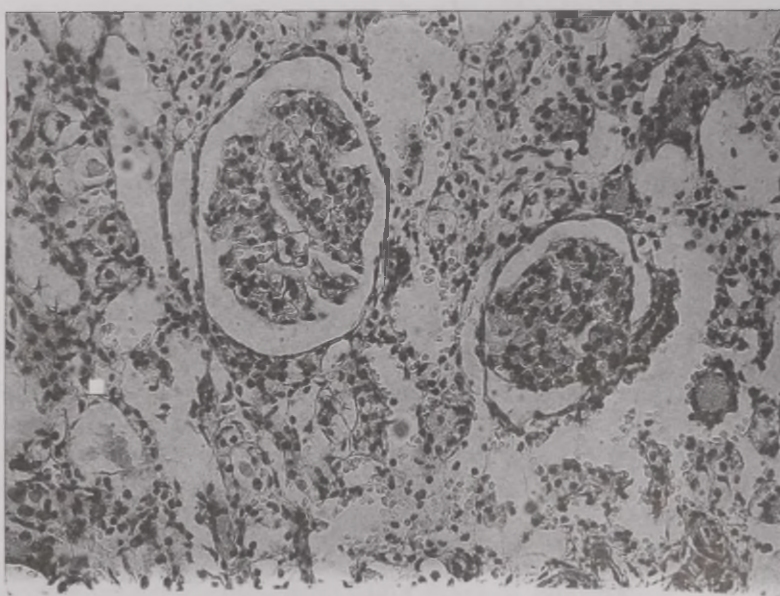

Figure 4. Glomerular and tubular necrosis without irradiation sclerosis. 3 Grey group. H&E 368×.

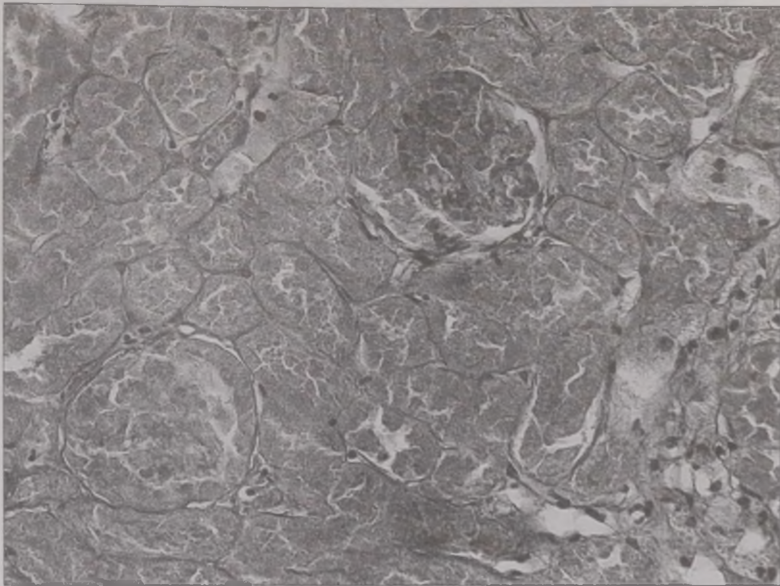

Figure 5. Tubular degeneration. Glomerulus with hyalinosis. Control group. H&E 368×.

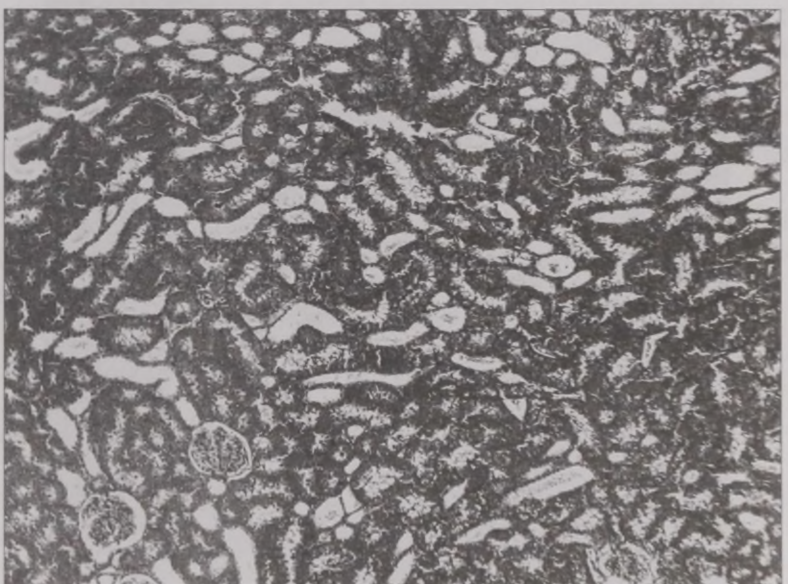

Figure 6. Focal-segmental glomerulosclerosis and interstitial fibrosis. 3 Grey group. Masson Trichrome 168×.

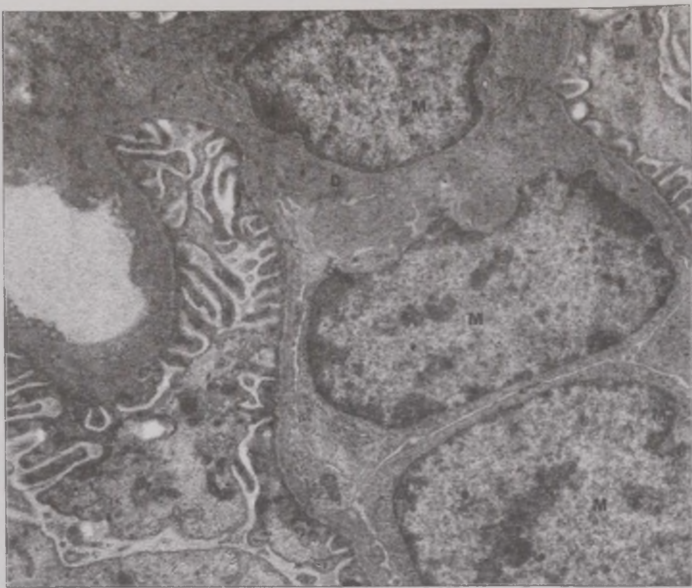

Figure 7. Increased number of mesangial cells (M). The mesangial matrix is increased without deposits (D). Control group. TEM 6200×.

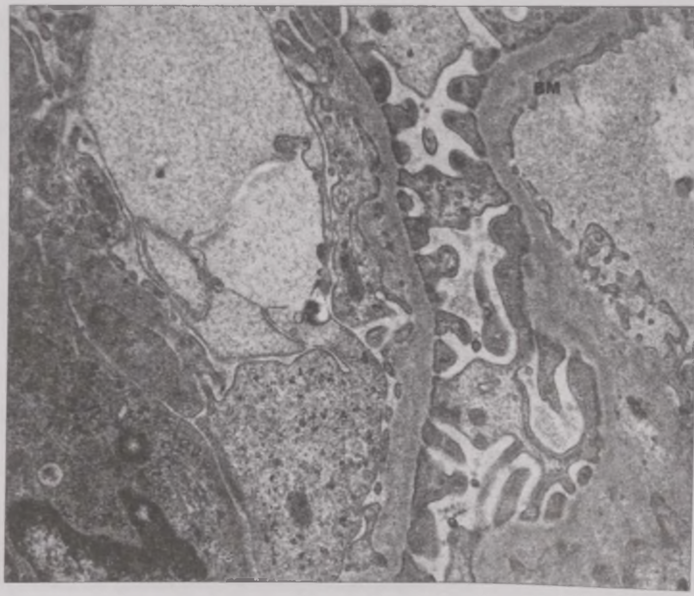

Figure 8. The thickened glomerular basement membrane (BM). 3 Grey group. TEM 12500×.

DISCUSSION

The results demonstrate that low-dose radiation is a factor for slow process for focal-segmental glomerulosclerosis and interstitial fibrosis. The measurements of systolic blood pressure we have done show that the rise of blood pressure after nephrectomy slows down under the influence of irradiation. The kidneys were examined after 4 weeks hypertension. Nephrectomized rats had higher blood pressure than the healthy control group [5, 7, 19] and 3 Grey group. Histological examination showed developed glomerular sclerosis, interstitial fibrosis and tubular atrophy. The glomeruli in remnant kidneys showed thickening of the renal capsule, foot process fusion and mesangial expansion [9]. During the progression of the disease, the glomerular endothelial cells decreased in number and maximum glomerulosclerosis expression was observed by month 6 [11]. During the morphological study of renal corpuscles it turned out that changes in the 3 Grey group were smaller than those in the control group. The morphological study showed that FSGS emerged most at control group animals (50,9%). This indicator was smaller in the 3 Grey group. Control group rats had especially strong performance of IF, this number was smaller in 3 Grey group. There was no IF in the healthy control group. The hyalinosis lesion was characterized by an accumulation of homogeneous electron-dense material beneath damaged endothelial cells [15]. In our study we observed atrophy of the tubules, sclerosis of the glomeruli, increase of interstitial tissue and connective tissue. The atrophied tubules and glomeruli in remnant kidney replacing in finish by connective tissue.

In conclusion, our investigation showed that low-dose radiation decreases the process of focal-segmental glomerulosclerosis and interstitial fibrosis.

ACKNOWLEDGEMENT

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EFFECT OF *HELICOBACTER PYLORI* ON THE RAT GASTRIC MUCOSA: A LIGHT AND ELECTRON MICROSCOPIC STUDY

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ABSTRACT

Influence of Helicobacter pylori (*H. pylori*) on gastric mucosa after indomethacin-induced damage was studied on the experimental white rat model. Gastric lesion was produced by intragastric administration of indomethacin (7 mg/kg) during three days followed by administration of *H. pylori* suspension (density 10^9 colony forming units). Animals receiving indomethacin only or in combination with *H. pylori* suspension were sacrificed on day 18. To evaluate cellular changes in the gastric mucosa, light and electron microscopic studies were performed.

Indomethacin caused deep gastric damage, which was not aggravated by addition of *H. pylori*. Alterations were found in the structure, number and functional activity of the surface epithelium, mucocytes, parietal cells and mast cells.

It was concluded that the role of *H. pylori* in the formation of gastric damage is not decisive.

Key words: Helicobacter pylori, rats, gastric mucosa, indomethacin, electron microscopy

INTRODUCTION

Helicobacter pylori (*H. pylori*) is a Gram-negative bacterium that has been recognized as a causative agent for gastritis and gastroduodenal ulcer [11]. Despite intensive studies the effect of *H. pylori* on the gastric mucosa is not fully understood. Discrepancies exist between reports on the effect of *H. pylori* on ulcer healing. Some groups show delayed ulcer healing [4], others report active proliferation of epithelial cells and activation of connective tissue cells in all layers of the gastric mucosa [6, 9]. This suggests that the healing process is accelerated. In general, it is believed that *H. pylori* damages the gastric mucosa and facilitates ulcer formation. *H. pylori* induces infiltration of gastric mucosa by neutrophilic granulocytes, lymphocytes and fibroblasts characteristic of inflammation [1, 4]. Important findings concern the number and degranulation of mast cells as these cells produce substances, which affect blood flow, and function and cellular composition of gastric glands. Several studies have shown increased degranulation of mast cells in *H. pylori* infection [5, 7, 9, 12, 14]. Decrease in the number of mast cells in *H. pylori* infection has also been reported [12].

Data about the correlation between *H. pylori* and parietal cells of gastric glands is relatively abundant. Berczi et al. [1] show that *H. pylori* does not affect hypersecretion of parietal cells. On the contrary, other reports claim that *H. pylori* suppresses secretion of parietal cells, i.e. production of hydrochloric acid [6, 13]. Decreased acidity of gastric content should favor in avoiding of gastric ulcers.

In addition to the increase of neutrophilic granulocytes in *H. pylori* infection rise in eosinophils has also been described [8].

Considering the conflicting data, this study was designed to evaluate the effect of *H. pylori* on the cells of gastric mucosa using the indomethacin-induced animal ulcer model.

METHODS

Animals

Male Wistar rats, weighing 220–280 g, were used in these experiments. All experimental procedures described below were approved by the Ethics Committee for Animal Research of the University of Tartu (Estonia).

To produce gastric lesion, indomethacin (8 mg/kg) was administered intragastrically during three days. Lesion of the rat's gastric mucosa on the third day mostly resembles human gastritis [2, 3]. Control animals received vehicle only. Animals of the first experimental group (Indo) received for three days only indomethacin. In the second experimental group (Indo+H.pylori), in addition to indomethacin, animals received from day 4 to day 10 intragastrically 2 ml of *H. pylori* suspension with the density of 10^9 colony forming units (CFU) [3]. *H. pylori* strain was isolated from a gastric biopsy specimen of a patient with duodenal ulcer. *H. pylori* was obtained through gastroscopy and multiplied on solid vehicle. Resistance to erythromycin was obtained by disk-diffusion method. At the end of the treatment, the animals were fasted overnight and sacrificed on day 18 by quick decapitation.

Sampling

Gastric mucosal specimens were fixed in 10% neutral formalin and embedded in paraffin for light microscopic studies. Sections were stained with haematoxylin and eosin, alcian blue and PAS. Number of mast cells was counted in ocular viewing fields; 10 viewing fields were estimated and the mean calculated. Degranulation of mast cells was simultaneously recorded and given in percentages. Number of parietal cells and activity of mucocytes was estimated using the following semiquantitative scale:

Score	Description
0	no positive results
1	low number or activity
2	moderate number or activity
3	high number or activity
4	extremely high number or activity

For electron microscopic studies, the samples were fixed in 2.5% glutaraldehyde in Na-cacodylate buffer, embedded in Epon 812 and ultrathin sections were studied by transmission electron microscope Philips Technai-10.

Statistics

The data obtained were analyzed using Student's t-test. All values are expressed as mean±SEM.

RESULTS

1. Light microscopic studies

The results of the light microscopic studies are summarised in Table 1. In all animals treated with indomethacin alone (group Indo) or indomethacin together with *H. pylori* suspension (Indo+H.pylori) alteration of gastric mucosa was described with signs of inflammation — increase in number of neutrophilic granulocytes and in amount of fibrous connective tissue between the glands.

Table 1. Light microscopical changes in cells of gastric mucosa

Treatment	Mast cells		PAS-positive material in gastric glands	Parietal cells in gastric glands
	No of cells per viewing field	Degranulation (%)		
Control (4 rats)	4.80 ± 0,77	23.5 ± 2.3	1.67 ± 0.30	2.3 ± 0.33
Indo (5)	4.36 ± 1,00	37.4 ± 8.2	1.50 ± 0.25	3.0 ± 0.32
Indo+*H. pylori* (5)	3.68 ± 1,25	32.0 ± 3.4	2.00 ± 0.41	2.0 ± 0.40

1.1. Number of mast cells and intensity of their degranulation

Mast cells were mostly found in submucosa, less often in propria between the gastric glands. Administration of indomethacin alone (Indo) or together with *H. pylori* suspension (Indo+H.pylori) did not cause statistically significant changes in the number of mast cells or in the intensity of their degranulation (Table 1; Figures 1 and 2).

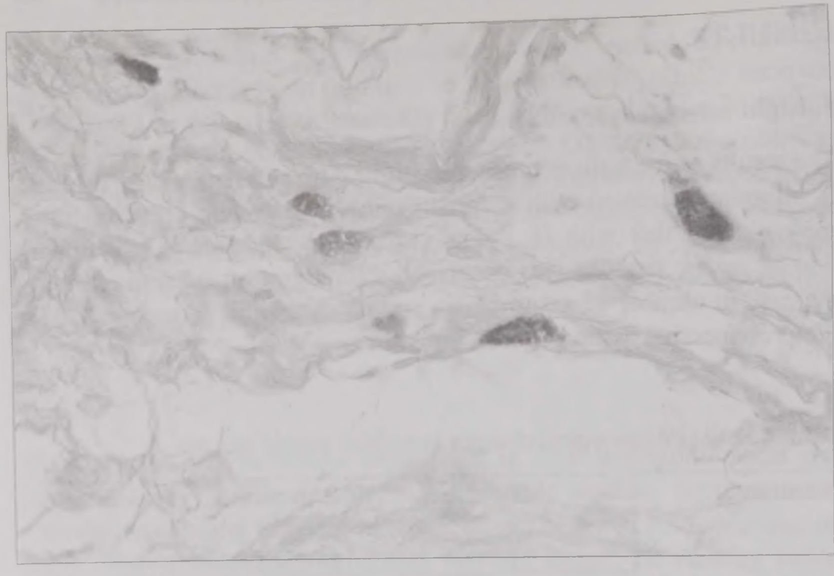

Figure 1. Mast cells in the mucosa of a control animal. Minimal degranulation of the cells. Alcian blue and neutral red. Magnification 600×.

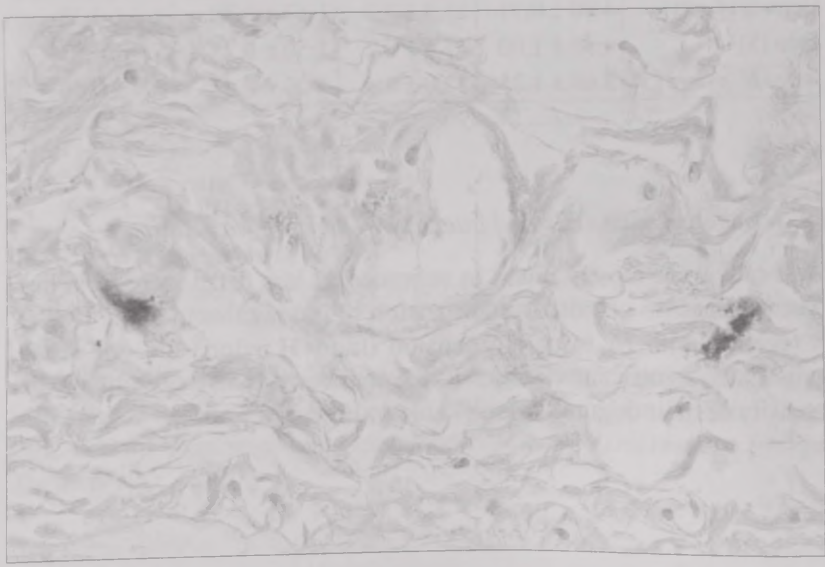

Figure 2. Mast cells in the mucosa of experimental animal received indomethacin and Helicobacter pylori suspension. Considerable degranulation of the cells. Alcian blue and neutral red. Magnification 600×.

1.2. Activity of mucus production by mucocytes

As decided by the amount of PAS-positive material in the gastric glands proper, the number of mucocytes and the activity of mucus production was highest in the group were animals received indomethacin and *H. pylori* suspension (Indo+H.pylori), but compared to the control group or to Indo the change was still insignificant (Table 1; Figures 4 and 5). Staining of mucocytes by alcian blue revealed them in the neck region of gastric glands in all groups — control, Indo and Indo+H.pylori. In Indo and Indo+H.pylori groups alcian blue stained mucocytes were also found in the body region of gastric glands, but in the control group almost no mucocytes were seen in that region.

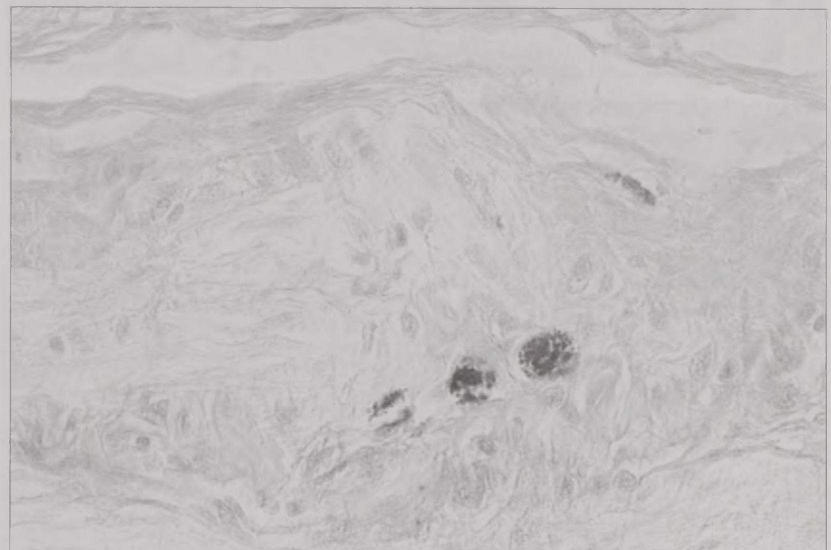

Figure 3. Mast cells in the gastric mucosa of the animal received indomethacin only. Relatively few cells, degranulation considerable. Alcian blue and neutral red. Magnification 600×.

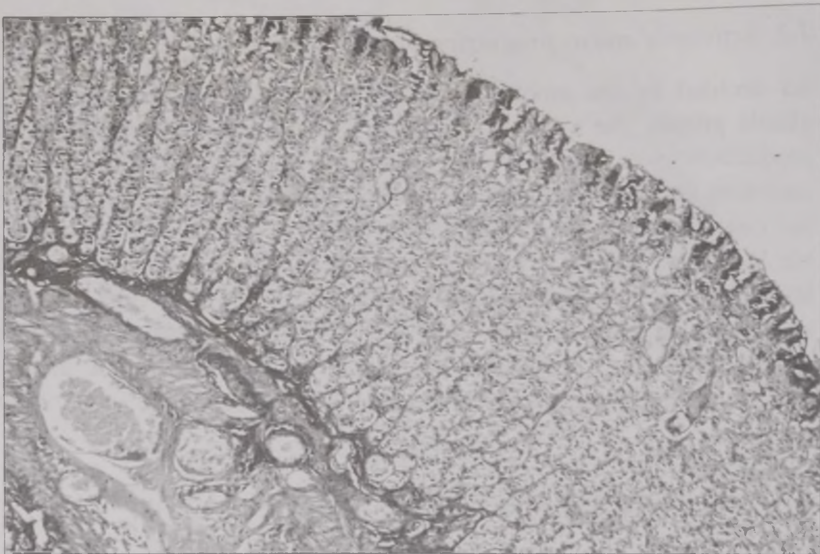

Figure 4. Gastric mucosa of the control animal. Few PAS-positive material is found mostly in the neck region of gastric glands. PAS reaction. Magnification 200×.

Figure 5. Gastric mucosa of the animal received indomethacin and Helicobacter pylori suspension. Active mucocytes in the gastric mucosa, intensive synthesis of PAS-positive material. PAS reaction. Magnification 100×.

1.3. Number of parietal cells

Parietal cells, which are important in formation of gastric damage, were counted in PAS-stained sections. Although the number of parietal cells was highest in the Indo group, the shift, as compared to control or Indo+Hpylori groups, was still insignificant.

2. Electron microscopic studies

Ultrastructural studies of the gastric mucosa showed that the surface epithelium in the control group animals was normal, while in all experimental groups it was damaged to a different extent. As a rule, mucus from the apical part of the cells was eliminated, but fully destroyed cells were also present (Fig. 6). In experimental groups, in propria and submucosa of the gastric mucosa neutrophilic granulocytes were found in large numbers together with a few eosinophilic

Figure 6. Transmission electron micrograph from the animal received indomethacin and Helicobacter pylori suspension. Seriously damaged cells of the surface epithelium still show intracytoplasmic mucus droplets. Magnification 2550×.

granulocytes (Fig. 7 and 8). Cells characteristic of inflammation — activated macrophages and lymphocytes — were found in addition to submucosa also in propria. In macrophages a large number of primary and secondary lysosomes was seen. In experimental groups, as compared to the control group, in the propria between the bottom of glands the number of fibroblasts and the activity of collagenogenesis was increased (Fig. 9).

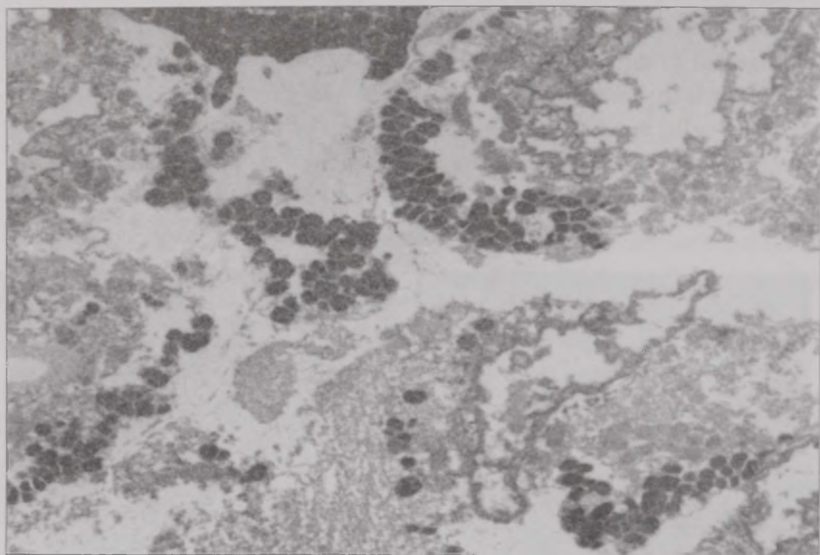

Figure 7. Transmission electron micrograph from the animal received indomethacin and Helicobacter pylori suspension. Compared to control animals the number of neutrophilic granulocytes is increased. Magnification 2550×.

In electron microscopic studies special attention was paid to the ultrastucture of mast cells. In control group animals, mast cells contained a large amount of electron dense granules of different size. In experimental groups mast cells contained electron lucent vacuoles (Fig. 11).

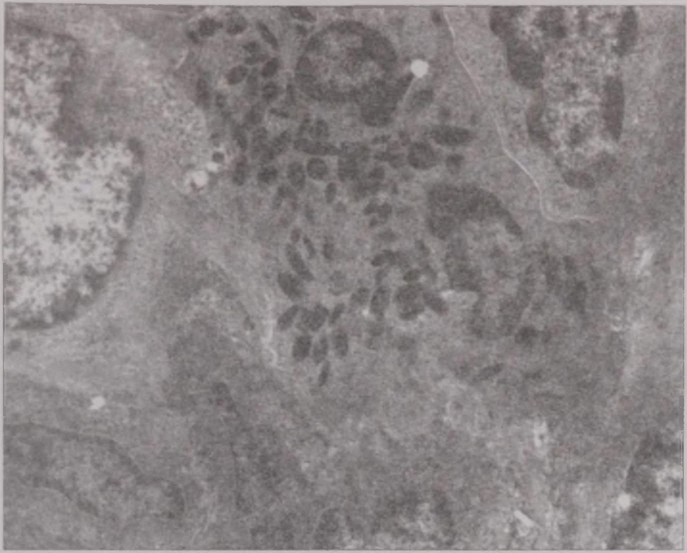

Figure 8. Transmission electron micrograph from the animal received indomethacin and Helicobacter pylori suspension. Between glands few eosinophilic granulocytes are seen. Magnification 6200×.

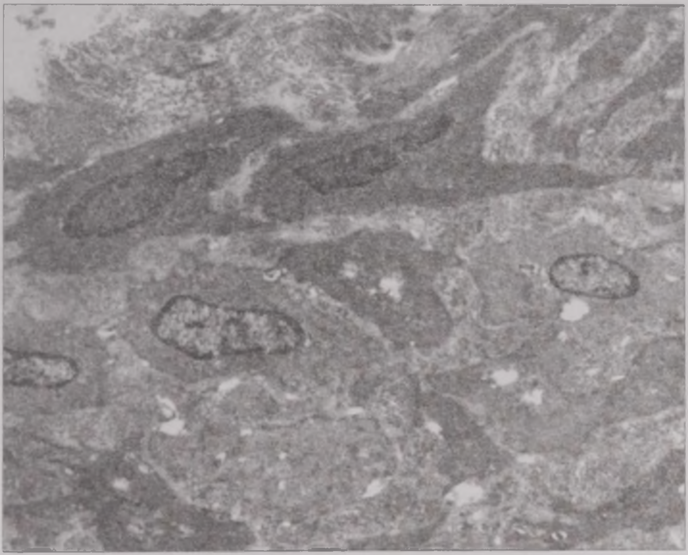

Figure 9. Transmission electron micrograph from the animal received indomethacin and Helicobacter pylori suspension. Active fibroblasts between gastric glands, ongoing collagenogenesis. Magnification 2550×.

In experimental groups damaged cell types of gastric gland were described, but the general morphology of preserved cells was not significantly changed. Mucocytes contained mucus droplets through the whole cytoplasm, chief cells showed well-developed rich in cisterns endoplasmic reticulum with secretory granules in the apical part (Fig. 12). Enteroendocrine cells were evenly seen both in control and experimental groups. Still, in experimental groups enteroendocrine cells showed slow degranulation (Fig. 10).

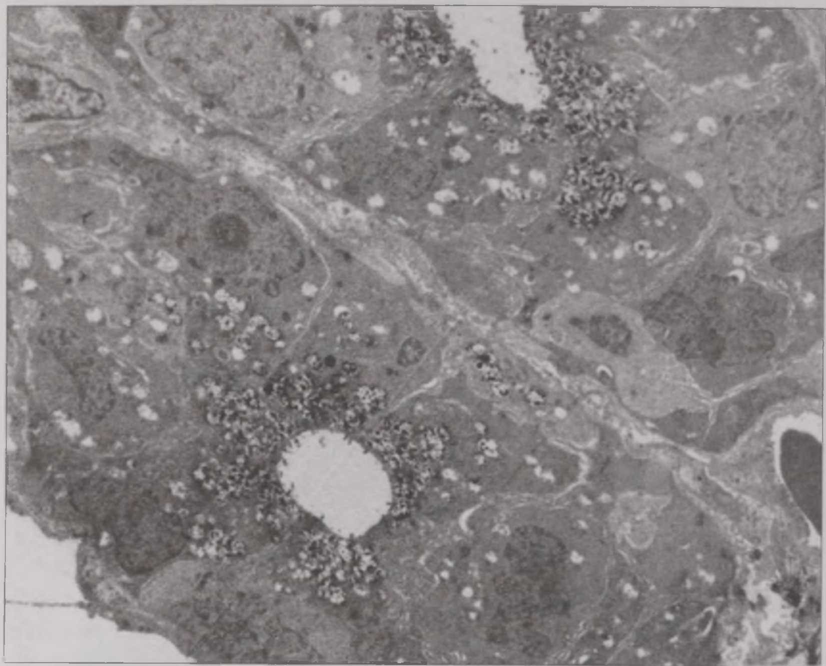

Figure 10. Transmission electron micrograph from the animal received indomethacin and Helicobacter pylori suspension. Slowly degranulating enteroendocrine cells in the wall of gastric glands. Magnification 2550×.

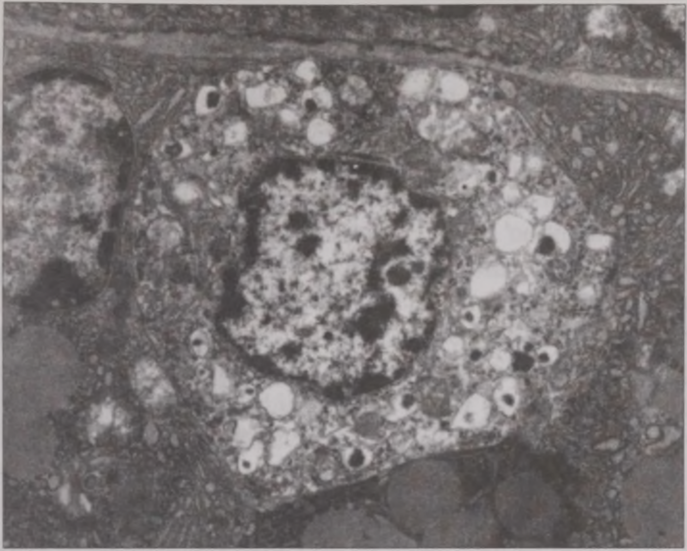

Figure 11. Transmission electron micrograph from the animal received indomethacin and Helicobacter pylori suspension. Mast cell between gastric glands. Electron dense granules are replaced by electron lucent vacuoles. Magnification 6200×.

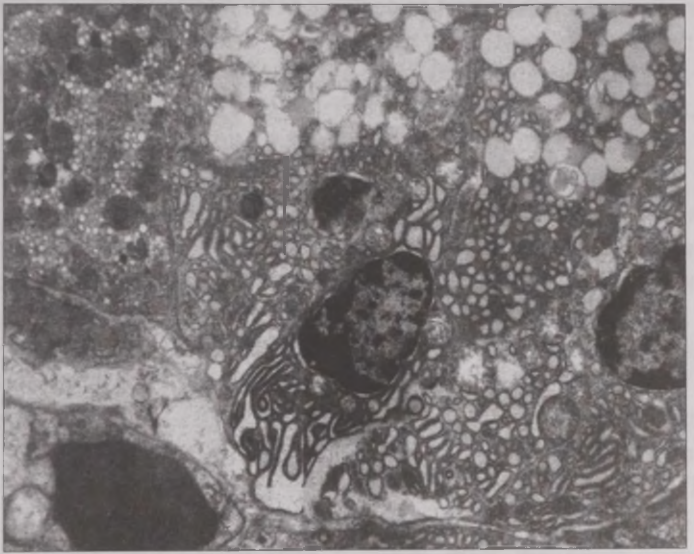

Figure 12. Transmission electron micrograph from the animal received indomethacin and Helicobacter pylori suspension. Chief cell of the gastric gland with normal structure. Magnification 8700×.

DISCUSSION

Both light and electron microscopic studies revealed the damage of gastric mucosa in all indomethacin-treated animals. The addition of *H. pylori* suspension to the treatment did not aggravate the mucosal damage. Light microscopic studies showed in all indomethacin-treated animals, in addition to the structural damage seen as destruction of epithelium and alteration of gastric cells, also an increase in the number of cells characteristic of inflammation. First of all this concerned neutrophilic granulocytes and lymphocytes, and their number did not change after the addition of *H. pylori* suspension. The acceleration of regenerative processes was not noted either. No changes in the structure of neutrophilic granulocytes and lymphocytes were found. Therefore, our results do not fully agree with other reports [1, 4, 5, 7, 8].

In ulcer disease, among the cells in the connective tissue, special attention is paid to mast cells as they produce substances regulating the function of gastric cells — histamin, serotonin, etc. — as well as substances supporting regeneration — prostaglandin E_2 etc. [5, 6, 10, 14]. In some authors' opinion, under the influence of *H. pylori* the number of these cells in the mucosa does not change, but according to other researchers the number declines [10]. We found the tendency of the number of mast cells to decrease after the administration of *H. pylori*, but because of the limited number of experimental animals the change was insignificant.

Among the cells of gastric glands more attention is paid to parietal cells. It is believed that in *H. pylori* infection their secretion activity is decreased [9, 12, 13]. We found the tendency of the number of parietal cells to decrease after the administration of *H. pylori* as compared to the group who received indomethacin only, but again, the change was insignificant. In electron micrographs, the few parietal cells, which were captured, had a deformed intracellular canalicular system. Our results suggest that in *H. pylori* infection the gastric content should be less acidic, which is definitely not a favorable factor for ulcer formation.

The function of mucocytes is characterized by the amount of mucus in the cells. In all experimental groups surface epithelium was seriously damaged; from survived cells mucus was exocytosed. In general, mucus production in gastric glands was increased, which in our opinion reflects the defence reaction of gastric mucosa.

In conclusion, the results of our experiments showed that the role of *H. pylori* in the formation of gastric damage was not decisive.

ACKNOWLEDGEMENT

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Papers on Anthropology 10, 2001, pp. 37–49

DIFFERENTIAL STRENGTH OF REACTION TO MATERNAL RISK FACTORS AS A POSSIBLE MANIFESTATION OF SEXUAL DIMORPHISM IN HUMAN FOETAL LIFE

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ABSTRACT

The study was performed on 3889 stillborn foetuses at gestational age ranging from 20 to 42 weeks. The material was characterised in biological and environmental terms, including: chronological age, pregnancy history, occurrences of foetal death, maternal condition. Furthermore, morphological development was considered, using the following variables: somatic dimensions — total body length, crown-rump length, body weight, circumferences of the head, chest and abdomen, and also mass of the internal organs, namely of the brain, heart, lung, liver, spleen, kidney, adrenal gland and thymus.

The purpose of the study was to establish and analyse sexual differences in reaction to influences of maternal risk factors. It was found that in human foetal development there exists a slight sexual differentiation in the strength of reaction to maternal risk factors. Males foetuses showed higher sensitivity by greater variation in most of the characteristics, as compared to female foetuses, between different categories of the factors under study.

Key words: human foetal development, maternal risk factors

INTRODUCTION

Rich literature in the area of postnatal dimorphism in human morphology has already made this issue thoroughly recognised. By contrast, hitherto research and writing on prenatal sexual differences in physical characteristics, like somatic dimensions and mass of the internal organs, is quite scanty and gives ambiguous and contradictory statements [4]. The discrepancies between conclusions of the scholars searching for the existence of foetal dimorphism are mainly due to the methodological and practical conditions, which, as known, are particularly troublesome in foetal studies. The discrepancies may also result from variation in non-genetic factors, which differently affected the growing foetuses.

It is known that the X and Y chromosomes play a secondary role in the determination of, for example, body dimensions, fat distribution, or muscle mass. Whereas the control is hormonal, regulated by many genes located on most autosomal chromosomes and by environmental factors, giving the resultant outcome [3]. The expression of a gene is then attributable not only to its properties but also to the interaction of a genotype and non-genetic factors. Among them there is a group of conditions, known as maternal risk factors, that have particularly strong effects during foetal period, according to some researchers, being of selective importance [5]. Our earlier research on the maternal conditions specified by perinatal medicine for risk factors shows that it seems reasonable to assume their selective value since they cause a decrease in the level of prenatal development and so may lead to growth retardation of a foetus. Yet our findings demonstrate that there is no clear evidence for definite acceptance of this statement. [1, 2].

Our other studies of foetal growth, showing that sexual dimorphism exists in this phase of human ontogenesis and also some suggestions coming from recent literature, prompted us to examine whether both sexes are alike or not in the sensitivity to influences of maternal risk factors.

MATERIAL AND METHODS

The studied sample — a total of 3889 foetuses, aged from 20 to 42 weeks, included 2203 male and 1686 female individuals (Table 1). The data were collected over the years 1970-1990 at the Institute of Gynaecology and Obstetrics of the Medical Academy in Poznań. The material consisted of stillborn foetuses. The causes of their death were not specified. There was made a selection of study objects — that is, if the clinical diagnosis allowed to recognise the disease which might lead to foetuses' death, they were not included in the group. Individuals with genetic defects and congenital abnormalities were not analysed either. Gestational age — measured from the date of the last menstruation of the mother, was taken as the chronological age of a foetus. The analysis of somatic features and mass of the internal organs was made in weekly groups. Biological and environmental description of the studied material was founded on information available from clinical documents (interviews with the mothers).

Table 1. The numbers in the studied age groups

week	20	21	22	23	24	25	26	27	28	29	30	31
males	53	45	61	91	120	128	127	104	162	153	137	131
females	26	22	47	66	94	95	96	112	102	82	107	108
week	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**totals**
males	122	120	103	90	83	75	77	83	58	50	30	2203
females	96	76	79	75	78	73	61	49	71	38	33	1686

Basic statistical methods were applied to evaluate the average values, dispersion measures and significance of the differences.

RESULTS AND CONCLUSIONS

To assess the effects of maternal age, the pregnancy order and previous spontaneous or induced abortions on foetal development of somatic dimensions and mass of the internal organs, the analysis for each sex was performed within a seven-month period of gestation, namely from the age 5 to 11 months. For each month of foetal life the data were considered in separate categories, defined according to the influencing factor.

Using the analysis of variance, it was found that male foetuses at 5 months of age showed differences between the specified categories only in morphologic characteristics. In the group of female foetuses the studied factors influenced body weight and circumferences. All other features did not vary significantly. It was observed that in female foetuses aged 5 months only the mother's age over 35 years was associated with the decline of the above-mentioned variables.

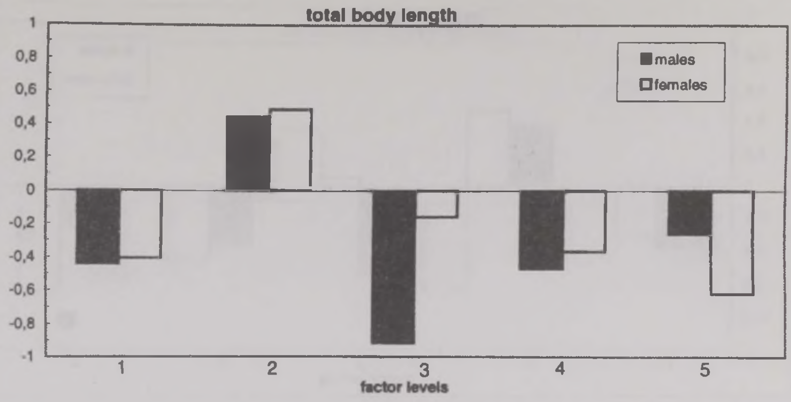
For both sexes in all subsequent months the calculated values of F-Snecodor test are greater than those for probability level at a = 0.01, thus it is indicated that the factors under study act significantly upon the development of somatic traits and mass of the internal organs from the 6th month of foetal life. It was observed that the largest measurements were characteristic of male and female foetuses from mothers without previous foetal loss, multiparous, aged between 20 to 35 years. Moreover, in both sexes the highest sensitivity to the maternal factors was stated the in case of body weight and brain mass.

To increase the number of observations in particular categories, the standard scores were obtained with removing foetal variation derived from age. Due to this procedure the entire foetal period was represented solely by the five categories (Table 2).

Table 2. The numbers in the categories of risk factors after standardisation

sex	categories				
	1	2	3	4	5
males	251	1124	16	411	56
females	187	774	13	322	72

The analysis supported the previous results, showing that the highest standardised values were gained by foetuses assigned to the second category, which are not exposed to risk factors. The highest sensitivity of body weight and brain mass was also confirmed. Concerning the sex-dissimilarities, it was found that maternal age varied the most the results obtained for the males and females. Even though primiparous gestation and previous miscarriages lowered the values of traits slightly more in male foetuses, both sexes are not different with respect to the sensitivity to the influence of maternal factors.


total body length
males
females
1
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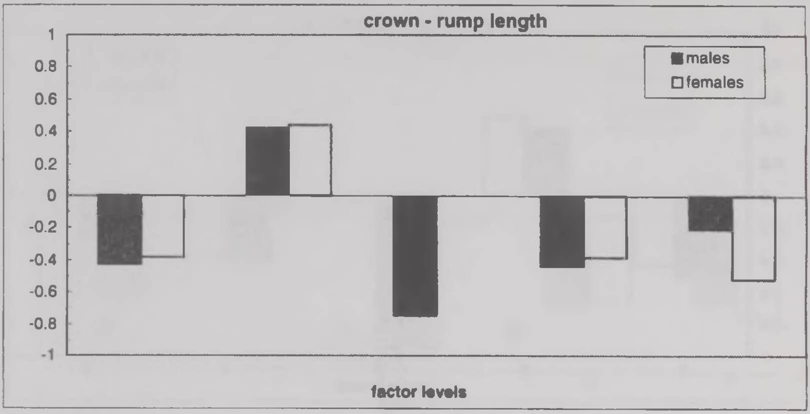
0,6
0,4
0,2
0
-0,2
-0,4
-0,6
-0,8
-1
1
2
3
4
5
factor levels


crown - rump length
males
females
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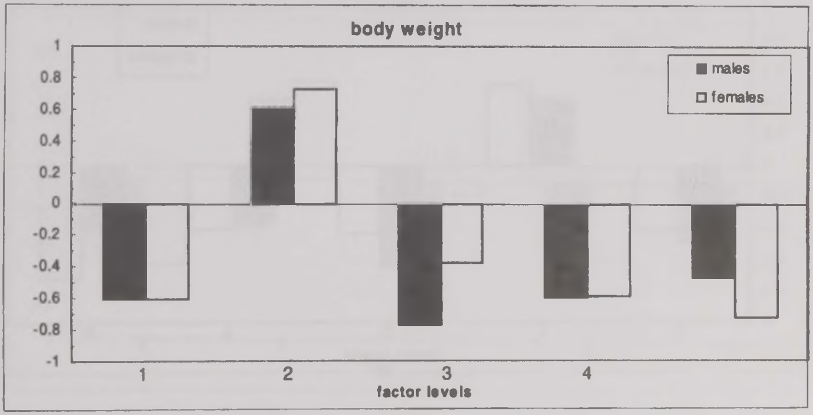
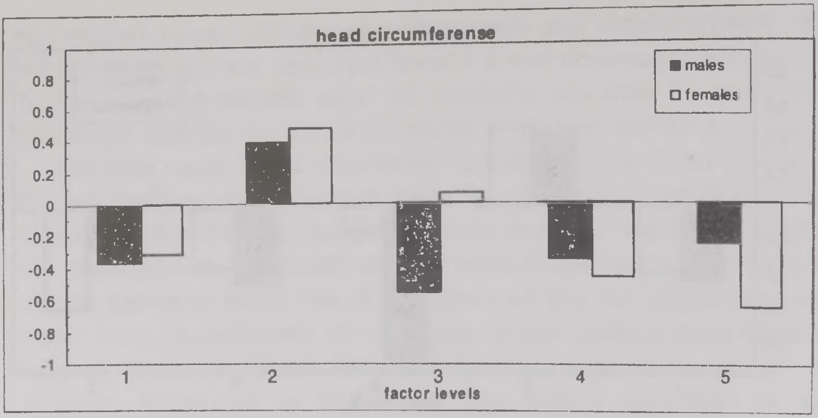
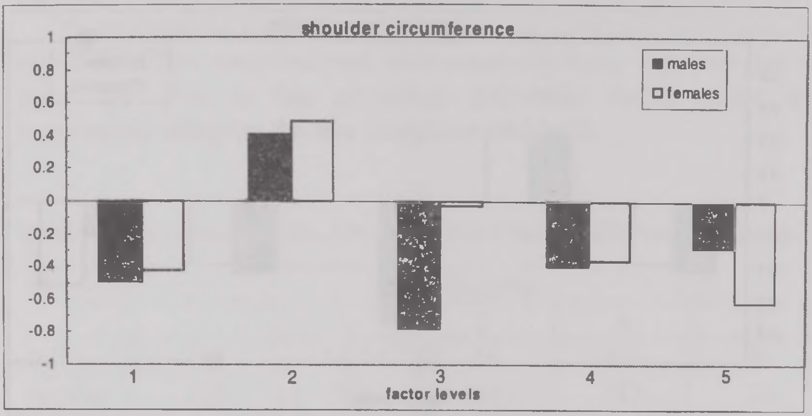
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
factor levels


body weight
males
females
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
2
3
4
factor levels


head circumferense
males
females
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1 2 3 4 5
factor levels


shoulder circumference
males
females
1
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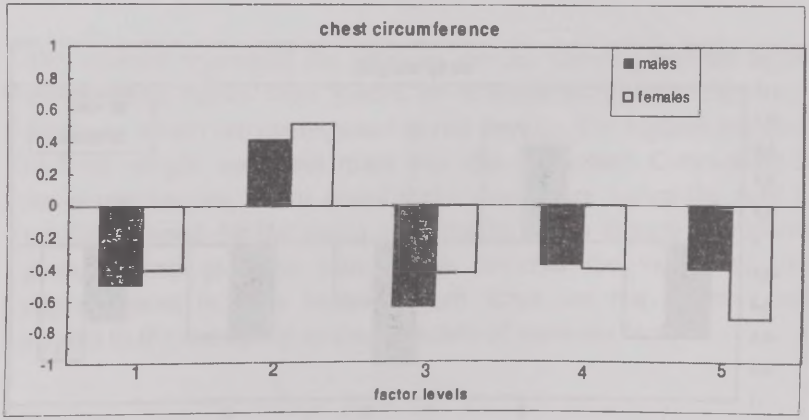
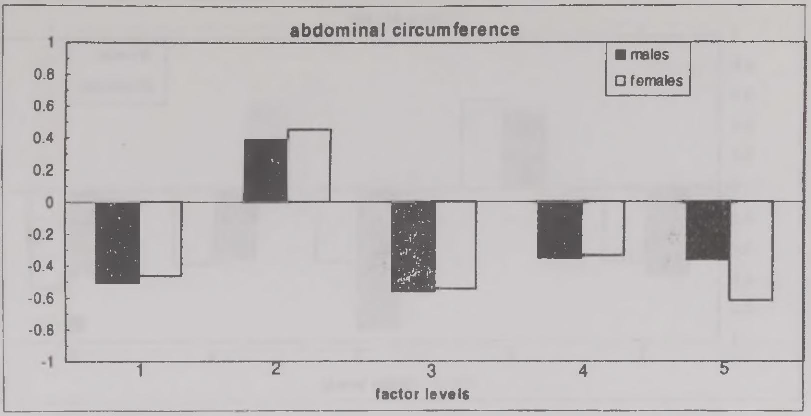
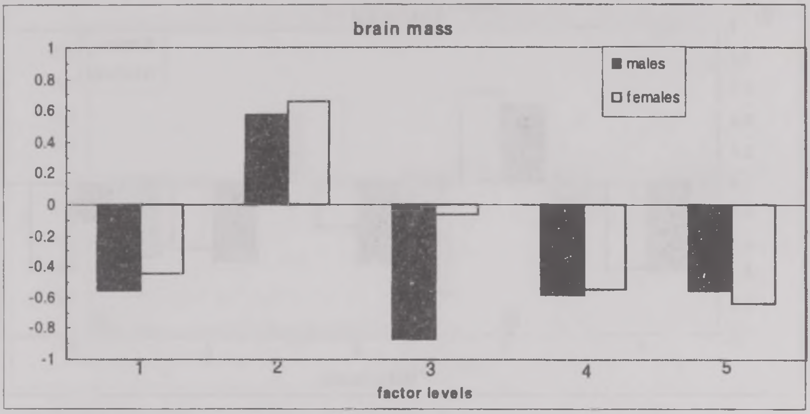
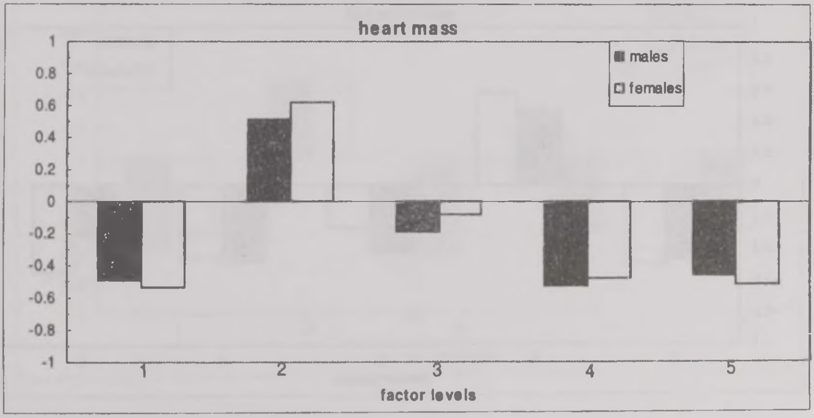
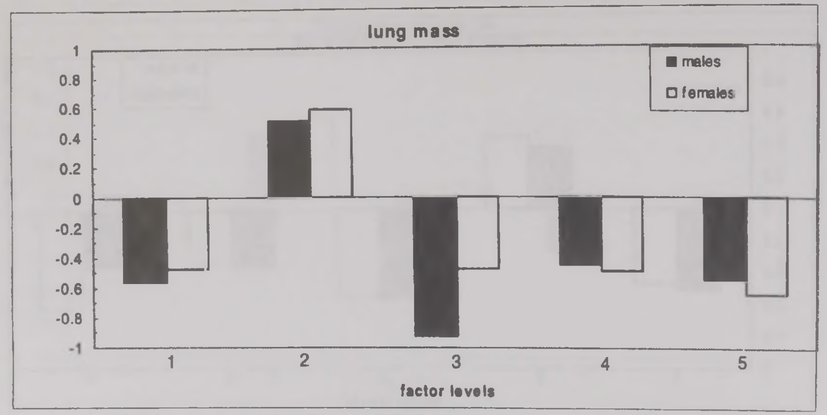
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1 2 3 4 5
factor levels

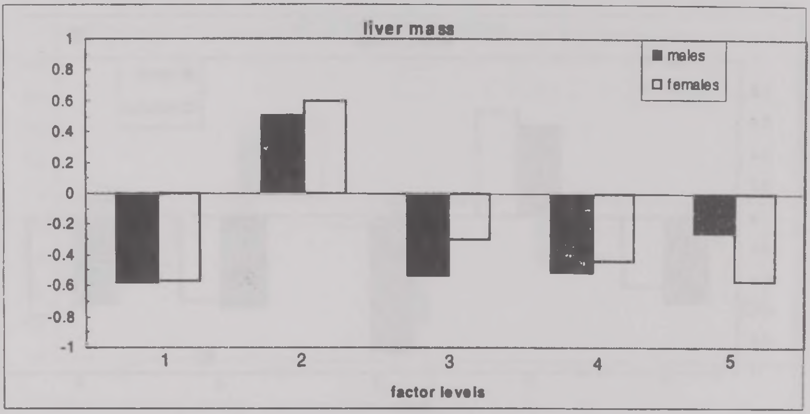

chest circumference
males
females
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1 2 3 4 5
factor levels

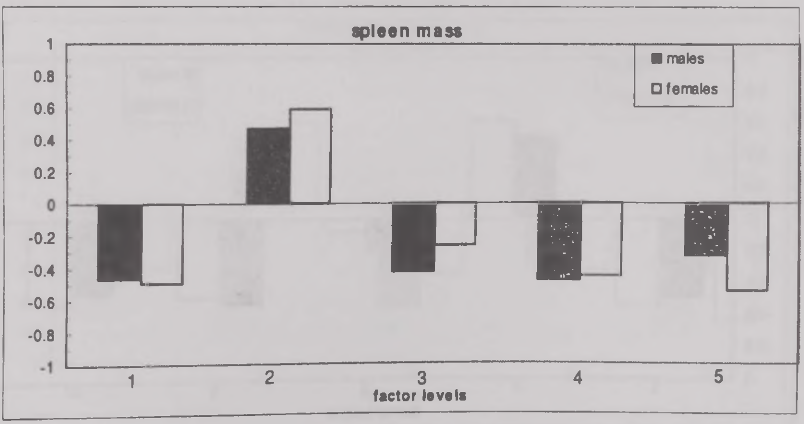

abdominal circumference
males
females
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
2
3
4
5
factor levels


brain mass
males
females
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
2
3
4
5
factor levels


heart mass
males
females
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
2
3
4
5
factor levels


lung mass
males
females
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
2
3
4
5
factor levels


liver mass
males
females
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
2
3
4
5
factor levels


spleen mass
males
females
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
2
3
4
5
factor levels

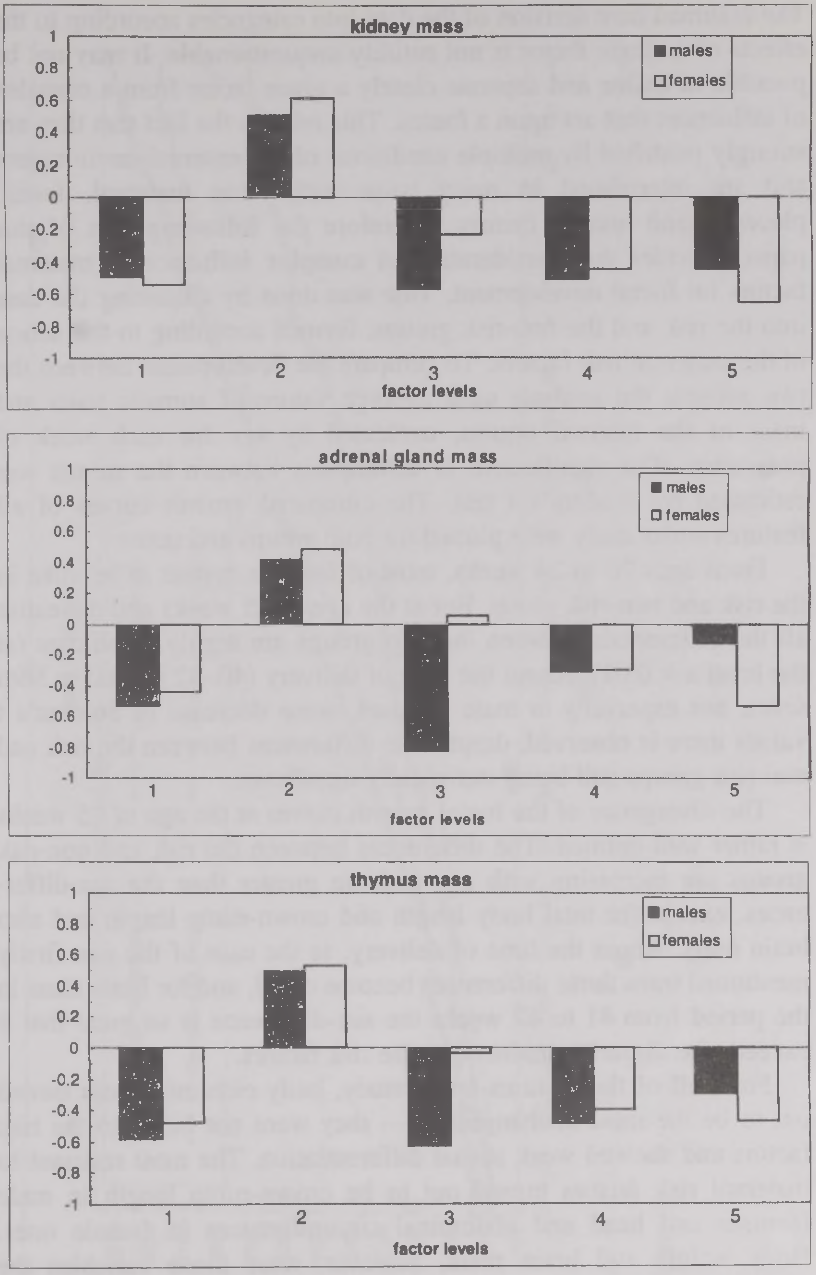


Figure 1. Standardies values of variances in the categories 1–5 of the factors.

The assumed here division of the data into categories according to the effects of a single factor is not entirely unquestionable. It may not be possible to define and separate clearly a given factor from a complex of influences that act upon a foetus. This reflects the fact that they are strongly modified by multiple conditions of the external environment and are interrelated in many ways with other maternal, foetal, placental and uterine factors. Therefore the following part of this paper provides the consideration of complex influence of maternal factors on foetal development. This was done by clustering the data into the risk and the non-risk groups, formed according to the action of the maternal risk factors. To compare the development between the two groups, the analysis used average values of somatic traits and mass of the internal organs, evaluated by sex for each week of pregnancy. The significance of differences between the means was estimated by Student's t test. The compared growth curves of all features under study were plotted for both groups and sexes.

From ages 20 to 24 weeks, most of features appear to be alike in the risk and non-risk group. But at the age of 25 weeks and thereafter all the differences between the two groups are highly significant (at the level a = 0.01). About the time of delivery (40–42 weeks) in both sexes, but especially in male foetuses, some decrease in Student's t values there is observed, despite the differences between the risk and non-risk groups still being statistically significant.

The divergence of the foetal growth curves at the age of 25 weeks is rather well-defined. The differences between the risk and non-risk groups are increasing with age and are greater than the sex-differences, except for total body length and crown-rump length and also brain mass. About the time of delivery, in the case of the two firstly mentioned traits those differences become equal, and for brain mass in the period from 41 to 42 weeks the sex-difference is so great that it exceeds the disparity produced by the risk factors.

From all of the features under study, body circumferences turned out to be the most unchangeable — they were not liable to the risk factors and showed weak sexual differentiation. The most resistant to maternal risk factors turned out to be crown-rump length in male foetuses and head and abdominal circumferences in female ones. Body weight and brain mass, however, were those variables the development of which was most strongly modified by the considered group of risk factors, both in males and females (Fig. 2).


body weight
males-risk group
males-non-risk group
females-risk group
females-non-risk-group
3750
3450
3150
2850
2550
2250
1950
1650
1350
1050
750
450
150
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
age in weeks

Figure 2.

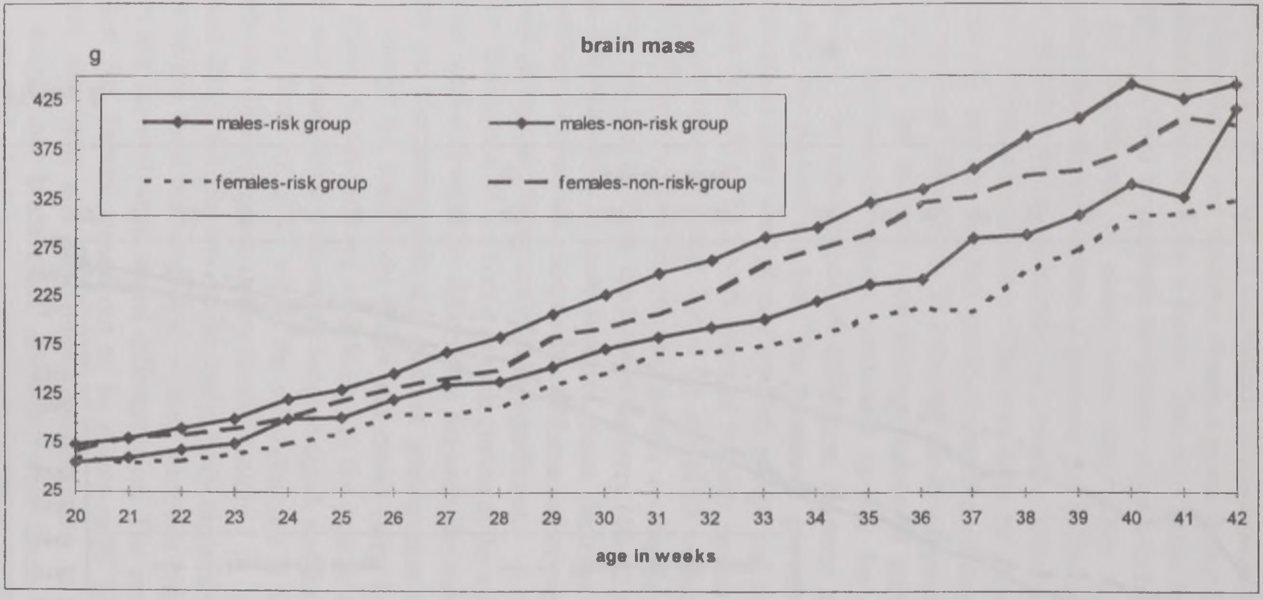


Figure 2. Growth curves for the variables in the risk and non-risk groups compared by sex.

Summarising the obtained results it may be concluded that in human foetal life there appears sexual dimorphism, though not great, in the strength of reaction to influences of maternal risk factors. The male foetuses revealed slightly higher sensitivity to the factors under study: maternal age, the pregnancy order and previous loss of gestation. It was evidenced by the fact that compared to the females, they showed greater variation between the specified categories of maternal influences in most variables. Probably it is the result of stronger genetic control of these traits in female foetuses.

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PROPORTIONS AND GROWTH OF FACE IN CHILDREN AGED 7–13 FROM THE CITY OF SOFIA

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ABSTRACT

The aim of the study was to disclose the tendencies in face growth at the age of 7 to 13 years. The subjects of the study included 143 boys and 154 girls from three schools in Sofia. The research was carried out in from 1993 to 1999. Eight cephalometric features and six indices were chosen for analysis. The ratios between the breadth and height dimensions were traced and the differing rate of change onset in various parts of the face was recorded. Both absolute sizes and indices prove the dynamic changes in face morphology during the age period from 7 to 13 years.

Key words: longitudinal study, cephalometry, age changes, sexual dimorphism

INTRODUCTION

A programme providing for cephalometric and cephaloscopic studies was included in the project entitled “A longitudinal study on the physical development and sexual maturation of pupils from Sofia at the age of 7 to 13 years.“ Its main aim was to trace changes due to age in the development of the brain and face parts of the head, the ratio between the height and width measurements, the presence of sexual dimorphism as well as to record the alterations in the pigmentation of the skin, eyes and hair, in the shape of the nose and the face profile. In the present study special attention has been paid to the changes taking place in the development of the face portion of the head whose metric characteristics undergo dynamic between 7 and 13 years of age.

MATERIAL AND METHODS

143 boys and 154 girls at the age of 7 to 13 years from three schools in Sofia were subjected to the study. The investigation was carried out in each successive year from 1993 to 1999 (during the months of October and November). Using the classical anthropological methods [1], the changes in nine measurements and six indices characterizing face development in its different parts have been traced and analyzed. The measurements comprise: breadth and height of face, bizygomatic breadth and bigonial breadth, total face, physiognomical upper face and morphological face height, nose width and height as well as the corresponding morphological face and physiognomic upper face indices, jugo-frontal, jugo-mandibular, fronto-mandibular and nasal indices.

RESULTS AND DISCUSSION

Since embryonic stage, human brain has been far ahead from other organs in its development, and accordingly the cerebral part of the head should reach its final stage of development much earlier than the facial part [4]. In contrast to the cerebral portion, the dimensions of the facial part reach the values typical of adult individuals considerably later. The close follow-up of age alteration in face metric characteristics reveals the varying rate at which they are taking place in its different parts. Increase both in absolute values and percentage shows several clearly outlined tendencies between 7 and 13 years of age.

Analyzing the basic measurements and proportions of the face in the seven age groups under study, two separate stages in the development of the facial portion are outlined: between 7 and 10 and from 10 to 13 years of age. They are distinguished from one another by the general morphological characterization and mainly by the rates of growth of the breadth and height measurements of the face in its different portions. The first period is characterized by a more rapid increase of the breadth measurements and a relative rounding of the face. Most distinct are the changes in the breadth of the mandible followed by those in the zygomatic and frontal portions (Table 1). Com-

Table 1. Age changes in the breadth dimensions of the face

Feature	Age Group	Boys			Girls		
		n	x	SD	n	x	SD
Frontal breadth	7	134	100.54	3.53	146	98.70	3.29
	8	142	102.05	3.58	154	100.49	3.07
	9	141	103.12	3.53	150	101.39	3.34
	10	143	103.86	3.49	154	102.39	3.14
	11	141	104.18	3.63	154	103.01	3.30
	12	132	104.80	3.53	144	103.86	3.39
	13	124	106.15	3.60	136	105.06	3.47
Bizygomatic breadth	7	134	118.69	4.42	146	116.48	4.19
	8	142	121.63	4.21	154	119.65	4.19
	9	141	123.24	4.38	150	120.90	4.25
	10	143	124.43	4.14	154	122.12	4.29
	11	141	124.90	4.27	154	122.43	4.32
	12	132	126.29	4.25	144	124.28	4.57
	13	124	127.89	4.58	136	125.50	4.60
Bigonial breadth	7	134	90.87	4.07	146	88.90	4.09
	8	142	94.78	3.90	154	92.92	4.26
	9	141	97.20	3.98	150	95.04	4.11
	10	143	98.75	3.85	154	96.82	3.99
	11	141	99.21	3.78	154	97.30	4.30
	12	132	100.42	3.90	144	99.18	4.17
	13	124	101.92	3.94	136	100.15	4.24
Nasal breadth	7	134	29.33	1.71	146	28.43	1.80
	8	142	31.01	1.59	154	30.06	1.80
	9	141	31.82	1.61	150	30.91	1.81
	10	143	32.51	1.52	154	31.89	1.71
	11	141	32.57	1.65	154	31.98	1.87
	12	132	33.32	1.75	144	32.92	1.89
	13	124	34.09	1.79	136	33.46	1.85

paring the breadths in the middle and lower parts of the face a considerably faster increase occurs in bigonial breadth — by 8.67% in boys and 8,91% in girls. Bizygomatic breadth grows more slowly — by 4.84 % in both sexes (Fig. 1). At this age the jugo-mandibular index

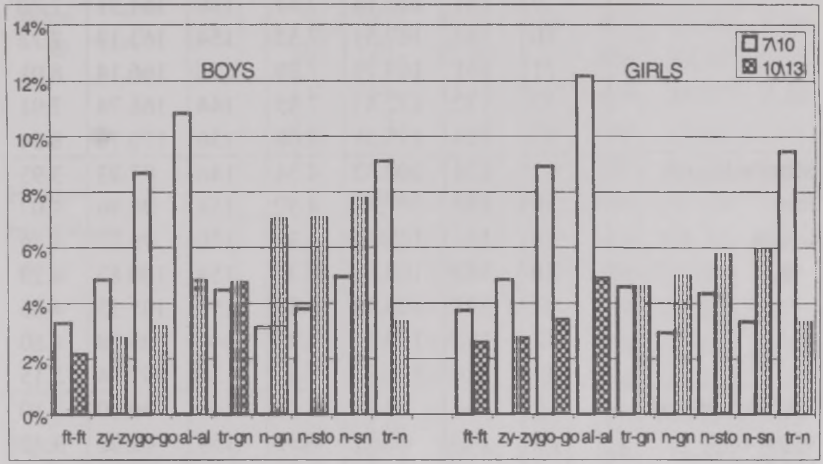

Figure 1. Rate of increase of the facial part of the head

(8:6) grows while the jugo-frontal (4:6) and the fronto-mandibular (4:8) indices show a tendency to decrease (Table 3). At the next stage (from 10 to 13 years of age) the breadth measurements of the face displayed tendencies towards slower and more even changes, and the indices retain close values. At the age of 13 the faces are evenly oval in contrast with the faces of the 7-year-olds that are markedly broader in the frontal region and with a narrow mandible. A significant finding of the close follow-up of the height measurements was that throughout the entire period of the investigation the physiognomical face height grew at an even rate, while the morphological facial and the physiognomical upper-facial heights increased considerably only after the age of 10 years (Table 2). The explanation to this fact is rooted in the almost three times quicker increase of the frontal height at the beginning of school age. The tendencies observed in the development of the face part are characteristic of both sexes. Differences between the boys and the girls were detected in the absolute values of the

Table2. Age changes in the height dimensions of the face

Feature	Age Group	Boys			Girls		
		n	x	SD	n	x	SD
Physiognomical face height	7	134	160.33	7.33	146	156.04	7.64
	8	142	162.47	7.59	154	157.86	8.00
	9	141	166.14	7.47	150	161.31	7.70
	10	143	167.51	7.55	154	163.19	7.72
	11	141	169.79	7.89	154	166.14	8.01
	12	132	172.45	7.85	144	168.74	7.91
	13	124	175.51	8.68	136	170.76	8.54
Morphological face height	7	134	100.52	4.54	146	97.93	3.95
	8	142	101.45	4.50	154	98.96	4.07
	9	141	102.38	4.32	150	99.72	4.16
	10	143	103.67	4.36	154	100.82	4.29
	11	141	105.98	4.83	154	103.53	4.66
	12	132	108.05	4.84	144	105.88	4.80
	13	124	111.00	5.41	136	107.54	5.15
Physiognomical upper face height	7	134	62.42	3.10	146	60.80	3.10
	8	142	63.25	3.36	154	62.03	3.12
	9	141	64.01	3.35	150	62.81	3.10
	10	143	64.79	3.26	154	63.44	3.10
	11	141	66.13	3.39	154	64.92	3.37
	12	132	67.67	3.60	144	66.21	3.46
	13	124	69.39	3.98	136	67.11	3.45
Frontal height	7	134	59.11	5.65	146	57.34	6.17
	8	142	60.67	5.98	154	58.71	6.60
	9	141	63.75	6.26	150	61.85	6.40
	10	143	64.49	6.06	154	62.76	6.12
	11	141	64.70	5.94	154	62.80	6.16
	12	132	65.80	5.99	144	64.01	5.96
	13	124	66.66	6.03	136	64.85	6.02
Nasal height	7	134	43.75	2.71	146	43.23	2.74
	8	142	44.49	2.84	154	44.01	2.95
	9	141	45.32	2.84	150	44.66	2.85
	10	143	45.91	2.82	154	45.48	2.85
	11	141	46.57	2.75	154	45.99	2.98
	12	132	47.70	3.01	144	47.30	2.97
	13	124	49.49	3.31	136	48.18	2.81

Table 3. Age changes in the basic face indices

Feature	Age Group	Boys			Girls		
		n	x	SD	n	x	SD
Jugo-frontal index	7	134	84.75	2.57	146	84.87	2.59
	8	142	83.92	2.63	154	84.06	2.46
	9	141	83.71	2.34	150	83.86	2.59
	10	143	83.50	2.17	154	83.56	2.42
	11	141	83.45	2.32	154	84.17	2.20
	12	132	82.97	2.38	144	83.62	2.38
	13	124	83.05	2.49	136	83.76	2.36
Fronto-mandibular index	7	134	110.78	4.62	146	111.26	4.42
	8	142	107.56	4.80	154	108.32	4.40
	9	141	106.09	3.85	150	106.80	3.95
	10	143	105.22	3.72	154	105.84	3.97
	11	141	105.09	3.74	154	106.05	3.86
	12	132	104.46	4.00	144	104.87	3.78
	13	124	104.24	3.83	136	105.02	3.65
Jugo-mandibular index	7	134	76.66	2.68	146	76.34	2.49
	8	142	78.08	2.81	154	77.69	2.76
	9	141	78.94	2.46	150	78.57	2.54
	10	143	79.43	2.22	154	79.28	2.55
	11	141	79.45	2.11	154	79.46	2.53
	12	132	79.50	2.30	144	79.77	2.42
	13	124	79.58	2.84	136	79.85	2.44
Morphological face index	7	134	84.76	4.18	146	84.12	3.28
	8	142	83.45	4.10	154	82.76	3.56
	9	141	83.16	3.99	150	82.50	3.40
	10	143	83.38	3.91	154	82.59	3.52
	11	141	84.92	4.04	154	84.61	3.70
	12	132	85.61	4.04	144	85.17	3.78
	13	124	86.85	4.32	136	85.68	3.93
Physiognomical upper face index	7	134	52.64	2.60	146	52.23	2.61
	8	142	52.02	2.87	154	51.91	2.73
	9	141	52.03	3.02	150	51.99	2.67
	10	143	52.11	2.80	154	51.98	2.65
	11	141	53.00	2.90	154	53.06	2.88
	12	132	53.59	2.92	144	53.32	2.90
	13	124	54.27	3.34	136	53.55	2.94

Feature	Age Group	Boys			Girls		
		n	x	SD	n	x	SD
Nasal index	7	134	67.29	5.42	146	66.00	5.46
	8	142	69.95	5.48	154	68.60	5.85
	9	141	70.49	5.80	150	59.54	6.06
	10	143	71.10	5.53	154	70.38	5.65
	11	141	70.11	5.56	154	69.80	5.98
	12	132	69.97	5.97	144	69.85	5.85
	13	124	69.21	5.29	136	69.66	5.28

studied features, which were on the average by 2 mm greater in boys of all age groups (Fig. 2). In the pubescence period the elongation of the faces takes place a little earlier in girls. The same tendency was discovered by Zellner in pupils from the town of Jena [5]. Morphological face height in girls shows an abruptly rapid growth between the years 11 and 12, after which this increase is retarded while in boys the tendency towards face elongation lasts till the 14th year of age. According to the face index, which decreases till the age of 10 in both sexes and later progressively increases, boys turn from euryprosop to mesoprosop, and girls change from mesoprosop into leptoprosop as early as at 12 years of age. The physiognomical upper-face index is at the level of mesen eurien in both sexes between 8 and 10 years of age, after which it grows, though remaining in the mesen category. The changes in nose sizes correspond to the general face proportions. From the 7^{th} to the 10^{th} year of age nose breadth grows significantly more rapidly, and the index changes from leptorrhin to mesorrhin, while after 11 years of age the height of the nose grows more rapidly than the breadth, and noses change to leptorrhin again (Fig. 3). Similar changes in face proportions have also been observed by Slovenian scientists. In studies on the growth of head and face in children from Ljubljana, Štefancič has established that intensive increase in facial and nasal height leads to changes of proportions between breadth and height, showing a distinct tendency to leptoprosopy and leptorrhiny [2, 3]. In the case of face parameters a noticeably earlier adolescent spurt was established in girls. Girls experience the most intensive spurt of growth between 10 and 12 years of age, while boys — between 12 and 14 years of age.

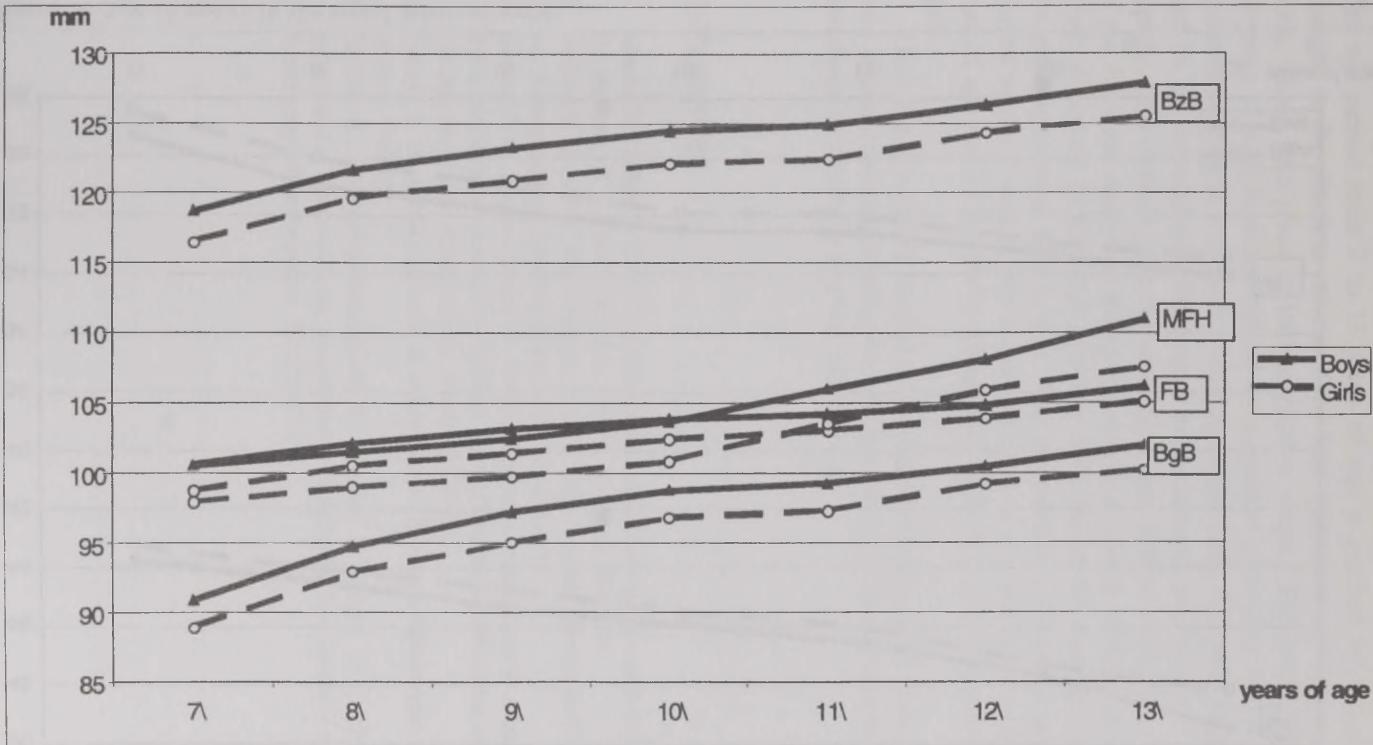

Figure 2. Age changes in the face measurements

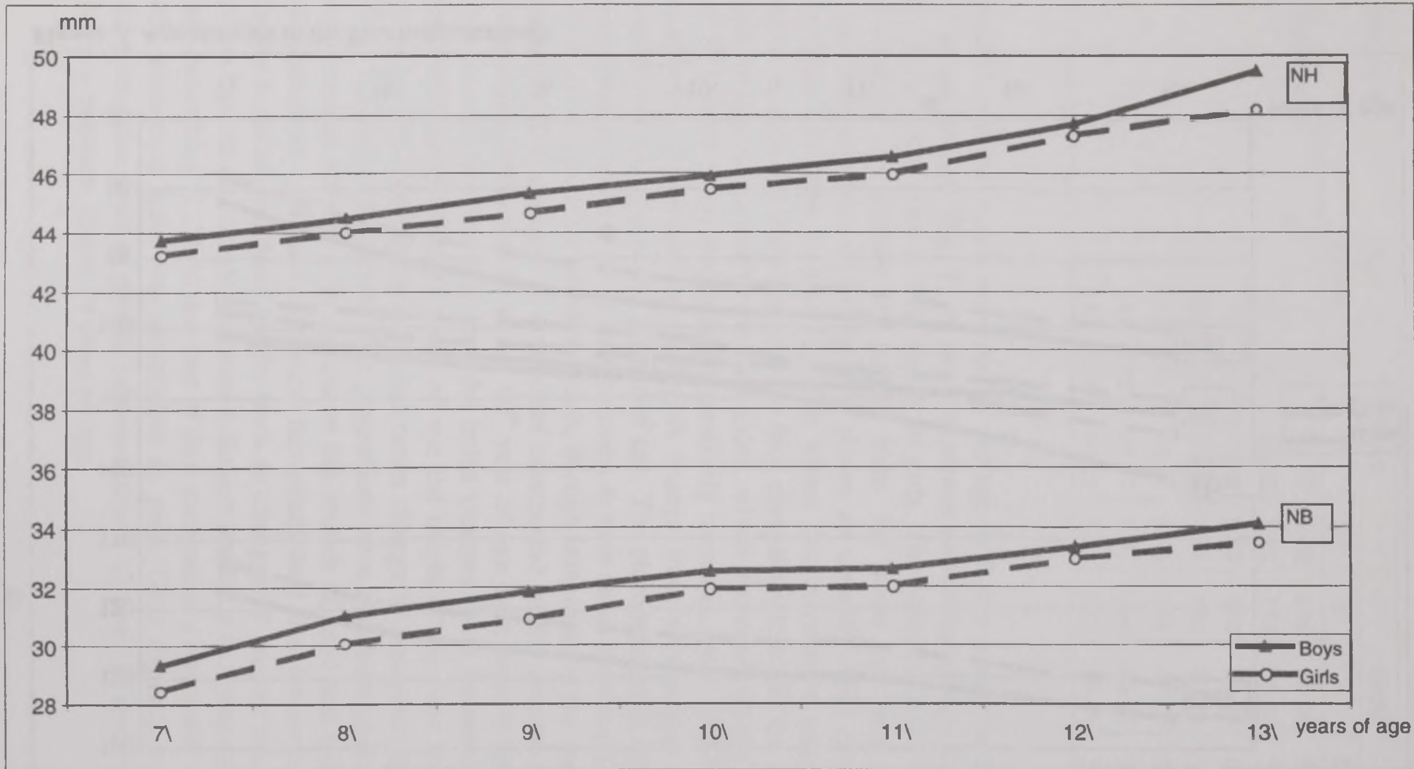

Figure 3. Age changes in the nasal measurements

The age period from 7 to 13 years of age is marked by significant changes in the absolute values of the face measurements and proportions, which take place in two successive stages. The first stage (7–10 years of age) is characterized by a quicker growth of the breadth measurements and a relative rounding of the face. Between years 10 and 13, on the contrary, the height measurements tend to grow more rapidly, thus changing the corresponding face indices. Only the height of the forehead makes an exception owing to the development of the cerebral portion of the skull which is reflected in the even growth of the physiognomical face height. The intersexual differences are displayed by the 2 mm bigger mean values in boys starting from the 7^{th} year of age and by the earlier elongation of the faces during puberty in girls.

Thus, the age period studied is associated with dynamic changes in face characteristics, yielding knowledge that can be of considerable assistance to clinically applied anthropology.

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SECULAR TREND OF MENARCHE IN ESTONIA

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ABSTRACT

Secular trend of menarche was followed on a sample of female residents of Tartu (Estonia). The first studies about menarche of Estonian women were published in 1893 and in 1896. The mean age at menarche has reduced by 2.09 years during the last hundred years.

Key words: age at menarche, Estonian girls

INTRODUCTION

The first menstrual period is a milestone in the maturation process of women. The age of menarche as well as other characteristics of menstrual function are determined by a combination of such biopsychosocial factors as genetic influences, socio-economic conditions, general health and well-being, nutritional status and certain types of exercise [2, 3, 5, 9, 10, 12, 14–17, 19, 22]. The first data about the menstrual function of Estonian women were published in a study by F. Bidder in 1893 [13] and in another by J. Miländer in 1896 [13, 20]. Both studies were made on a sample of women giving birth to their first children in the Women's Hospital of the University of Tartu. The data about the age at menarche of Estonians from the last decade of the 19th century show that it was quite similar to the age at menarche of Swedes, Jews, Russians and Japanese (Fig. 1). J. Miländer found that in 70% of women (n = 158) menarche occurred at the age of 14 to 16; the earliest onset of menarche was at the age of 12 and the latest at the age

20, while the mean age at menarche was 15.1 years (see also Fig. 2). In 1926, a study carried out on the students of the Girls' Gymnasium of Tartu (n = 517) was published [13], where the earliest onset of menarche was at the age of 11 years, and 81% of the girls had menarche between the age of 13 and 15 years with the mean age of 14.58 years. In the 1990s the mean age of Estonians at menarche has been reported at 13.2 ± 0.97 years on the sample of schoolgirls living in the South Estonia (n = 497) [6]) and at 13.1 ± 1.1 years on the sample of schoolgirls living in the city of Tartu (n = 1187) [9].

The present study surveyed the age at menarche of Estonian girls and compared the results with the previously published data. For studying the date of the onset of menarche, the data collected in an early postmenarcheal period are of higher credibility than data collected later [11]. For that reason, secondary school students from grades 9 to 12 were chosen for the sample of the study.

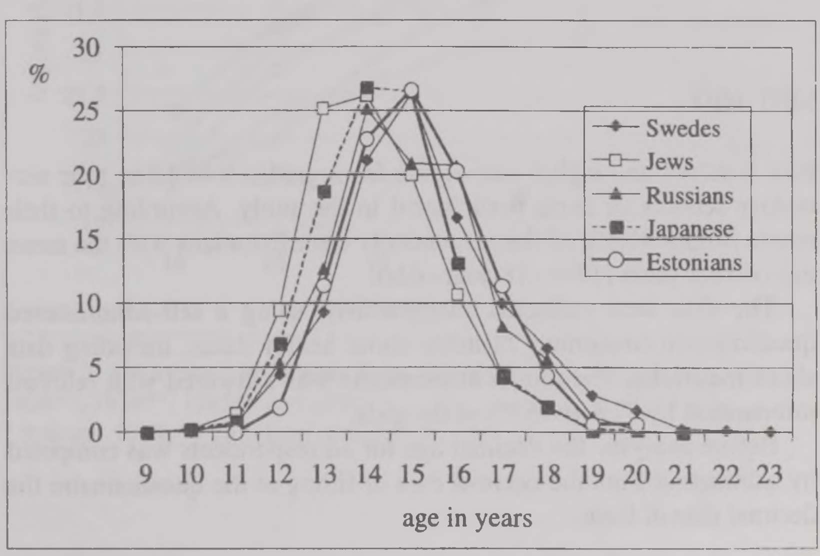

Figure 1. Distribution of age at menarche of Estonians by J. Miländer (Silla & Teoste, 1989), Swedes (Essen-Müller, 1906), Jews and Russian (Weissenberg, 1909), Japanese (Yamasaki, 1909) at the end of the 19^{th} century.

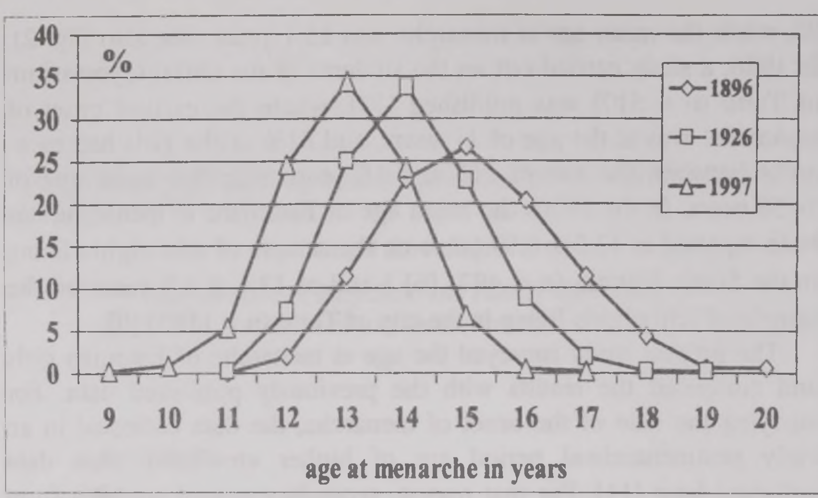

Figure 2. Estonians' age at menarche in 1896 (by J. Miländer), in 1926 (by H. Madisson) and in 1997.

METHOD

Five hundred and eighty schoolgirls from grades 9 to 12 in four secondary schools in Tartu participated in the study. According to their ethnic origin, 99.1% of the respondents were Estonians with the mean age of 16.2 years (13- to 18-year-olds).

The data were collected anonymously, using a self-administered questionnaire containing 72 items about health status, including data about menarche. The month at menarche was answered with relevant information by 87% (n=505) of the girls.

Before analysis the decimal age for all respondents was computed by subtracting from the decimal date of filling in the questionnaire the decimal date of birth.

RESULTS

The mean age at menarche was 13.01 years, varying from 9 to 17 years (Fig. 2). For 6.5% of the respondents the age at menarche was between 9 and 11 years, for 84% between 12 and 14 years and for 7.5% between 15 and 17 years, and 17 of the respondents were pre-menarcheal (mean age 14.8 years; 14- to 17-year-olds).

Compared with the earlier observations, the age of Estonians at menarche showed a decline of 0.43 years during the period from 1896 to 1926, of 1.29 years from 1926 to 1971 and 0.28 years from 1971 to 1997.

The comparison of data from 1896 and 1997 revealed the total secular trend of reduction of age at menarche by 2.09 years (Fig. 2).

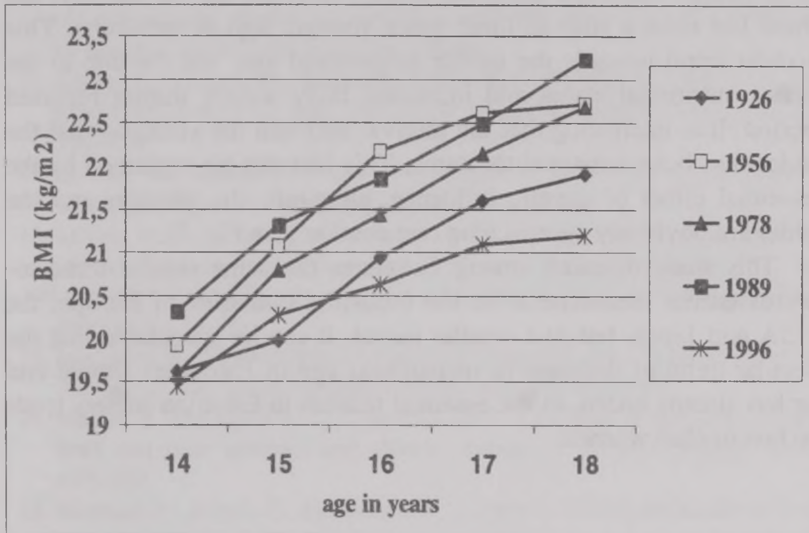

Figure 3. The average body mass index (kg/m2) of Estonian girls in 1926*, 1956**, 1978**, 1985** and 1996**.
* Reiman, 1928; ** Grünberg *et al.*, 1998

DISCUSSION

In the current study, similarly to the studies carried out in 1896, 1926 and 1933, the sample represented female residents of the city of Tartu. The reported fall in the age at menarche of Estonians is 2.5 months per decade during the last one hundred years. This is a slower trend towards earlier menarche than reported in the industrialised countries of Europe, the USA and Japan, with a decrease of about three or four months per decade [17]. The decelerated trend towards earlier menarche is seen in the period from 1971 to 1997. This can be explained by the simultaneous fall in body mass in Estonian population during the last decade [6, 7].

In 1896, the onset of menarche of Estonians fell between the ages of 12 and 20 years, in 1926 between the ages of 11 and 19 years and in 1997 between the ages of 9 and 17 years, which characterises well the secular shift in the maturation process of Estonian women. The difference between the age of the youngest and the oldest respondent at menarche has been the same (nine years) during the century, but there has been a shift to three years younger age at menarche. This secular trend towards the earlier menarcheal age can be due to the better nutritional status and increased body weight during reported period. It is interesting that the interval between the youngest and the oldest has been remained the same. This fact can be explained by the essential effect of genetic influence, although the younger and the older are obviously approaching one another (see Fig. 2).

This study revealed among Estonians the same secular trend towards earlier menarche as in the industrial countries of Europe, the USA and Japan, but to a smaller extent. It can be speculated that the secular trend of decrease in menarcheal age of Estonians should end or has already ended, as the essential fashion in Estonian society tends to favour slim women.

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BODY COMPOSITION ANALYSIS BY BIOELECTRICAL IMPEDANCE: EFFECT OF A SINGLE TRAINING SESSION IN MALE ROWERS

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ABSTRACT

The aim of the study was to investigate the influence of 30 minutes maximal rowing ergometer training session on body fluid parameters using bioelectrical impedance analysis method in 10 experienced rowers (22.8±4.8 yrs; 187.2±4.2 cm; 84.6±9.1 kg; percentage of body fat 15.7±4.0%). All rowers had a light traditional breakfast about three hours before the training session. Before and immediately after the training session and after 30 minutes of recovery body fluid balance was measured using a multiple-frequency bioelectrical impedance device (Multiscan-5000, Bodystat Ltd, UK). Extracellular (ECW), intracellular (ICW) and total body water (TBW) were measured at 5, 200 and 50 kHz, respectively. During maximal rowing ergometer training body mass of rowers decreased significantly from 84.7±9.1 to 83.6±9.6 kg. Significant changes in the amount of TBW occurred immediately after the training session (46.5±3.1 to 46.0±3.0 l), while the amount of ECW decreased significantly during the first 30 min of recovery (22.0±1.4 to 21.2±1.1 l). There were no significant changes in the balance of ICW. There were significant relationships between the covered distance and the following parameters after the training session: TBW (r=–0.71) and ECW (r=–0.71). It was concluded that 30 minutes maximal rowing ergometer training session changed significantly the balance of body fluids in rowers. In addition, the covered distance was significantly related to changes in body fluids.

Key words: bioelectrical impedance method, total body water, extracellular body water, intracellular body water, rowing ergometer

INTRODUCTION

Sweat is believed to be an important factor in affecting the body fluid balance because thermoregulatory responses produce cutaneous vasodilation, which depletes the central blood volume and, thereby, reduces the available blood to perfuse the working muscles [5]. Dehydration and redistribution of blood volume that occurs at the beginning of exercise may play an important role in exercise adaptation [5].

A simple and non-invasive method for the determination of body fluid distribution is needed to study the effects of exercise on body fluid balance. It is most likely that bioelectrical impedance analysis (BIA) may meet these criteria. It has been reported that body fluid loss resulting from sweating during jogging and cycling for 90 to 120 minutes substantially reduces body resistance (50 to 70 Ω) [7, 8]. The decrease in resistance after exercise is likely to reflect the relatively greater loss of body water through sweating and expired air compared to the loss of electrolytes [3]. This increases the electrolyte concentration in body fluids and lowers the resistance values of BIA measurements [3].

The aim of the present study was to measure repeatedly intracellular (ICW), extracellular (ECW), and total body water (TBW) using the BIA method. Specifically, the impact of a 30 minutes maximal rowing ergometer training session on body fluid balance in experienced rowers was investigated.

MATERIAL AND METHODS

Ten experienced male rowers (22.8±4.8 yrs; 187.2±4.2 cm; 84.6±9.1 kg; percentage of body fat 15.7±4.0%) volunteered to participate in the study. The subjects were training regularly and had been doing so for the last 5.1±1.7 years. The rowers were fully familiarized with the procedures and possible risks before providing their consent to participate in the experiment as approved by the Medical Ethics Committee of the University of Tartu. Heart rate (HR) was measured continuously and stored at five second intervals during the training session (Sporttester Polar Vantage NV, Kempele, Finland). The rowers were asked not to participate in any physical activity 24 hours before the training session and to abstain from eating three hours before the training session. They were allowed to drink as usual. The training session consisted of 30 minutes maximal rowing on a rowing ergometer (Concept II, Morrisville, USA). After voiding, the subjects' baseline (PRE) measurements were performed. Following the baseline measurements, the subjects warmed up by stretching and jogging for 15 minutes, and then performed 30 minutes maximal rowing on a rowing ergometer (mean covered distance: 7741.3±377.0 m). Exercise mean HR was 175.6±9.9 beats.min^{-1}. Lactate concentration in blood before exercise was 1.8±0.4 mmol.l^{-1}, and it increased significantly during the training session (after: 14.4±4.7 mmol.l^{-1}). The following procedures were repeated immediately postexercise (POST) and at 30 minutes (POST-30') from the exercise: weighing and the BIA. The subjects were not allowed to drink during the exercise and the 30 minutes recovery period.

BIA was performed using a four terminal multiple-frequency impedance analyser (Multiscan Bodystat-5000, Isle of Man, UK) to the nearest 1Ω. Resistance (R) values were recorded using electrodes placed on the right side of the body (right wrist to right ankle) [6]. The mean bioelectrical resistance of two trials was used. Extracellular (ECW), intracellular (ICW) and total body water (TBW) were determined at 5, 200 and 50 KHz, respectively, according to Hannan *et al.* [6].

Descriptive statistics (mean±standard deviation [SD]) for each dependent variable were determined after each measurement occasion. The non-parametric Friedman analyses of variance (ANOVAs) by ranks were used to examine changes at each test point as the raw data and their logarithmic transformations were not normally distributed. An alpha level of 0.05 was adopted. The Wilcoxon matched-pairs signed-ranks test was used where post hoc analysis was necessary. The Kendall Rank Correlation coefficient was used to determine the relationship between dependent variables at each time point. Again, an alpha level of 0.05 was used.

RESULTS AND DISCUSSION

Body mass and body fluid responses to rowing ergometer training session are presented in Table 1. The results of the present study demonstrated that a maximal rowing ergometer training session significantly changed the balance of body fluids in rowers (Table 1). The decrease in the body mass as a result of maximal rowing training was associated with a net fluid loss mostly from extracellular places, while the amount of ICW remained relatively unchanged during the 30 minutes recovery period (Table 1). This is in accordance with Dill and Costill [4] who suggested that less water is surrounded by intracellular places with their high protein concentration than by extracellular places during dehydration. In addition, the covered distance of 30 minutes maximal rowing ergometer training was significantly related to the post-exercise TBW ($r=-0.71$) and ECW ($r=-0.71$) indices but not to the post-exercise content of ICW. Thus, it appears that exercise-induced dehydration occurs primarily from extracellular places. The exercise-induced losses in the body mass and TBW were 1.1 kg (1.3%; $p<0.05$) and 0.5 l (1.1%; $p<0.05$), respectively, while no significant changes occurred in the ECW (0.5 l; 2.3%; $p>0.05$) and ICW (0 l; 0%; $p>0.05$) values immediately after the exercise. However, ECW value decreased significantly during the first 30 minutes of recovery (0.8 l; 3.6%; $p<0.05$) in comparison with pre-exercise value.

It is likely that there may be more changes in body fluids during the first 30 minutes of recovery than during exercise. HR, energy expenditure, and sweating rate are relatively high and decrease slowly during recovery. Skin temperature also normalizes during this time. All these parameters influence the body fluid balance and body resistance. Therefore, it is difficult to determine which independent parameters influenced more the values of body mass and TBW balance during the relatively short time of recovery after a maximal rowing ergometer training session.

The well-known limitations of BIA measurement should be taken into account when analysing the results of this investigation. It has been argued that BIA has "limitations for quantifying fluid compartments in the trunk and thus in the whole body" [2]. Furthermore, the BIA method is able to accurately detect only water volume changes when the electrolyte concentration is maintained constant [10]. The standard error of estimate under carefully controlled conditions for

TBW is < 2 l of water [1]. This is less than a 4% error by comparison with about 50 l of TBW in adults [1]. Accordingly, it is difficult to measure only a few litres of changes in the amount of TBW correctly.

Table 1. Body mass and body fluid responses to intensive endurance rowing training (X±SD)

Variable	PRE	POST	POST-30'
Body mass (kg)	84.7±9.1	83.6±9.0*	83.5±9.0*
TBW (l)	46.5±3.1	46.0±3.0*	45.6±3.2*
ECW (l)	22.0±1.4	21.5±1.2	21.2±1.1*#
ICW (l)	24.5±2.0	24.5±2.2	24.4±2.3

TBW — total body water. ECW — extracellular body water. ICW — intracellular body water.

* Significantly different from PRE; $p<0.05$.

Significantly different from POST; $p<0.05$.

In summary, the acceptability of multifrequency BIA for the measurement of body fluid balance during exercise training needs further research. For example, the study of Saunders et al. [9] indicated that even small changes in the body fluid balance that occur during endurance training may be interpreted incorrectly as changes in body fat content in athletes.

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RELATIONSHIPS BETWEEN ANTHROPOMETRIC PARAMETERS AND BODY RESISTANCE IN PREPUBERTAL GIRLS WITH DIFFERENT BODY MASS INDEX

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ABSTRACT

The purpose of the study was to investigate the possible relationships between skinfold thickness, girth, length and breadth/length parameters and body resistance in 9-11-year old girls (n=105) with different body mass index (BMI). Body stature and body mass were measured and BMI calculated. Girls were divided into six BMI categories — under 15, 15–16, 16–17, 17–18, 18–19 and over 19. Nine skinfolds, 13 girths, eight lengths and eight breadths/lengths were measured. Body resistance was measured with a multiple-frequency impedance device (MULTISCAN 5000, UK) at 50 kHz. Stepwise multiple regression analysis indicated that in the whole group of girls skinfold thickness values influenced body resistance by 9.2% ($R^2 \times 100$). The influence of skinfolds thicknesses was very different in the homogeneous subgroups selected by BMI (from 7.8% to 40.8%). Girth parameters characterized 51.2% of the total variance in the total group. The importance of length parameters in the whole group was relatively low (5.1%). The breadth/length parameters influenced body resistance in the whole group by 15.8%. In conclusion, the traditional use of body stature as a single anthropometric measure used in the presentation of prediction equations for body composition measurement is not acceptable. It is important to add girth and/or breadth/length parameters to stature in the prediction of body composition in prepubertal girls with different body constitution.

Key words: bioelectrical impedance, anthropometry, BMI.

INTRODUCTION

The theoretical basis for the bioelectrical impedance analysis (BIA) was proposed in the 1970s [8, 13]. The BIA method is based on Ohm's law which relates the impedance of a cylindrical conductor to its volume and length to the power of two. In prediction equations for BIA, the length of the biological conductor is taken to be the body stature [8, 13]. An electrical signal of known frequency is transmitted across a tissue bed and the impedance to this transmission is related to the conduction properties of the tissue. Electrolyte-containing fluids have a relatively low impedance while tissues devoid of fluids such as bone have a high impedance [10]. Total body impedance, measured at the constant frequency of 50 kHz (800μA), primarily reflects the volumes of water and muscle compartments comprising the fat-free mass (FFM) and the extracellular water volume [10].

Different segments of the body contribute to the resistance of the whole body to an extent that is out of proportion to their contribution to body mass [3, 5]. For example, the arm contributes only about 4% to body mass but as much as 45% to the resistance of the whole body in adults [5]. The thinner segments of the body provide the greatest resistance, especially when these segments are also long [5]. The influence of different anthropometric variables on body resistance in children has been poorly studied. However, the percentage of body water in boys from birth to 10 years of age has been reported to decrease as does the ratio of extra- and intracellular water [4]. Variation in hydration of FFM in children is relatively high [7].

From among the simple anthropometric parameters, body mass has been reported to be a good predictor of FFM in young males. This is not surprising, but the fact that body mass has a stronger predictive value than stature is important because stature is the most commonly used measurement in classical BIA prediction equations [6]. Houtkooper *et al.* [9] have also indicated that more information is needed regarding the size and shape of the conductor than provided by body stature in children aged 10–14 years. The purpose of this study was to investigate the possible relationships between skinfold thickness, girth, length and breadth/length parameters and body resistance in 9–11-year-old girls with different body mass index.

METHODS

The subjects of this study were 105 girls at 9–11 years of age. The children were from several schools in Tartu, Estonia (about 100,000 inhabitants), and all of them were of Estonian origin. School physical education consisted of 2–3 physical education lessons per week. All children, parents and teachers were thoroughly informed about the purposes and content of the study and written informed consent was obtained from the parent or the adult proband before participation. The study was approved by the Medical Ethics Committee of the University of Tartu (Estonia).

Measurements were performed in the morning at school after emptying the bladder. Girls had a light traditional breakfast and they did not exercise before the testing. All children were classified prepubertal Tanner stage 1 as pubic hair and breast ratings were both scored as stage 1 [14].

Stature was measured, using a Martin metal anthropometer, in cm (±0.1 cm) and body mass with medical scales in kg (±0.05 kg), and BMI (kg/m^2) was calculated. Girls were divided into six BMI categories (underweight to slightly obese) — under 15, 15–16, 16–17, 17–18, 18–19 and over 19, respectively.

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, iliospinale-box height, trochanterion-box height, trochanterion-tibiale laterale, tibiale laterale to floor, tibiale mediale-sphyrion tibiale) and eight breadths/lengths (biacromial, biiliocristal, foot length, sitting height, transverse chest, A-P chest depth, humerus, femur) were measured. Three series of anthropometric measurements were taken by a trained anthropometrist who had previously shown test-retest reliability of $r>0.90$. Skinfold thicknesses were measured using Holtain (Crymmych, UK) skinfold callipers. Other anthropometrical parameters were measured using the Centurion Kit instrumentation (Rosscraft, Surrey, BC, Canada). Calibration of all equipment was conducted prior to and at regular intervals during the data collection period. All anthropometric parameters were measured according to the protocol recommended by the International Society for Advancement of Kinanthropometry [12].

Body resistance was measured with a multiple-frequency impedance device (MULTISCAN 5000, Bodystat Ltd, UK). Children were placed in a supine position with limbs slightly abducted. Skin current electrodes were placed at the right dorsal surface on the hand and on the foot at the metacarpals and metatarsals, respectively, after the skin had been cleaned with 70% alcohol. The distance between the source and receiving electrodes was at all times greater than 5 cm [3]. Only the resistance measured at 50 kHz was used. The analyzer was calibrated before each test by using the standard resistor provided by the manufacturer. All measurements of children were performed on the same day and were completed within one hour from the commencement of testing.

Standard statistical methods were used to calculate the mean ($\overline{X}$) and standard deviation (±SD). Spearman correlation coefficients were used to determine the relationships between dependent variables. The effect of different anthropometric parameters on body resistance was analyzed by stepwise multiple regression analysis. Prediction errors for the equations were evaluated using standard error of estimate (SEE). Significance was set at $p<0.05$.

RESULTS

The mean data for anthropometric parameters are presented in Table 1. The mean body resistance in girls at 50 kHz was 626.8±56.6Ω.

Spearman correlation analysis indicated that stature significantly influenced body resistance (r=–0.19). However, the most important predictors were body mass (r=–0.42) and BMI (r=–0.45). All skinfold thicknesses correlated significantly with body resistance (r=0.20–0.35). As a rule, the girth parameters correlated significantly (r=–0.19–0.62) with body resistance. There were only a very few length parameters which influenced significantly body resistance. Most of the measured breadth/length parameters correlated significantly with body resistance at a relatively low level (r=0.20–0.53).

Table 1. Mean anthropometric variables in prepubertal girls ($\overline{X} \pm SD$)

	$\overline{X} \pm SD$
Age (yrs)	9.79±0.72
Stature (cm)	141.49±7.34
Body mass (kg)	33.29±6.43
BMI ($kg \cdot m^{-2}$)	16.50±2.15
Skinfolds (mm)	
Triceps	11.17±3.91
Subscapular	8.42±5.06
Biceps	7.50±3.38
Iliac crest	9.30±5.46
Supraspinale	6.20±3.84
Abdominal	9.67±6.20
Front thigh	18.02±5.85
Medial calf	13.32±5.18
Mid axilla	6.22±3.65
Girths (cm)	
Head	52.55±1.56
Neck	26.74±1.35
Arm relaxed	19.62±2.32
Arm flexed and tensed	20.98±2.36
Forearm	18.95±1.57
Wrist	12.94±0.81
Chest	65.98±6.04
Waist	56.39±5.08
Gluteal	71.57±6.31
Thigh	42.40±4.94
Thigh mid troch-tibiale laterale	38.99±3.98
Calf	28.25±2.48
Ankle	18.26±1.41
Lengths (cm)	
Acromiale radiale	30.02±1.91
Radiale-stylion	22.41±1.50
Midstylion-dactylion	16.19±1.06
Iliospinale box height	81.30±4.88

	$\overline{X} \pm SD$
Trochanterion box height	74.94±5.40
Trochanterion-tibiale laterale	38.71±2.85
Tibiale-laterale to floor	36.48±2.58
Tibiale mediale-sphyrion tibiale	29.05±2.06
Breadths/lengths (cm)	
Biacromial	30.94±2.03
Biiliocristal	21.88±1.63
Foot length	21.91±1.30
Sitting height	74.46±3.83
Transverse chest	20.73±1.35
A-P chest depth	14.42±2.59
Humerus	5.82±0.35
Femur	8.36±0.47

Stepwise multiple regression analysis indicated that in the whole group of girls skinfold thicknesses influenced body resistance only by 9.2% ($R^2 \times 100$) (Table 2). However, the influence of skinfold thicknesses was very different (from 7.8% to 40.8%) in different homogeneous subgroups selected by BMI.

Neck, arm flexed and tensed and waist girths characterized by 31.1% of the total variance in the whole group of girls (Table 3).

The importance of length parameters in whole group of girls (5.1%) was relatively low (Table 4), being very low or even absent in some subgroups.

The breadth/length parameters influenced the resistance in the whole group of girls by 15.8% (Table 5).

Table 2. The regression summary between body resistance and skinfold thicknesses in girls with different BMI

BMI	Skinfolds	Intercept	F	R^2×100	p	SEE
<15 (n=23)		605.6	6.9	40.8	<0.005	39.2
	Iliac crest	19.3				
	Subscapular	33.0				
15–16 (n=21)		590.4	3.0	9.5	<0.05	55.6
	Iliac crest	7.8				
16–17 (n=15)	NO					
17–18 (n=17)		549.2	2.8	28.4	<0.05	33.0
	Medial calf	6.9				
	Iliac crest	–5.0				
18–19 (n=13)		259.0	7.0	7.8	<0.05	26.4
	Medial calf	16.9				
>19 (n=16)		489.2	4.3	40.1	<0.05	47.0
	Biceps	15.5				
	Medial calf	–4.5				
Total (n=105)		670.8	10.4	9.2	<0.002	54.2
	Medial calf	–3.3				

Table 3. The regression summary between body resistance and girths parameters in girls with different BMI

BMI	Girths	Intercept	F	R^2×100	p	SEE
<15 (n=23)		1013.8	8.9	47.0	<0.002	37.1
	Wrist	–90.7				
	Ankle	45.0				
15–16 (n=21)		656.1	3.4	19.3	<0.05	53.4
	Gluteal	10.4				
	Ankle	–41.3				
16–17 (n=15)	NO					
17–18 (n=17)		546.5	4.0	27.4	<0.01	48.3
	Neck	–29.7				
	Head	16.4				
18–19 (n=13)		86.9	3.5	19.9	<0.05	51.1
	Arm relaxed	58.2				
	Waist	–13.6				

BMI	Girths	Intercept	F	R^2×100	p	SEE
>19		1560.6	4.3	40.0	<0.04	47.0
(n=16)	Neck	–23.6				
	Calf	–9.1				
Total		1096.0	15.4	31.3	<0.000	47.6
(n=105)	Neck	–19.9				
	Arm flexed and tensed	–14.9				
	Waist	6.7				

Table 4. The regression summary between body resistance and lengths parameters in girls with different BMI

BMI	Lengths	Intercept	F	R^2×100	p	SEE
<15		905.0	3.6	7.3	<0.05	47.9
(n=23)	Acromiale radiale	–8.2				
15–16		205.3	3.8	21.5	<0.03	52.7
(n=21)	Radiale stylion	41.2				
	Tibiale laterale	–13.1				
16–17 (n=15)	NO					
17–18 (n=17)	NO					
18–19 (n=13)	NO					
>19		1193.2	4.9	25.8	<0.04	50.4
(n=16)	Midstylion	–35.9				
Total		828.5	5.6	5.1	<0.02	55.4
(n=105)	Acromiale-radiale	–6.7				

Table 5. The regression summary between body resistance and breadths/lengths parameters in girls with different BMI

BMI	Breadths/lengths	Intercept	F	R^2×100	p	SEE
<15		1026.6	6.4	23.4	<0.02	43.5
(n=23)	Biiliocristal	–16.8				
15–16		290.1	5.5	16.0	<0.03	53.6
(n=21)	Biiliocristal	16.4				
16–17 (n=15)	NO					

BMI	Breadths/lengths	Intercept	F	$R^2 \times 100$	p	SEE
17–18 (n=17)	 Transverse chest	33.0 25.9	2.9	3.5	<0.05	34.7
18–19 (n=13)	NO					
>19 (n=16)	 Biacromiale Transverse chest	1887.2 –32.7 –10.1	2.4	3.3	<0.05	41.5
Total (n=105)	 Transverse chest A-P chest depth	956.3 –12.4 –5.1	9.6	15.8	<0.0002	52.4

DISCUSSION

Significant associations between body resistance and different anthropometric data can assist the selection of independent variables to be included in predictive equations. Baumgartner *et al.* [1] showed that 70% of the variance in resistance could be accounted for by a small set of anthropometric variables. The use of shoulder height and arm length rather than stature alone as a measure of the length of the conductor improves the accuracy of prediction marginally in adults [3]. However, there is a lack of similar data in children.

Theoretically, estimates of body composition using whole-body bioelectrical impedance have been based on the equation $V = p \times S^2/R$, in which conductive volume (V) is assumed to represent total body volume or FFM, p is the specific resistivity of the conductor, stature (S) is taken as an estimate of the length of the conductor and R is body impedance [2, 5, 10]. However, probably stature is not the true conductor length when using the four-electrode wrist-to-ankle method of BIA. The true length of the conductor could be better represented by acromial height and arm length [6]. In our study, stature characterized only 3.8% ($p<0.05$) of the total variance in girls, while body mass characterized 17.4% of the total variance. The best predictor of body resistance was stature and body mass combined (20.7%), which was slightly higher than BMI (20.2%).

Results of the current study indicated that best predictors of body resistance were girth parameters which characterized 19.3–47.0% of the total variance. Interestingly, in both extreme subgroups selected by

BMI (BMI<15 and BMI>19) the influence of girth parameters on body resistance was higher than in the total group (see Table 3). Fuller and Elia [5] have indicated that only the thinner segments of the body provide the greatest resistance.

As in adults [2, 10], length parameters influenced body resistance only slightly in children (see Table 4). This is surprising as body resistance depends on the conductor length. Potentially, the very small girths of the upper and lower body in children are more reliable predictors than the length of the limbs. It is very difficult to explain the very high variability of the influence of length parameters of different subgroups.

The influence of skinfold thicknesses to body resistance in the whole group was low, characterizing less than 10% of the total variance (Table 2). This is due to the fact that body fat is a very bad electric conductor [2, 10, 11]. In the whole group of girls the influence of breadth/length parameters on body resistance was relatively high (Table 5). The influence was the highest in the thinnest group of girls by 23.4% of the total variance.

In conclusion, the traditional use of body stature as a single anthropometric measure used in the presentation of equations for body composition measurement is not acceptable. It is important to add girth and breadth/length parameters to stature in the prediction of body composition in preadolescent girls with different body constitution.

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CHANGES IN BIOELECTRICAL IMPEDANCE DURING 30 MINUTES OF CONSTANT WORKLOADS ON BICYCLE AND ROWING ERGOMETERS IN SPORTSMEN

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ABSTRACT

The aim of the present study was to compare differences of the possible changes in body impedance during vertical (bicycle ergometer) and horizontal (rowing ergometer) workloads for 30 minutes with constant intensity in male sport game players (n=15, 21.9±2.8 yrs, 182.9±3.7 cm, 77.38±6.70 kg, BMI 23.13±2.16, body fat % 9.3±2.1). Thirty minutes tests with an intensity of 130-140 beats min^{-1} were used. BIA was performed (BODYSTAT-500, UK) every 5 minutes during the exercise and every 5 minutes during the 30 minutes of recovery. During both exercise tests the subjects lost about 0.4 kg of their body mass ($p>0.05$) and impedance decreased about 20 Ω ($p>0.05$). During the first 5 minutes of recovery impedance increased to the initial level and after that was stable during the following 30 minutes. Correlation analysis indicated that all measured resistances correlated highly with each other ($r>0.90$). It was concluded that during 30 minutes of aerobic exercise body impedance did not decrease significantly. Neither were there any significant changes during the recovery period.

Key words: bicycle ergometer exercise, rowing ergometer exercise, bioelectrical impedance.

INTRODUCTION

During long aerobic exercise sportsmen may lose a considerable amount of body fluids through sweating, which is induced by the regulation of body temperature. However, body fluid compartments may contribute to water loss to a different extent [3,5]. Accordingly, hypohydration may play an important role in adaptation to exercise [4]. Until recently, changes in body fluid compartments have been determined using tracer methods, including radioactive tracers. However, repeated measurements using the tracer methods are difficult to perform as they require either a waiting period, while the tracers are cleared from the body, or the use of higher doses [7]. In addition, the repeated use of radioactive tracers to assess the adaptation to exercise in sportsmen is rather questionable. Dehydration and redistribution of control blood volume that occurs at the beginning of exercise may play an important role in adaptation to exercise [4].

A simple, inexpensive, accurate, reliable, and non-invasive method to determine fluid distribution is needed to study the effects of endurance training on body fluid balance. It is most likely that impedance methods will meet this criteria. Bioelectrical impedance analysis (BIA) is based on the theoretical relation between the volume of a conductor (human body), the length of the conductor (stature), the components of the conductor (fat and fat-free mass), and the impedance of the conductor [8].

The aim of this study was to compare the differences of body impedance changes during vertical (bicycle ergometer) and horizontal (rowing ergometer) 30 minutes loads with constant intensity in male sport game players.

SUBJECTS AND METHODS

The subjects of this study were 15 sportsmen specializing in sport games (basketball, volleyball, handball). They exercised 3–4 times per week and were non-smokers. The subjects were familiarized with the procedures before providing their consent to participate in the experiment as approved by the Medical Ethics Committee of the University of Tartu. Height (Martin metal anthropometer) and body mass (A & D

Instruments Ltd, UK) of the subjects were measured to the nearest 0.1 cm and 0.05 kg, respectively.

Two exercise sessions were interspaced by at least two days, and the participants were asked not to participate in any physical activity for 24 hours and to abstain from eating for three hours before the tests. On different days, cycle ergometer (Tunturi, Finland) and rowing ergometer (Concept II, Morrisville, USA) tests were used. The aims of the tests were to exercise 30 minutes on ergometer with constant HR 130–140 beats min^{-1} (controlled by Sporttester POLAR VANTAGE NV, Finland). Body mass was measured before, 15 min during exercise, immediately after and after 30 minutes of recovery (after drying the skin with a towel) (A & D Instruments Ltd, UK). BIA was performed using Bodystat-500 (Isle of Man, UK) every 5 minutes during the exercise and every 5 minutes during the 30 minutes of the recovery period to the nearest 1 Ω. Impedance values were recorded using electrodes placed on the right side of the body (from the right wrist to the right ankle). The analyzer was calibrated before each test by using the standard resistor provided by the manufacturer. During the 30 minutes of recovery the subject was lying.

Mean ± standard deviation (SD) was determined. Friedman analysis of variance was used as the raw data and their logarithmic transformations were not normally distributed. The Wilcoxon matched-pairs signed-ranks test was used where post hoc analysis was necessary. Kendall Rank Correlation coefficient was used to determine the relationship between dependent variables. An alpha level of 0.05 was adapted.

RESULTS

The anthropometric parameters of the subjects are presented in Table 1. Changes in body mass during 30 minutes cycle and rowing ergometer tests and during 30 minutes of recovery period are presented in Figure 1. During both exercises the subjects lost about 0.4 kg of body mass ($p>0.05$). Changes in bioelectrical impedance during exercise and recovery are presented in Figures 2 and 3. During both exercises, impedance decreased by about 20 Ω ($p>0.05$). During the first 5 minutes of recovery impedance increased to the initial level and after that was stable during the whole 30 minutes recovery period. Correlation analysis indicated that all the measured resistances correlated highly with each other (r>0.90).

Table 1. Anthropometric parameters of the subjects ($\overline{X}$ ±SD)

	$\overline{X}$ ±SD	Minimum	Maximum
Age (yrs)	21.9±2.8	19	27
Height (cm)	182.9±3.7	178.7	191.1
Weight (kg)	77.38±6.70	68.00	82.25
BMI (kg/m^2)	23.13±2.16	20.67	25.93
Fat %	9.3±2.1	13.2	6.9
LBM (kg)	68.4±5.4	57.7	74.3

LBM — lean body mass

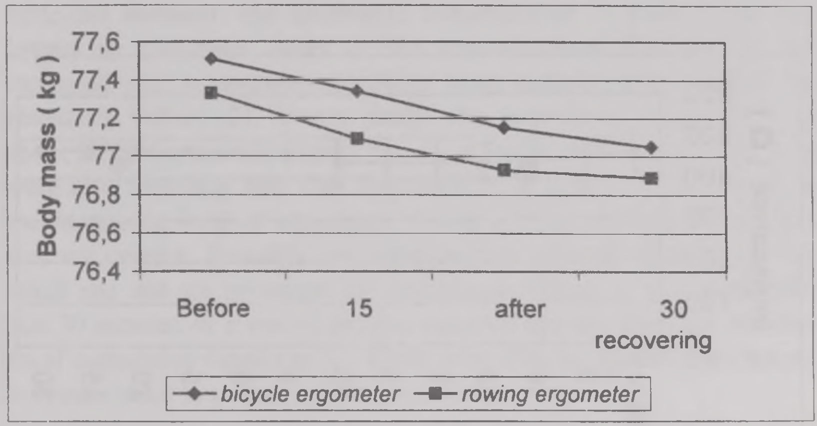

Figure 1. Changes in body mass during bicycle ergometer and rowing ergometer tests and during recovery.

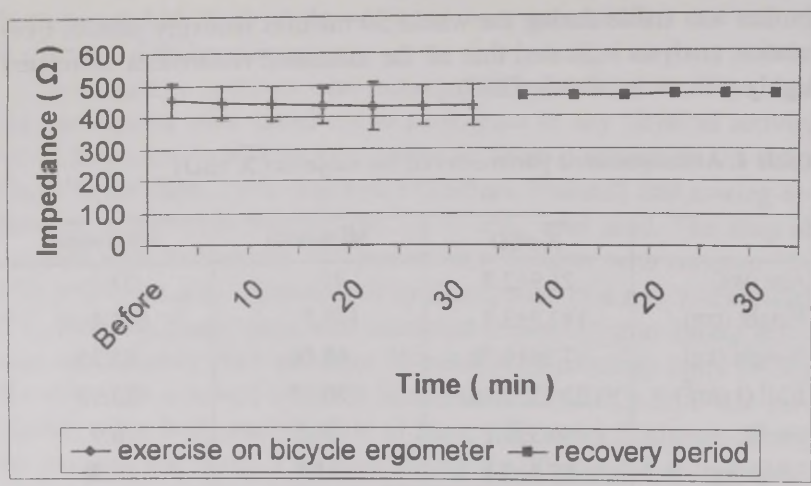

Figure 2. Changes in bioelectrical impedance during bicycle ergometer exercise and during recovery.

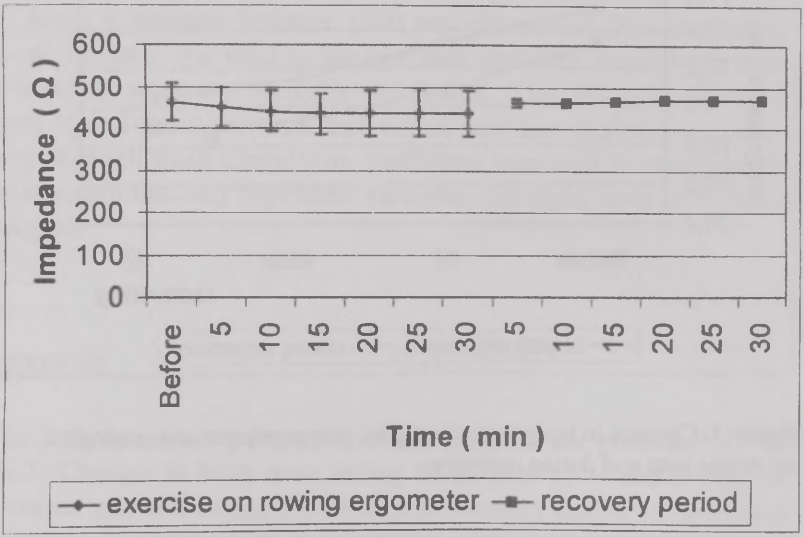

Figure 3. Changes in bioelectrical impedance during rowing ergometer exercise and during recovery.

DISCUSSION

Our results indicated that changes in body mass and bioelectrical impedance during 30 minutes of constant intensity exercise and 30 minutes of recovery were minimal. There were no differences in bioelectrical impedance values when exercising in horizontal or vertical position.

Change in body mass during 30 minutes of exercise was only about 0.4 kg (0.44%). In contrast, it has been reported that during 30 minutes of sauna body mass decreases by 0.91±0.34% [9]. Probably the intensity during ergometer loads in our experiment was relatively low, and therefore the total energy expenditure was also low.

Loss of body fluids from sweating during jogging and cycling for 90 to 120 minutes has been reported to substantially reduce body resistance (50 to 70 Ω) [1, 6]. The decrease in resistance after exercise is likely to reflect the relatively greater loss of body water through sweating and expired air compared to the loss of electrolytes [2]. In turn, this increases the electrolyte concentration in body fluids and lowers the resistance values of BIA measurements. Furthermore, the increased skin temperature resulting from exercise also reduces the resistance values [2]. In our study, the impedance decreased only about 20 Ω. On the other hand, the duration (30 minutes) and intensity were also relatively low. Our hypothesis that there are differences in the decreasing level of impedance during vertical and horizontal loads was not correct. Probably the redistribution of body fluids was very small and did not influence the impedance values. It was concluded that 30 minutes of constant aerobic exercise did not decrease bioelectrical impedance significantly. There were also no significant changes in bioelectrical impedance during recovery.

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EFFECT OF BODY COMPOSITION ON PLASMA LEPTIN CONCENTRATIONS IN POSTMENOPAUSAL WOMEN

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ABSTRACT

The aim of the present study was to evaluate if the basic body composition parameters are significantly related to leptin concentration in blood in postmenopausal women (n=31, 68.7±6.4 yrs, 161.5±5.5 cm, 69.3±10.7 kg, % body fat: 38.7±7.1%). Body composition was measured using dual-energy X-ray absorptiometry and leptin concentrations were determined by means of radioimmunoassays (RIAs). The mean blood leptin concentration was 20.73±16.81 mg/ml (minimum 3.26 and maximum 86.41 mg/ml). Correlation analysis indicated that body mass (r=0.39), BMI (r=0.46) and percentage of body fat (r=0.51) correlated significantly with blood leptin concentration. It was concluded that body mass, BMI and percentage of body fat were significantly related to blood leptin concentrations in postmenopausal women. However, further studies are needed to determine the best body composition parameter to predict blood leptin concentration.

Key words: body composition, dual-energy X-ray absorptiometry, leptin, postmenopausal women.

INTRODUCTION

The identification and sequencing of leptin, a product of the OB gene, heralded a renaissance in research of the regulation of energy balance. Leptin, synthesized and secreted by adipocytes in proportion to the amount of lipid stored, appears to act as a signal to the brain of body energy stores, thus meeting the basic criteria of the lipostatic factor postulated by Kennedy [7]. Leptin is a polypeptide synthesized and secreted by adipose cells, which is believed to play an important role in the control of body mass. An increase in body mass after the menopause has been observed in several clinical trials [8, 10]. However, the exact mechanism of the menopausal effect on body mass and fat distribution after the loss of estrogen has not been fully determined in vivo. It is well established that plasma leptin levels are strongly correlated with body mass, body mass index (BMI) and body fat content [1]. However, these relationships in postmenopausal women have not been well studied.

The aim of the present study was to evaluate if the basic body composition parameters are significantly related to blood leptin concentration in postmenopausal women.

METHODS

Thirty one postmenopausal women (age range 55–83 years) participated in the study. Before entering the study, all women had answered a detailed questionnaire on important risk factors and given written informed consent.

The subjects attended female gymnastics classes regularly 1–3 times per week. All the subjects were non-smokers. The subjects were asked to avoid any strenuous exercise 24 h prior to testing and eating or ingesting caffeine within 2 h prior testing. Height (Martin anthropometer) and body mass (A & D Instruments Ltd, UK) were measured, and body mass index (BMI, kg/m^2) was calculated.

Body composition was measured using dual-energy X-ray absorptiometry. Scans of the whole body were performed on each of the subjects using a LUNAR DPX scanner (Lunar Corp., Madison, USA) [2] and analyzed for percentage of body fat.

Venous blood samples were taken after an overnight fast. Leptin was determined by means of radioimmunoassays (RIAs, Mediagnost Tübingen, Germany). This assay has a detection limit of 0.01 mg/ml, and intra-assay and inter-assay coefficients of variation (CV) were <5% and <7.5%, respectively.

Standard statistical methods were used to calculate the mean (X) and standard deviation (±SD). Spearman correlation coefficients were used to determine the relationships between dependent variables. The effect of different anthropometric and body composition parameters on blood leptin concentration was analyzed by stepwise multiple regression analysis. Significance was set at $p<0.05$.

RESULTS

The mean anthropometric parameters of postmenopausal women are presented in Table 1. The group was not homogenous (percentage of body fat ranged from 22.5 to 56.3%). The mean blood leptin concentration was 20.73±16.81 mg/ml (minimum 3.26, maximum 86.41 mg/ml).

Table 1. Anthropometric parameters of postmenopausal women (n=31)

	$\overline{X}$ ±SD	Minimum	Maximum
Age (yrs)	68.7±6.4	55	83
Height (cm)	161.5±5.5	149	170
Weight (kg)	69.3±10.7	53	95
BMI	26.6±4.3	21	39.1
% body fat	38.7±7.1	22.5	56.3

Correlation analysis indicated that body mass (r=0.39), BMI (r=0.46) and percentage of body fat (r=0.51) correlated significantly with blood leptin concentration in postmenopausal women. However, body height was not significantly related to blood leptin concentration (Table 2). Stepwise multiple regression analysis indicated that percentage of body fat characterized 25.9% ($R^2 \times 100$) of the blood leptin concentration in postmenopausal women.

Table 2. Relationships between anthropometric parameters and blood leptin concentrations in postmenopausal women

	Age	Height	Weight	BMI	Leptin
Height	–0.07				
Weight	0.10	0.16			
BMI	0.06	–0.29	0.90*		
Leptin	0.08	–0.13	0.39*	0.46*	
% body fat	–0.17	–0.12	0.78*	0.80*	0.51*

* $p<0.05$

DISCUSSION

Our results indicated that in postmenopausal women blood leptin concentration correlated significantly with body mass, BMI and percentage of body fat. In our subjects, the mean and minimum-maximum leptin concentrations were relatively high. However, leptin concentration has been reported to be 2–4 times higher in females than in males [6, 11]. On the other hand, the mean results of our subjects were similar to other postmenopausal women studied [3, 5]. The closest relationship (r=0.51) existed between blood leptin level and percentage of body fat; the relationship with BMI (r=0.46) was only slightly weaker. Previously published data have demonstrated a strong positive correlation between serum leptin concentrations and BMI, suggesting that leptin signals the magnitude of fat stores to the brain [1]. Hadji et al. [5] have indicated that only BMI remained a statistically significant independent predictor for leptin concentration in postmenopausal women. However, other studies [4, 9] have indicated that the main anthropometric parameter is the percentage of body fat. Finally, the large variation in leptin concentration among individuals with similar body composition parameters suggests that factors other than adiposity may play a role in regulating leptin concentrations [12].

It was concluded that body mass, BMI and percentage of body fat were significantly related to blood leptin concentration in postmenopausal women. However, which body composition parameter best predicts the level of leptin in postmenopausal women needs further research.

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DETERMINATION OF BODY FAT CONTENT BY OMRON BF 300 AT THE ESTONIAN BORDER GUARD HEALTH CENTRE

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ABSTRACT

The aim of the study was to analyse the anthropometric parameters (weight, height, BMI, body fat content) of Estonian border guards in relation to their physical performance determined by a velo-ergometrical load test. 895 men and 246 women at the age of 20–65 were tested. The velo-ergometrical test was passed by 753 men and 153 women. All geographical regions of Estonia were covered. The subjects were divided into five age groups: under 30 years, 31–40 years, 41–50 years, 51–60 years and over 61 years. Men's average height was 177.97 cm, weight 85.42 kg, BMI 26.95 and body fat content 21.95%. The average BMI increased with age (24.41±3.37 in the youngest group; 28.10±2.24 in the oldest group). The average percentage of the body fat content also increased (under 30 years — 14.49±5.53%, over 61 years — 27.75±2.96%). Women's average height was 165.51 cm, weight 66.02 kg, BMI 24.09 and body fat content 28.57%. In women the average BMI and body fat percentage did not increase significantly after 41 years. All the subjects were divided into five somatotypes: small, medium, big, leptosomic, pycnic. Based on body fat content, all the subjects were also divided into five groups: thin, normal, moderately overweight, considerably overweight, obese. Fat percentage in different somatotypes was calculated. Overweight was found in all somatotypes, mostly in big and pycnic subjects. Based on physical working capacity all the subjects were divided into 5 groups from insufficient to excellent. Increasing body fat content brought along a decrease in the percentage of good and excellent functional capacity and an increase in the percentage of insufficient functional capacity.

Key words: body fat, OMRON BF 300, BMI

INTRODUCTION

To discover border guards' possible health risks at an early stage, regular physical check-up has been carried out annually since 1997. The aim of this study was to analyse the anthropometric parameters (weight, height, body mass index, body fat content) of border guards in relation to their physical performance determined by a velo-ergometrical load test.

MATERIAL AND METHODS

Subjects

1141 persons at the age of 20–65 were tested, 895 men and 246 women. The age of the tested border guards was as follows: under 30: 407 men and 81 women; 31–40: 260 men and 103 women; 41–50: 152 men and 45 women; 51–60: 62 men and 15 women; over 61: 14 men and 2 women. The velo-ergometrical test was passed by 753 men and 153 women. The research was carried out during the year 2000 and all geographical regions of Estonia were covered.

Methods

1. Anthropometry

Weight (Soehnle electron-scale) was measured to the nearest 0.1 kg, height to the nearest 0.5 cm. Body mass index (BMI) was calculated as weight (kg) divided by the square of height (in meters). Body fat content was determined by the bio-impedance method using the body fat analyser OMRON BF 300.

2. Testing procedures

The load test was passed on the velo-ergometer "Ergoline" er 800 es. To determine the frequency of hearth beats a Polar Accurex Plus pulse tester was used. Aerobic physical capacity was measured using the "Eurofit" velo-ergometrical testing system [1] — introduction 3 min., 3 step-wise increased loads à 4 min. The maximum physical ability

[Wmax (W)] and indirectly the maximum oxygen uptake [VO_2 max (ml/kg/min)] were calculated [1].

The results were analysed by the computer program "Excel". Arithmetical average (X) and standard deviation (SD) were found.

RESULTS AND DISCUSSION

All the subjects were divided into five age groups: under 30 years, 31–40 years, 41–50 years, 51–60 years and over 61 years.

Table 1 shows the weight, height, BMI and fat percentage of men in different age groups — the arithmetical average, standard deviation, and minimum and maximum values.

Increase in age caused an increase in the average BMI (24.41±3.37 in the youngest group; 28.10±2.24 in the oldest group). The biggest rise in numbers was seen in the average percentage of the body fat content (under 30 years 14.49±5.53%; over 61 years 27.75±2.96%).

Table 2 shows the same anthropometric variables in women.

In women the average BMI and body fat percentage did not increase significantly after 41 years.

Based on height and weight, all the subjects were divided into five somatotypes [4]: 1. small weight and height — small; 2. medium weight and height — medium; 3. big height and weight — big; 4. dominating height — leptosomes; 5. dominating weight — pycnics. The medium group was determined as the arithmetical average ± 0.5 SD. The values of other groups were determined out of these limits.

Based on these somatotypes, men were distributed as follows: small 17%, medium 18%, big 13%, leptosomes 29%, pycnics 23%. Women, based on these somatotypes, were classified as: small 18%, medium 19%, big 16%, leptosomes 16% and pycnics 21%.

Based on body fat content, all the subjects were divided into five groups [2]:

1. thin — fat percentage in men < 10%, in women < 20%;
2. normal — fat percentage in men 10.1–20%, in women 20.1–30%;
3. moderately overweight — fat percent in men 20.1–25%, in women 30.1–35%;
4. considerably overweight — fat percent in men 25.1–30%, in women 35.1–40%;
5. obese — fat percentage in men > 30.1%, in women > 40.1%.

Table 1.

Age in years	n	Height (cm)				Weight (kg)				Body mass index				Fat percentage			
		X	SD	min	max	X	SD	min	max	X	SD	min	max	X	SD	min	max
below 30	407	179,40	6,04	156.5	200	78,72	12,44	50	122	24,41	3,37	18.1	37.2	14,49	5,53	4.1	31.4
31–40	260	179,90	5,84	165	200	85,44	12,98	59.8	142	26,41	3,78	19.4	41.5	19,31	5,70	4.2	34.6
41–50	152	178,56	5,42	164	192	88,59	14,79	60	147	27,73	4,26	20.4	47.4	22,90	5,29	11.4	38
51–60	62	176,90	6,12	162	190	88,18	14,42	62	126.8	28,10	3,98	20.4	40	25,31	4,81	14.1	33.2
over 61	14	175,1	2,30	172	180	86,17	8,08	72	105	28,10	2,24	24.3	32.4	27,75	2,96	21.5	33.2
total	895	177.97		156.5	200	85.42		50	147	26.95		18.1	47.4	21.95		4.1	38

Table 2.

Age in years	n	Height (cm)				Weight (kg)				Body mass index				Fat percentage			
		X	SD	min	max	X	SD	min	max	X	SD	min	max	X	SD	min	max
below 30	81	168,17	6,16	151	184	65,53	11,83	43	96	23.15	4,02	16.1	36.8	23,59	6,55	12.2	41.5
31–40	103	165,95	6,34	154	183	65,84	10,00	43.8	97	23,86	3,21	17.8	35.2	26,52	5,30	13	40
41–50	45	165,46	5,37	155	176	69,26	11,10	50	108	25,16	4,16	19.5	40	30,70	5,12	17.8	44.4
51–60	15	162,70	4,26	154	171	66,97	7,30	58	84	25,26	2,37	21.6	30.1	31,73	3,35	25.7	38
over 61	2	165,25	3,89	162.5	168	62,50	3,54	60	65	23,00	0,00	23	23	30,3	7,07	25.3	35.3
total	246	165.51		151	184	66.02		43	108	24.09		16.1	40	28.57		12.2	44.4

On the basis of body fat content, men were classified as: thin 11%, normal 49%, moderately overweight 22%, considerably overweight 14% and obese 4%. Women's distribution, based on body fat content, was: thin 15%, normal 53%, moderately overweight 26%, considerably overweight 5% and obese 1%.

Figure 1 and 2 show the percentage of the men and women with different fat content in age groups.

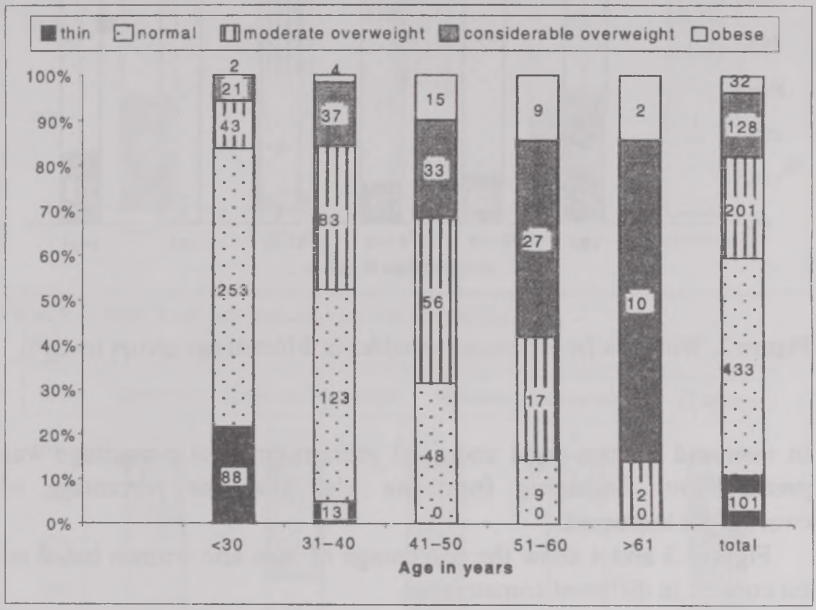

Figure 1. Men's fat percentage variables in different age groups (n=895).

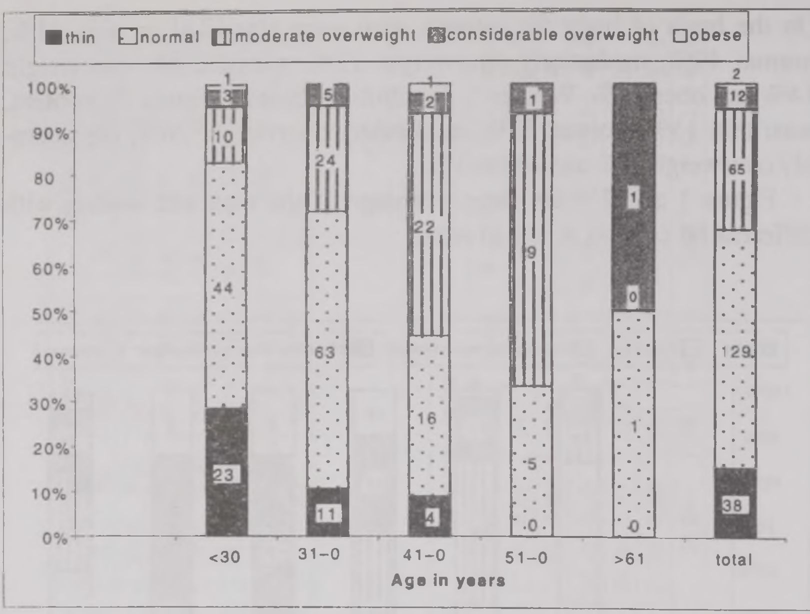

Figure 2. Women's fat percentage variables in different age groups (n=246).

In men and women aged under 40 years normal fat percentage was predominant. Beginning from the 41st year the percentage of overweight increased.

Figures 3 and 4 show the percentage of men and women based on fat content in different somatotypes.

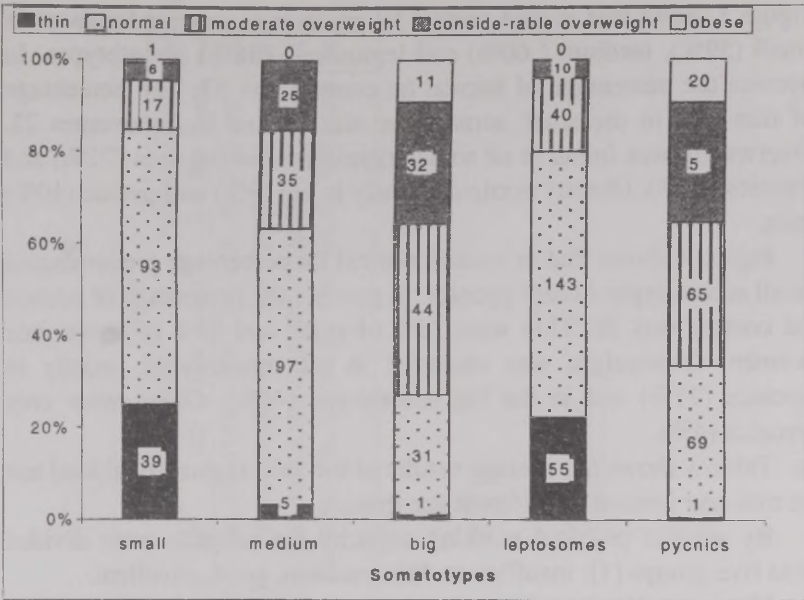

Figure 3. Men's fat percentage variables in different.

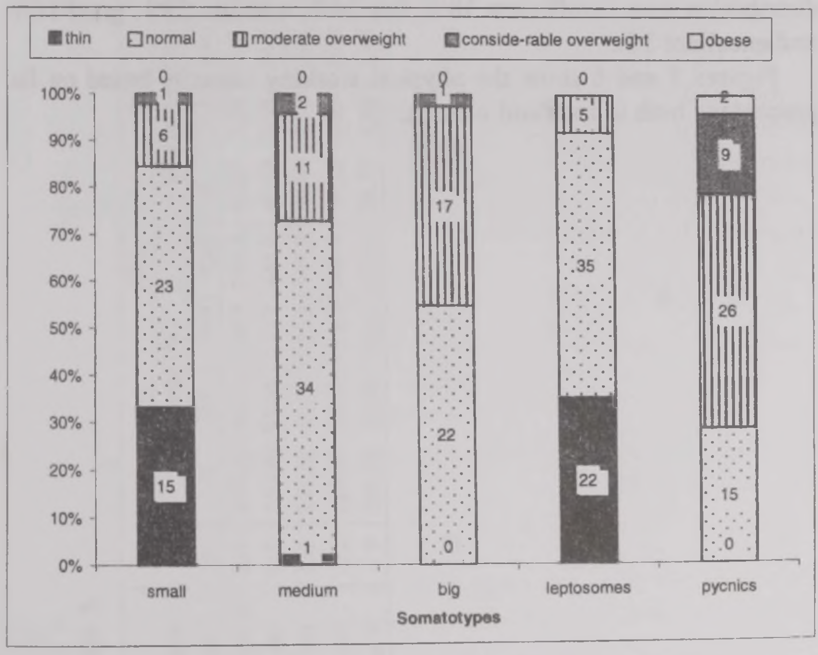

Figure 4. Women's fat percentage variables in different somatotypes (n=246).

Figure 3 shows that in men normal fat percentage was predominant in small (59%), medium (60%) and leptosomic (58%) somatotypes. In pycnics the percentage of normal fat content was 33. The percentage of thin men in the small somatotype was 25 and in leptosomes 22. Overweight was found in all somatotypes, most in big men (73%) and pycnics (67%). Obesity occurred mostly in big (9%) and pycnic (10%) men.

Figure 4 shows that in women normal fat percentage predominated in all somatotypes except pycnics. In pycnics the percentage of normal fat content was 29. Thin were 33% of small and 35% of leptosomic women. Overweight was observed in all somatotypes, mostly in pycnics (71%) and in the big somatotype (46%). Obese were only pycnics (4%).

Table 3 shows the average results of the velo-ergometrical load test in men and women of different age groups.

By aerobic physical working capacity the subjects were divided into five groups [1]: insufficient, fair, medium, good, excellent.

Men were distributed into these groups as follows: insufficient 8%, fair 34%, medium 36%, good 17% and excellent 5%. Women's distribution was: insufficient 18%, fair 34%, medium 29%, good 16% and excellent 3%.

Figures 5 and 6 show the physical working capacity based on fat percentage both in men and women.

Table 3.

Age in years	Male									Female								
	n	Wmax (W)				VO_2 max (ml/kg/min)				n	Wmax (W)				VO_2 max (ml/kg/min)			
		X	SD	min	max	X	SD	min	max		X	SD	min	max	X	SD	min	max
below 30	335	247,20	54,52	126.9	518.5	42,07	7,58	21.2	63.1	51	161,10	43,62	94.6	283.2	33,65	6,96	21.3	50.7
31–40	217	255,80	54,05	132.7	442.2	40,15	7,65	24.7	60.6	71	145,20	29,89	88	228	31,28	5,64	20.4	47.8
41–50	137	237,10	52,57	127.3	387.8	36,49	7,44	23.3	56.2	23	147,30	26,50	110.6	207.6	30,64	6,03	21.4	44.6
51–60	55	225,00	55,12	120.3	340.8	34,75	6,80	20.4	49.1	7	145,80	26,37	100.6	178	30,37	4,98	22.4	38.9
over 61	9	183,90	36,62	126.2	232.1	28,73	4,80	23.3	36.5									

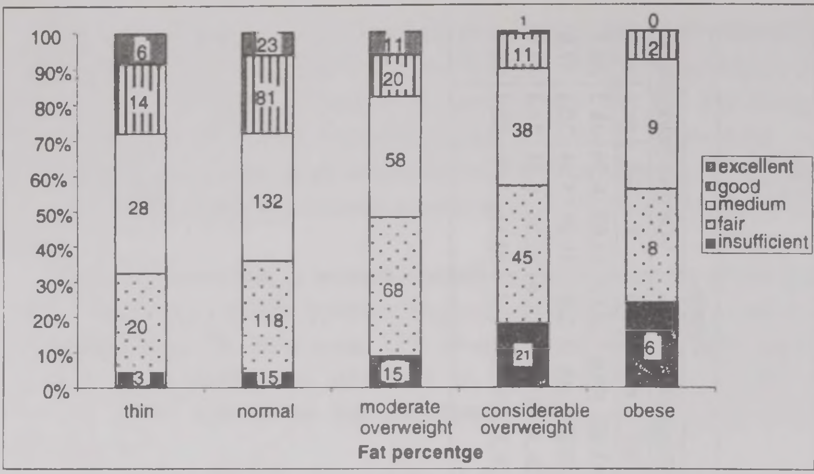

Figure 5. Men's physical working capacity variables in different fat percentage groups (n=753).

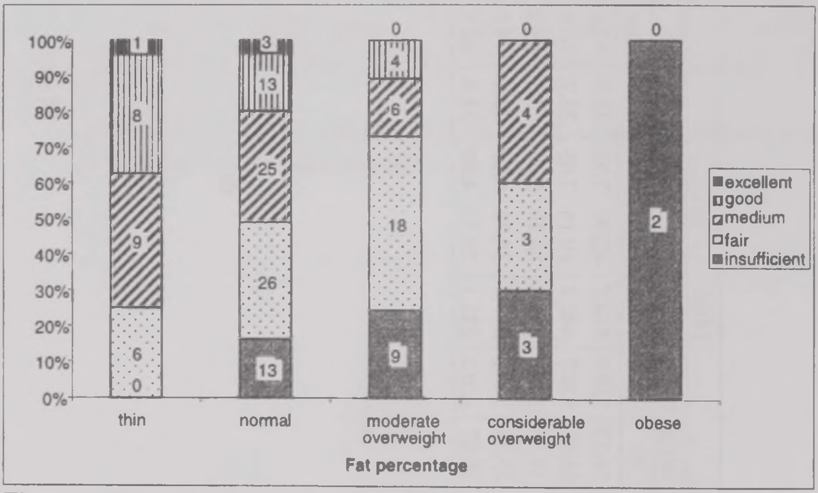

Figure 6. Women's physical working capacity variables in different fat percentage groups (n=153).

Figure 5 shows that increasing body fat content also increased the percentage of men with insufficient physical working capacity (thin 4%, normal 4%, moderately overweight 9%, considerably overweight

18%, and obese 24%). The percentage of fair and medium working capacity was approximately the same in all the groups (68–73%). By increasing body fat content the percentage of men with good and excellent physical working capacity decreased (from 28% in thin and normal to 8% in obese men).

In women (Figure 6) excellent physical working capacity was observed only in thin (4%) and normal (4%) subjects. Good physical working capacity was observed in 33% of thin, 16% of normal and 11% of moderately overweight women. The percentage of insufficient physical working capacity increased with body fat content (from 16% in normal to 30% in obese women).

In conclusion, the increasing fat content results in more persons being at an unsatisfactory level of functional capacity that may cause heart diseases.

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SOME CHARACTERISTICS OF CONCONI TEST IN CHILDREN WITH SMALL AIRWAY OBSTRUCTION

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ABSTRACT

The purpose of the study was to compare some Conconi test's characteristics in children with small airway obstruction and in children without obstruction. Ninety eight children participated in the study, among them 14 children (I group) with and 84 children (II group) without small airway obstruction. Pulmonary function tests were performed by hot wire spiroanalyser SA-03 and standard Conconi test using an electronic treadmill Tunturi J 660. Within the two groups of children there were significant differences in FEV1, MEF 75, MEF 50 and MEF 25 with lower data in group I. No differences were revealed in maximal heart rate, maximal running speed, heart rate at AT level (HRDP), running speed at the AT level, heart rate at AeT level and running speed at AeT level data between the two groups of children.

Statistically significant differences were observed in the length of the test performed at AT level (percentage of the whole test) and in the length of the test performed between the AeT heart rate level and AT heart rate level (percentage of the whole test). The children of group I spent longer test time at higher heart rate levels than the children of group II.

Key words: pulmonary function in children, small airway obstruction

INTRODUCTION

Physical activity should be part of the overall management of children with airway obstruction as well as a part of their life quality. Some investigations suggest that children with asthma can show the level of exercise performance similar to that of healthy children [1]. Others have found that physical fitness of asthmatic children is the result of cardiovascular conditioning and is unrelated to respiratory limitations [2]. Airway obstruction has been usually tested by flow-volume curve registration during pulmonary function testing [3]. In more resent studies, maximal expiratory flow when 25% of forced vital capacity remains to be expired (MEF_{25}) has been used for determination of small airway obstruction [4]. The limits of normal MEF_{25} values are determined by the centile approach when expressed results by percentage predicted between a lower 5 and upper 95 procentile are quantified as normal. For MEF_{25} the 95% confidence interval is 52-191% of predicted in Estonia [5].

In 1982, Conconi and colleagues [6] presented for the first time a non-invasive method to determine the "anaerobic threshold" by means of heart rate performance curve (HRPC) analysis. The heart rate deflection point (HRDP) (downward or upward change from the linear heart rate-work relationship during progressive incremental exercise testing) is reported to be coincident with the anaerobic threshold. As this test is non-invasive and very simple to perform, it is very popular in training practice. It has also been modified for several applications, like for children and untrained subjects and different patients. Testing can be performed in the field and in the laboratory.

The heart rate method of Conconi test has been criticised because of its low objectivity and reproducibility [7], but it has also been supported by many authors [8, 9].

AIM OF THE STUDY

This study compared the following Conconi test's characteristics in children with small airway obstruction and in children without obstruction:

- maximal heart rate,
- maximal running speed,
- the heart rate deflection point (HRDP) or heart rate at the anaerobic threshold level (AT),
- running speed at the AT level,

- heart rate at the aerobic level (AeT),
- running speed at the aerobic threshold,
- the percentage of the test length performed at the AT level to the whole test,
- the percentage of the test length performed between the AeT heart rate level and AT heart rate level to the whole test.

MATERIAL AND METHODS

Subjects

The subjects of this study were 98 6–18-year-old children and adolescents who went through pulmonary function tests and physical working capacity tests by Conconi protocol in Nõmme Children's Hospital laboratory of pulmonary physiology in the year 2000. All the 98 children were able to run at least 12 laps on the treadmill.

Methods

Pulmonary function tests were performed by hot wire spiroanalyser SA-03 [10].

The following lung volumes and maximal expiratory flow parameters were included in the study: FVC, forced vital capacity, FEV_1, forced expiratory volume in 1 second, MEF_{75}, MEF_{50} and MEF_{25}, maximal expiratory flows when 75%, 50%, 25% of FVC remains to be expired and FEF_{25-75}, maximal mid-expiratory flow. The lung volumes were measured in litres (l) and maximal expiratory flow parameters in l/sec.

The children were divided into two groups according to the pulmonary function tests results. The I group included 14 children with small airway obstruction; their maximal expiratory flow index MEF_{25} was lower than the lower limit of 95%CI, lower than 52% of predicted. In the II group there were 84 children without small airway obstruction (the 95%CI for MEF_{25}: 53–191% of predicted) [5, 11]. All results of pulmonary function tests were presented as the percentage of predicted (100 × observed / predicted).

A standard Conconi test using an electronic treadmill (Tunturi J 660) was performed by every child with lap length 50 meters and elevation 10%. The running speed progressively increased by 0,5 km / h until the subject was unable to continue. Heart rate was recorded every 5 seconds continuously by heart rate monitor Polar Vantage NV. The running speed was presented in km/h and the heart rate in beats/min.

The children's maximal heart rate, maximal running speed, the heart rate deflection point (HRDP) or anaerobic heart rate threshold, running speed at the anaerobic heart rate threshold, aerobic heart rate threshold (20 heart beats lower than the anaerobic threshold), running speed at the aerobic heart rate threshold were calculated by Polar Precision Performance Software for Windows version 2.

The percentage of the test length performed at the AT level to the whole test was calculated from the equation:

100 × the length of the test from heart rate at AT level to the maximal heart rate/ the length of the whole test.

The percentage of the test length performed between the AeT heart rate level and AT heart rate level to the whole test was calculated from the equation:

100 × the length of the test between the AeT heart rate level and the AT heart rate level/ the length of the whole test

Data analysis

Statistical package SPSS for Windows 8.0 was used (*Statistical Package for the Social Sciences (SPSS/PC+) . SPSS Inc., Chicago, Illinois, USA.)* Values are shown as means and standard deviations from the mean. Independent samples t-test was used to analyse the differences in between pulmonary function tests results and Conconi tests characteristics in two groups of children. A level of $p < 0.05$ was selected to indicate statistical significance.

RESULTS

The statistical characteristics of children's age and height data are presented in Table 1.

Table 1. Anthropometric characteristics of children in two groups

Group		Heigh	Age
Group I	Mean	156.86	13.07
	N	14	14
	Std. Deviation	11.21	2.62
	Minimum	136	8
	Maximum	171	17
Group II	Mean	153.65	11.90
	N	84	84
	Std. Deviation	16.55	3.04
	Minimum	117	6
	Maximum	187	18
Total	Mean	154.11	12.07
	N	98	98
	Std. Deviation	15.89	3.00
	Minimum	117	6
	Maximum	187	18

Significant differences calculated by independent samples t-test were not evident in the age and height data of the two groups of children.

Pulmonary function tests results of the two groups of children can be seen in Table 2.

Table 2. The lung volumes and maximal expiratory flow parameters in two groups of children

	Group	N	Mean	Std. Deviation	Std. Error Mean
FEVC	group I	14	96.6	14.53	3.88
	group II	84	95.6	9.99	1.09
FEV1*	group I	14	87.7	11.05	2.95
	group II	84	98.7	9.40	1.03
MEF75*	group I	14	76.1	13.97	3.73
	group II	84	92.2	20.24	2.21
MEF50*	group I	14	58.0	7.77	2.08
	group II	84	88.4	20.15	2.20
MEF 25*	group I	14	44.78	6.22	1.66
	group II	84	84.50	24.43	2.67
FEF 25–75	group I	14	93.1	17.47	4.67
	group II	84	100.01	26.22	2.86

Note: * $p < 0.05$ between 2 groups

Significant differences ($p = 0.002$) were indicated in FEV_1, MEF_{75}, MEF_{50} and MEF_{25} indexes results between the two groups of children, with lower data in group I. The mean data of the indexes MEF_{50} and MEF_{25} in group I were lower than the lower limit of 95% CI of reference data (the 95% CI for MEF_{50} was 62–162 and for MEF_{25} it was 52–195). The FEV_1 index data were in the 95% CI (the 95% CI for FEV_1 was 79–127).

No significant differences were observed in the mean data of indexes FVC and $FEF_{25\text{-}75}$.

The pulmonary function tests data were in the range of 95% CI of reference data in group II.

According the data, the children in group I suffered small (MEF_{25}) and medium (MEF_{50}) airway obstruction before the Conconi tests.

Table 3 presents the mean and standard deviation data of some characteristics of Conconi test.

Table 3. Conconi tests characteristics in two groups of children

	Group	N	Mean	Std. Deviation
Maximal heart rate	group I	14	190	10.59
	group II	84	190	9.27
Maximal running speed	group I	14	10.34	2.68
	group II	84	11.51	2.88
Anaerobic heart rate threshold	group I	14	173	19.17
	group II	84	182	11.79
Running speed at the AT	group I	14	7.87	2.29
	group II	84	9.62	2.70
Heart rate at aerobic threshold	group I	14	153	19.17
	group II	84	162	11.79
Running speed at the AeT	group I	14	5.76	2.47
	group II	84	7.17	1.97
Test length at the heart rate over the AT (%)*	group I	14	3.91	2.99
	group II	84	2.56	1.35
Test length between the AeT and AT heart rate level (%)*	group I	14	6.11	5.67
	group II	84	4.17	2.09

Note: * $p < 0.05$ between 2 groups

No differences were revealed in maximal heart rate, maximal running speed, the heart rate at the AT level (HRDP), running speed at the AT level, heart rate at the AeT level and running speed at the AeT level data between the two groups of children.

Statistically significant differences were observed in the length of the test performed at the AT level (percentage of the whole test) and in the length of the test performed between the AeT heart rate level and AT heart rate level (percentage of the whole test). The children of group I spent longer time at higher heart rate levels than the children of group II, i.e. the latter did the test longer with lower heart rates.

DISCUSSION

This study aimed to describe the differences in Conconi test's characteristics in children with small airway obstruction and in children without obstruction.

The children from both groups interrupted Conconi test at the heart rate 190 beats /min, but the running speed in group I was slightly lower (without significant differences). HRDP (AT) was found at lower heart rate in group I and their running speed was also lower, although without statistically significant difference. They reached anaerobic metabolism at slightly lower heart rates and workouts. The children with small airway obstruction also spent significantly longer time in the anaerobic metabolism zone. During anaerobic work, the body is working so hard that the demands for oxygen exceed the rate of supply. The muscles take the body into a state of oxygen debt. An HRTP (AT) "shift to the left" in the Conconi test indicates the subject's decreased ability to postpone exhaustion during exercises. The HRTP of children with small airway obstruction was slightly "shifted to the left" if compared to children without obstruction. They had to be more exhausted in terms of metabolism and possibly needed longer recovery time.

Santuz *et al.* [1] have also revealed in children with asthma the level of exercise performance similar to that of healthy children. We found no difference in maximal heart rate and no statistical difference in maximal running speed. The results of Fink *et al.* [2] that the physical fitness of asthmatic children was unrelated to respiratory limitations were not supported by our findings. The children with small airway obstruction obviously develop more serious oxygen debt. We presume that emotionally they suffer during longer anaerobic work more than children without airway obstruction.

The children of group I also spent statistically longer time at the heart rate level between AeT and AT, in the stage at which anaerobic energy pathways start to operate.

Unexpected findings

The statistically similar maximal running speed and the running speed at AeT and AT level in both groups of children was an unexpected result. It was supposed that the children with small airway obstruction have to be slower runners than healthy ones. Children with airway obstruction often complain about the difficulty of keeping pace with healthy children in physical education classes. The results of this study direct us to see the reasons of the complaints in more serious oxygen debt.

Limits of this study

The heart rate deflection point (HRDP) was considered in this study to be coincident with the anaerobic threshold. The level of lactic acid was not measured in children because of the invasive method. Neither was the direct method of oxygen exchange assessment used as the technology is expensive.

Another fact that might have influenced the study results concerns the selection of children. Those children who had serious airway obstructions did not perform exercise tests. Those children who interrupted their movement before 12 laps of 50 meters (walking or jogging up to 600m) were also excluded from the study. The latter possibly had more serious airway obstruction.

The group of children with small airway obstruction was small. Therefore, it is not reasonable to make extensive generalisations and future studies of physical working capacity of children with airway obstruction are necessary.

CONCLUSIONS

The study of Conconi test performance in children with and without small airways obstruction revealed that the children with small airway obstruction exercised longer in the anaerobic metabolism zone.

This directs us to the idea about correct therapeutic check-up of the airways function in children with obstruction.

Conconi test results should be used to set exercise intensity parameters in physical education classes for children with airway obstruction.

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ABOUT THE ESTABLISHMENT OF THE ANTHROPOLOGICAL COLLECTION OF YURYEV (TARTU) UNIVERSITY IN 1911

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In the final year when Prof. August Rauber (1841–1917), Director of the Institute of Anatomy at Yuryev (Tartu) University, was in office [1], more precisely on 6 November

1910, *Privatdozent* Abram Eber Landau, MD (1878–1959), the supernumerary assistant of the prosector of the institute, submitted an application to the Faculty of Medicine, where he asked, if possible, to allocate one or two rooms for his anthropological collection in one of the University buildings. In his view, these rooms could be found in the first student dormitory of the University [2] in Hetzel Street near the Old Anatomical Theatre (at present 4, J. Liivi St.), which had been completed in 1904 [3]. He had set up a private collection in order to illustrate the anthropology lectures that he had delivered since the autumn of the previous year. The audience had amounted to 40–50 students; many of them had taken a deeper interest in anthropology. The above-named collection was housed in two rooms of an apartment, the rent for which he had paid from his own pocket. In his view, the anthropological collection was still in its infancy. While teaching, he had also used by kind permission of Prof. A. Rauber some instruments and materials from the Institute of Anatomy. As, in the course of time, his small-scale collection had grown into a full-scale anthropological museum, he expected a benevolent attitude and support from the Faculty of Medicine. His application ended with a request for funding in the range of 200–300 roubles per year to supplement and arrange the anthropological collection. Right below the signature of *Privatdozent* A. E. Landau at the end of the application Prof. A. Rauber had written by hand that he supported the application and expected a favourable solution from the Faculty. Another plea for funding at the end of Landau's application gave reason to submit an additional written explanation concerning the problem. The explanatory letter of 15 November 1910 shows that he applied for this sum to pay only the rent of the private apartment, where the anthropological collection was located, in case no space could be found in University buildings. On the same day he submitted to the Faculty of Medicine a list of those students who had acquired the anthropological technique in the course of studies and who were already involved in research. Students H. Niggol, V. Bortkevich, and A. Tumm were studying the chest, G. Michelson was studying skeletons, V. Sukhoruchkin jawbones and teeth, K. Kühne the mongol spots that occurred in some newborns, and A. Noskov and D. Richter were studying dactyloscopic material.

On 15 November 1910 the Council of the Faculty of Medical decided (seven votes for and one against) to apply to the University Council for the allocation of one or two rooms for *Privatdozent* Landau's collection in University buildings, or, should that be impossible, then 200–300 roubles per year. The substantiated opinion of the Faculty for the University Council (on three typewritten pages) had been drafted by N. Savelyev [2], full professor of polyclinic, medical diagnostics and propaedeutics. It was signed by A. Rauber, full professor of anatomy, W. M. Fr. Zoege von Manteuffel, full professor of surgery, A. Yarotski, extraordinary professor of special pathology and clinic, Y. Shepilevski, extraordinary professor of state medicine (in hygiene), D. Lavrov, extraordinary professor of pharmacology, dietetics, and history of medicine, and V. Tshizh, full professor of psychiatry [4]. The document gave a favourable evaluation of A. E. Landau, *Privatdozent* of anatomy, whose lectures and practical classes had inspired an entire group of students to take an interest in anthropology and some of them even to conduct research. It was also pointed out that without spending any University funds he had obtained the necessary equipment for successful teaching and plaster casts of bone finds of excavated humans. He had bought a set of most recent anthropological instruments in Zurich; the well-known Swiss professor of anthropology R. Martin himself had helped him to choose them. As a zoology professor from another faculty was using the collection, too, it was considered to be a serious drawback that the collection was located in Landau's private apartment near the railway station. Attention was then drawn to the fact that the University had a long tradition of studying general and special problems of anthropology, which was proved by the research papers by anatomy professors and their numerous disciples. The names of K. E. von Baer, L. Stieda, F. Waldhauer, I. Brennsohn, A. Rauber, R. Weinberg, E. Hugo and others were mentioned. As the previous thirty years had witnessed an interest in anthropological knowledge among criminalists and psychiatrists, then most council members found that this subject was of utmost importance to future doctors, who, by working in different areas, could conduct the necessary research and contribute to the development of this branch of science. At the same time they felt that the teaching of anthropology was hindered because all the teaching aids were located away from the University in Landau's private apartment, which in itself was inconvenient to students and lecturers alike. The council also believed that if efforts to find rooms for the anthropological collection failed, then, as a consequence, the University might lose its significance as an academic centre in the field of anthropology. Therefore, it was decided that the Faculty would apply to the University Council for the endorsement of the application by *Privatdozent* A. E. Landau (either to allocate one or two rooms for the collection in a University building, or if that proves impossible, to allocate 200–300 roubles per year to pay the rent for the private apartment that accommodated the collection in two rooms).

On 20 November 1910 P. Polyakov, full professor of comparative anatomy, embryology, and histology, submitted a different opinion that takes up slightly more than one hand-written page. He disagreed with the position of the Faculty of Medicine concerning the allocation of space and funds to the private anthropological collection of Landau. Prof. Polyakov found that there was no need to open a new ancillary teaching institution because the University constitution of 1884 did not foresee it, and the existing ancillary teaching institutions were insufficiently provided with necessary equipment. He also pointed out that at Russian universities the teaching of anthropology and the anthropological museum had always been affiliated to the department of human anatomy. He then asked why the University should allocate space and funding for a private collection. He regarded it as a dangerous precedent — in the future any *Privatdozent* who for some reason was not satisfied with his department and ancillary teaching institution could apply for his own rooms and funding for its equipment. By way of conclusion Prof. P. Polyakov suggested that the anthropological collection should be affiliated to the Institute of Anatomy, which would result in the extension of its rooms and the allocation of additional funding to the director of the Institute but not to the private collection of Dr Landau.

On 30 November 1910 the University Council discussed the application of the council of the Faculty of Medicine concerning the collection of *Privatdozent* Landau, and decided that the problem would be solved at a later time. The same application was on the agenda once again on 10 December, and it was decided then that it would be forwarded to the University Administration, which in its turn on 21 December sent an enquiry to J. Gravit, the director of the student dormitory, about vacant rooms. In his reply of 29 December the director of the dormitory pointed out that no vacant rooms were available — but taking into account the fact that all the University institutions should render assistance in order to improve teaching, the main task of the University, then it would be possible to allocate a two-person corner room on the first floor for the anthropological collection. The room would never be empty, but students would use it reluctantly because in winter it was colder than the other rooms. It was located close to the hall and the lecture room of the dormitory; therefore it was always noisier than the other dormitory rooms.

On 30 December 30 University Administration decided not to create any obstacles for the allocation of this room on condition that the collection had to be donated to the University. The resolution was forwarded to the University Council.

On 28 January 1911 the University Council decided to endorse the allocation of the room in the dormitory on the same terms, asking *Privatdozent* Landau to submit a list of the items belonging to the collection and to apply to the curator of the Riga Educational District for the endorsement of this resolution at least on a temporary basis until the completion of some new University building. On 1 February 1911 *Privatdozent* A. E. Landau submitted a two-page hand-written list of the items that he would hand over for the future anthropological collection.

He had divided his donation into five sections. The first section comprised plaster casts of excavated bone finds. The second section consisted of two skeletons, the third one consisted of instruments and equipment, the fourth section included charts and photos, and the fifth section consisted of a small library. *Privatdozent* Landau also promised to supplement the collection in the future in accordance with his possibilities.

In his letter of 17 February 1911 the curator of the educational district informed the Rector of the University that the University Council's resolution concerning the allocation of the rooms for *Privatdozent* Landau's anthropological collection would be endorsed on condition that the owner of the collection would transfer it completely to the ownership of the University.

After receiving the list of the anthropological collection on 25 February 1911, the University Council thanked *Privatdozent* Landau for his donation and asked him to act as the director of the anthropological collection [2]. Thus, in February 1911 the University created a new ancillary teaching institution — No. 36. The previous list of such institutions included the University library, three museums, two observatories, the botanical garden, the drawing school, two collections, seven institutes, ten studies, six clinics, a polyclinic, and an outpatient clinic [5]. A few days before (as of 22 February 1911) A. Rauber, the distinguished professor of anatomy, whose favourable attitude had contributed to the successful teaching and research in anthropology, had retired. His position was taken up by *Privatdozent* Hermann Ernst Adolphi MD (1863–1919), who had worked 20 years at the same institute as a prosector [1].

On 31 January 1912 A. E. Landau, the director of the anthropological collection, reported on the first year of its activity. The report shows that the collection included 12 plaster items in 41 copies, 15 units of anthropological instruments and devices, two skeletons, 13 charts and maps, 19 titles of books in 20 volumes and two cabinets. Added is a hand-written note that all the above-named items were purchased for his personal funds [6]. As of 20 June 1912 *Privatdozent* A. E. Landau was appointed as director of the anthropological museum. The University Administration, in coordination with the curator of the Riga Educational Department doubled the available space in the student dormitory; another room was added to the existing two-person room [2].

The museum report of 30 January 1913 by *Privatdozent* Landau indicates that during the previous year the museum had acquired one chart, three models, two museum tables, nine models of representatives of various races and an atlas of photos of Estonian brains. To this report, too, the director had added a remark that all the above-named items had been purchased for his personal funds [7]. Landau had written this report already after leaving the University (as of 12 January 1913) for Berne, where he became an extraordinary professor of anatomy [8]. The abandoned anthropological museum soon became inactive and stopped its existence at the end of the First World War although H. E. Adolphi, extraordinary professor of anatomy, had been appointed as acting director.

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GROWTH CURVES OF ANTHROPOLOGICAL MEASUREMENTS OF 0–13-MONTH-OLD ESTONIAN CHILDREN

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ABSTRACT

In the present paper, growth curves are found to predict and analyse the weight, height and head circumference of children during their first 13 months of life. A total of 4749 children were measured. Each child was measured twice: at birth and 1–13 months later. The most important parameter in the models is age, but birth parameters were significant as well.

Key words: growth curves

INTRODUCTION

Growth is a complex biological phenomenon, which has a vital part in the child's development. It is important to study the growth curves of normal children. Disease or bad living conditions inhibit the child's growth. On the other hand, abnormally quick height growth and especially weight growth can be a sign of a disease. Accurate measurements over time and comparisons with established standards are essential for the early recognition, diagnostic evaluation and successful management of growth and nutritional problems in infants or children.

MATERIALS AND METHODS

The data for this study were collected in 1989-1997 from different regions of Estonia. A total of 4749 subjects were studied, 2344 girls and 2405 boys. The following parameters were measured: birth weight, birth height, head circumference at birth and weight, height, head circumference 1-13 months later.

Table 1 gives the mean values and standard deviations of anthropometric measurements at birth.

Table 1 Basic statistics

		Birth weight		Birth height		Head circumference at birth	
	n	Mean	SD	Mean	SD	Mean	SD
Total	4749	3508	492	50.66	2.37	35.53	1.47
Female	2344	3425	478	50.35	2.37	35.28	1.46
Male	2405	3589	492	50.97	2.34	35.77	1.44

Age is the most important parameter in the model and is given as in our earlier study [2]. Age is a child's age at the second measurement (1–13 months).

1–45 days =1.5	136–165 days =5.5	261–290 days =9.5
46–75 days =2.5	166–200 days =6.5	291–320 days =10.5
76–105 days =3.5	201–230 days =7.5	321–350 days =11.5
106–135 days =4.5	231–260 days =8.5	351–380 days =12.5

In this paper growth = weight – birth weight (height – birth height and head circumference – head circumference at birth).

In order to predict the growth curves we used non-linear regression analysis. We compiled two different groups of models. There are few parameters in the first group of models, and we can easily use these models to predict the weight, height and head circumference growth. In the second group the models contained many arguments like sex, birth measurements and age. Using all this information, we can analyse children's growth more specifically.

The statistical package SAS was used for data processing.

RESULTS

We compiled several linear models of changes in the growth measurements.

1) To predict the weight, height and head circumference of children during their first 13 months, the following models were found:

Weight growth = –429.26 + 992.53 (age) – 33.69 (age^2) R^2= 0.862

Height growth = –0.21 + 3.33 (age) – 0.11 (age^2) R^2= 0.875

Growth of head circumference = 0.40 + 1.57 (age) – 0.06 (age^2) R^2= 0.756

Graphically the changes in the growth of measurements are presented on Figures 1 and 2.

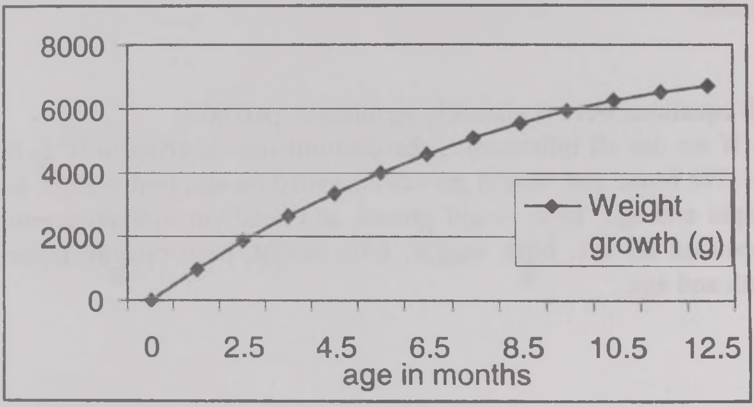

Figure 1. Change in weight during the first 13 months.

2) To analyse the weight, height and head circumference of children during their first 13 month the following models were found:

Weight growth = –1286.05 + 403.25 (sex) – 0.31 (birth weight) + 34.25 (birth height) + 992.64 (age) – 33.69 (age^2) R^2= 0.872

Height growth = 29.39 + 1.06(sex) + 0.002 (birth weight) – 0.76 (birth height) + 0.07 (head circumference at birth) + 3.36 (age) – 0.11 (age^2) R^2 = 0.909

Growth of head circumference = 24.48 + 0.74 (sex) + 0.0005 (birth weight) + 0.03 (birth height) – 0.77 (head circumference at birth) + 1.53 (age) – 0.05 (age^2) R^2= 0.841

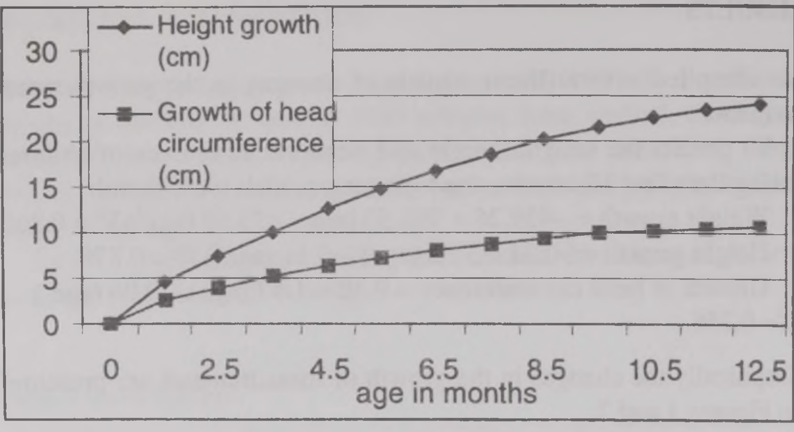

Figure 2. Change in height and head circumference during the first 13 months.

All equations were statistically significant (p<0.001).

If we use all information, the determination coefficient R^2 is bigger. We found that weight growth depended on sex, birth weight, birth height and age. Both height growth and head circumference growth depended on sex, birth weight, birth height, head circumference at birth and age.

DISCUSSION

Evaluation of the child's pattern of growth is the most helpful clue in the determination of growth disorders. Growth disorders may be the first manifestation of certain diseases.

The best model to predict growth is the quadratic model. At the end of child's first year of life the growth of linear measurements slows down. We use all information to analyse the weight, height and head circumference growth: sex, birth measurements and age. Practising doctors may find these formulae helpful in evaluating children's growth disturbances.

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ODONTOLOGY OF PADA CEMETERY (12^{TH}–13^{TH} CENTURY) INDIVIDUALS

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ABSTRACT

The odontological study included 117 individuals from Pada cemetery (11^{th}–13^{th} cc.) in Northeast Estonia. 13 odontological and 2 odontoglyphical traits were registered and odontological type of Pada individuals was defined. Individuals of Pada cemetery have the same northern gracile odontological type as north-east Estonians today. Pada skulls have quite low frequency of Carabelli cusp, but most of North-European series from the end of the Iron Age have similarly low frequencies of Carabelli cusp. Pada individuals have high reduction of M_1 and M_2, which is typical of Northern Caucasoids, but high incidence of some eastern features was also registered. The frequency of moderate and pronounced shovel-shaped medial and lateral incisors, and the frequency of deflecting wrinkle on M_1 were quite high. The high frequency of four cusped M_1 and deflecting wrinkle on M_1 means that ISC was high too, which is typical of most of Finno-Ugric groups. The high incidence of shovel- shaped upper incisors is also typical of Finno-Ugric groups. The Pada group was compared with other historical groups from the end of the Iron Age from Estonia, Latvia and Northwest Russia. Cluster analysis showed greater odontological similarity between all Estonian historical groups and Zemgals from Latvia. The Slavonic groups but also the Livonians and Latgals from Vidzeme were more different.

Key words: odontological traits, odontoglyphical traits, Iron Age, Pada cemetery

INTRODUCTION

The odontological data of historical populations contribute to the knowledge of their anthropological character, to the history of their formation, and, in this way, they are of great importance for solving complicated ethnological problems [10]. For historical population is concerning that differently preserved skulls belong to different age groups, which complicates the determination of true features which can be observed only on non-abrased teeth.

Odontological types of present day Estonians have been determined and there is thorough overview of odontological features from various parts of Estonia [9]. Nowadays the classical variant of the northern gracile type prevails in Northeast Estonia. To the west and south the odontological complex is mixed — northern gracile, Central European and North European relic types occur in different proportions. As one nears the Western coastal districts and islands, the features common to the Central European type dominate, though gracility of denture that is characteristic of Estonians is peculiar to Western parts of Estonia, too. All present-day odontological types in northern Europe have formed in the distant past. By the end of the Iron Age these types had already formed. The currently examined skulls date from the same age period.

From historical populations of Estonia, skulls from the cemeteries of Jõuga (12^{th}–14^{th} century) and Tääksi (14^{th}–17^{th} century) have been odontologically studied [1, 8]. Jõuga cemetery is situated in Northeast Estonia, and G. Sarap has determined that the skulls from Jõuga belong to the north-gracile odontological type like those of present-day north-east Estonians. The cemeteries of Jõuga and Pada are both from the end of the Iron Age, but they do not share the same burial customs. The cemetery of Jõuga has Votic graves differently from Pada, which has pit graves. The cemetery of Tääksi is from a later period, and the accurate odontological type has not been determined. The aim of the current study is to describe the odontological type of Pada and to find an accurate description on the base of which we can evaluate the odontological resemblance of culturally different groups who occupied the same habitat. It is important to compare them to present-day north-east Estonians and establish their ethnic origin. The study also observes different groups from Latvia and North-west Russia from the end of the Iron Age.

MATERIALS AND METHODS

The cemetery of Pada was excavated from 1987 to 1989 by T. Tamla. The cemetery belonged to the Pada stronghold, which was the largest Iron Age stronghold in Viru County. The cemetery is situated in North-east Estonia near the Pada River beside the Tallinn–St. Petersburg road. The graves date from the 12^{th}–13^{th} centuries (the end of the Iron Age), and they are Pit Graves. The skeletons were quite well preserved, and craniological studies (discrete features) have been made by T. Kivisild [4].

The study included 117 skulls. All the skulls are deposited in the ossary of the Institute of History of the Estonian Academy of Sciences. The skulls of very old individuals having no teeth or having great pathology and a great degree of dental attrition, and also the skulls of very young individuals having no permanent teeth were excluded. The spacing (diastema) between upper medial incisors (I^1–${}^1I$), the crowding of the upper second incisors, the reduction level of second upper incisor, the shape of lingual surfaces of the upper incisors, the enamel prolongments on the second upper molar (M^2), the form of the upper molars, connected with the hypocone reduction, the shape of the lower molars, the distal trigonid crest (M_1), the deflecting wrinkle (M_1), the inner medial supplementary tubercle on the first lower molar were checked odontoscopically. The crowns of the upper first molar and lower molars of 54 infantile skulls were examined odontoglyphically. The shape of the first paracone furrow on the first upper molar, the course of the second metaconid furrow on the first lower molar and the courses of furrows of entoconid on the second lower molar were registered (Table 1). Odontoscopical and odontoglyphical examination was carried out by the method of A. Zubov [11, 12].

For comparison with Pada materials, odontological data of historical populations from the neighbouring territories Latvia and Russia (the end of Iron Age) were used (Table 2) [2, 3, 15]. Some contemporary populations from Estonia and two Estonian historical groups from Jõuga (12^{th}–14^{th} century) and Tääksi (14^{th}–18^{th} century) were also used [1, 8, 9].

Table 1. Distribution of odontological and odontoglyphical traits in the dentition of Pada group

SPACING I^1–^1I		GROWDING		REDUCTION I^2		SHOVEL – SHAPED I^1		SHOVEL – SHAPED I^2		DEFLECTING METACONID WRINCLE	
N	61	N	77	N	82	N	69	N	69	N	50
0	93,5%	0	93,5%	0	95,1%	1	43,5%	1	33,3%	0	88%
1	6,5%	1	6,5%	1	3,6%	2+3	17,3%	2+3	39,1%	1	12%
				2	1,2%						
CARABELLI CUSP		**M^2 SHAPE**		**M_1 SHAPE**		**M^2**		**DISTAL TRIGONID CREST**		**TAMI**	
N	66	N	97	N	100	N	93	N	56	N	90
1	42,4%	4	23,7%	6K	2%	4K	92,5%	0	98,2%	0	97,8%
2–5	30,3%	4–	44,3%	5K	78%	5K	7,5%	1	1,8%	1	2,2%
		3&3+	32,0%	4K	20%						
M_2 ENAMEL PROLONGMENTS		**RUN OF 2 MED ON M_2**		**SHAPE OF 1 PA ON M_1**							
N	75	N	45	N	43						
0	44%	2MEDII	33,3%	1	46,5%						
4	25,3%	2MEDIII	42,2%	2	44,2%						
5+6	30,7%	2MEDFC	24,4%	3	9,3%						

Table 2. Distribution of odontological and odontoglyphical traits of Pada group (12^{th}–13^{th} cc.) and neighbouring synchronous materials

	Spacing	Growding	Reduction I^1 (degree 2+3)	Reduction I^1 (degree 1)	Reduction Hy M^2	Carabelli cusp (degree 2–5)	4 M_1	6 M_1	4 M_2	Shovel shaped I^1(degree 1)
Pada	14.1	6.5	1.25	3.6	32.63	30.64	21	2	92.55	36.23
Jõuga 12^{th}–16^{th} cc***	22.9	0	0	3.6	25	20	25	0	90.8	30.2
North East Estonians today**	10	7.8	1.8	22.6	58.7	43	22.3	3.3	90.3	41.1
Zemgals 6^{th}–13^{th} cc*	22.7	15.8	4.8	19	29.4	14.3	16.1	0	89.8	
Livonians 10^{th}–13^{th} cc*	0	0	0	37.5	34.1	55.4	11.8	7.3	87.7	
Ladoga 9^{th} cc*	0	17.3	0	20	13.5	27.7	11.5	7.7	87.5	
Beguns 9^{th}–13^{th} cc*	5.6	6.7	0	13.3	30.2	48.3	17.1	2.9	88.6	
Valgovits 13^{th}–14^{th} cc*	0	0	0	28.6	7.4	54.5	3.6	7.1	70	
Tääksi 14^{th}–18^{th} cc****	11.4	15.6	0	9.5	52.5	29.4	18.4	2.6	81.3	
Contemporary Estonians**		13.3	1.5	18	53	46.2	13.5	0.99	85.7	38.2
Slavs of St. Petersburg 9^{th}–14^{th} cc *	4.3	0	0	14.3	28.2	41.4	8	4	86.2	
Slovens of Novgorod 9^{th}–14^{th} cc*	7.9	13	0	0	37.7	45.7	11.6	2.3	90.6	

	Shovel shaped I^1 (degree 2–3)	Shovel shaped I^2 (degree 2–3)	Deflecting wrinkle	Distal trigonid crest	TAMI	2med II	2med III	1pa 3
Pada	17.3	34.28	12	3.44	2.12	33.3	48.8	9.09
Jõuga 12^{th}–16^{th} cc***	14	65.4	21.3	4.9				
North East Estonians today**	10	18	22.5	2.3		47.9	34.4	
Zemgals 6^{th}–13^{th} cc*	5		14.3	0		40	26.7	21.4
Livonians 10^{th}–13^{th} cc*	16.7		16.9	0		31.6	32.9	39.3
Ladoga 9^{th} cc*	0		14.3	11.8		9.1	54.5	16.7
Beguns 9^{th}–13^{th} cc*	0		16	12		20	20	33.3
Valgovits 13^{th}–14^{th} cc*	0		13.3	6.7		37.5	25	15.4
Tääksi 14^{th}–18^{th} cc****	15.6		5.3	0	0			
Contemporary Estonians**	11.2	14.9	12.5	0.47		43.3	26.6	
Slavs of St. Petersburg 9^{th}–14^{th} cc*	0		5.9	0		27.8	33.3	30
Slovens of Novgorod 9^{th}–14^{th} cc*	0		8.3	0	4.2	24	24	21.5

* — Gravere 1987, ** — Sarap 1994, *** — Sarap 1993, **** — Allmäe 1999

RESULTS

Spacing (diastema between the upper medial incisors) and **crowding** (lingual displacement of the upper lateral incisors) are traditional components of odontological programmes [10]. The frequency of spacing in Pada population is 15.7% and the frequency of crowding 6.33%. This is quite similar to the present-day populations in North-east Estonia (spacing 18.5% and crowding 7.9%), although the population of Pada is quite archaic.

Reduction of the upper lateral incisors (degrees 2+3) appeared in one skull (1.19%) and frequency of 1 degree of the I^2 reduction was 2.38%.

Shovel-shaped upper incisors are a feature of eastern orientation, and they are quite common in Mongoloids. There are, however, some regions in Europe with higher incidence of shovel-shaped incisors. One of the regions of high frequency of shovel-shaped medial incisors begins from East and North Latvia, proceeds through Estonia and covers Finland [3, 13]. Contemporary Estonians have quite a high frequency of shovel-shaped medial incisors (degrees 2+3) — 11.5%; in eastern populations it is even higher — 18.6–23.9%. The incidence of shovel-shaped lateral incisors is also high — 14.9%, in Eastern parts up to 31.4% [9].

In Pada group the incidence of shovel-shaped medial incisors (degrees 2+3) was 17.39%, and the incidence of shovel-shaped lateral incisors (degrees 2+3) was 35.71%. The initial stage of shovel-shaped I^1 was also high — 36.23%. The high percentage of initial stage I1 indicates the "Finnish" tendency in this group.

The enamel extensions are valuable odontological traits while investigating palaeoanthtropological materials. Masticatory surfaces of molars are usually markedly abrased in ancient skulls, and many odontological traits situated on the surfaces of teeth are not observable [12]. Frequency of enamel extensions on M^2 usually does not reach 30.0% in Caucasoid populations. In Pada group the frequency of the M^2 enamel extensions' pronounced forms (degrees 5 and 6) was registered in 30.7%.

The hypocone reduction of upper second molar is an odontological trait that varies quite irregularly even among racially close populations. Therefore, it is of low taxonomic value. It is also likely to be very sensitive to epochal changes [10]. Contemporary Estonians have a high percentage of reduction of hypoconus (3 and 3+) — 53%, which is typical for present-day European populations. The incidence of this feature in Pada group was lower — 31.95%.

Carabelli cusp in upper first molar is a remarkable feature since it is simultaneously a feature of Western orientation and also an epochic feature. In the present-day European populations the incidence of this feature is below 40%, but in historical groups from Europe the frequency of Carabelli cusp (degrees 2–5) is considerably lower [7]. In Pada group the frequency of the feature was 30.3%.

The shape of the lower molars is a very valuable trait in ethnic odontology. M_1 has commonly five cusps, but in Western populations, in many cases, M_1 has four cusps (on an average 10%) [12]. In Eastern groups, on the contrary, M_1 is often six-cusped (up to 65%) [7]. The reduction of lower molars in Pada group was quite high, the frequency of four-cusped first lower molars was 20% and of second molars 92.5%. The incidence of six-cusped first lower molars was typically low for an European group — only 2%.

The distal trigonid crest is a trait connected with the eastern and particularly with the south-eastern areas of Europe. This trait occurs rarely in North European populations [12]. In Pada group the incidence of the distal trigonide crest was 1.8%.

The deflecting wrinkle of the metaconid on M_1 is the main "oriental" indicator that penetrated Europe most intensively from the east via the "northern channel" [13]. In present-day European groups the incidence of the deflecting wrinkle does not exceed 10%, with one exception in the area of North Europe (from North Latvia to North Finland), where the incidence of this feature is quite high (up to 34% in north-east Finland) [3]. In Pada group the frequency of deflecting wrinkle was 12%.

The inner medial supplementary tubercle (T.A.M.I.) is of low frequency in "Western" groups and in Pada group the frequency of T.A.M.I. was 2.2%.

The run of the second metaconid furrow (2 med) on the M_1 is one of the odontoglyphical features. Within the confines of the Western odontological complex, a high incidence of the version 2 med II is considered to be a northern peculiarity [10]. The incidence of this version in Pada group was 33.3%.

The shape of the first paracone furrow (1 pa) is also an odontoglyphical feature and the third type, or lyre-shaped 1 pa, is usually taken into account. The lyriform 1 pa is a satisfactorily examined marker of the Mongoloid race [10]. In Pada skulls it was found quite rarely (9.3%).

DISCUSSION

Two odontological types are most common to present-day Estonians. The first type is northern gracile, which is dominant in North-east and East Estonia, the second major type is the Middle European type, which occurs mostly in West Estonia. The Middle European type is characterised by low gracilacion of lower molars and low frequencies of Eastern features. The occurrence of Western features, Carabelli's cusp and 2 med II, is high. High incidence of four-cusped lower molars but also higher occurrence of some eastern features such as shovel-shaped I^1 and crowding are mostly common to the Northern gracile type. Particularly distinctive is the higher occurrence of deflective wrinkle than in Europeans in average. ISC (multiplication of four-cusped M_1 and deflecting wrinkle) is also above the average, which is a distinctive feature of the Northern gracile type, where ISC exceeds 150. The occurrence of Carabelli cusp is high as well.

A distinctive feature of Pada group is high reduction of lower molars (M_1 and M_2). Four-cusped lower first molars are less common to present-day Estonians by 13.5% [8]. Frequent occurrence of shovel-shaped incisors (degree 2 and 3), which are also distinctive to other Finno-Ugric groups, was also observed. Although this is quite an old series, we can see a high rate of crowding. Since there is high reduction of M_1 and high rate of deflective wrinkle, the value of ISC (240) is high as well. So we can state that the individuals of Pada have the Northern gracile odontological type, the same as present day north-east Estonians. Jõuga individuals also belong to the Northern gracile type, but still there are different burial customs in Jõuga (Votic graves) than in Pada (pit graves). Despite different cultural backgrounds, both groups are odontologically very similar.

To find odontological similarities between different groups from neighbouring territories, the cluster analysis method was used (Fig. 1). Groups from Estonia, Latvia and North-west Russia from the end of the Iron Age were studied. The analysis showed similarities between the Estonian historical series and Zemgals, which form one comprehensive cluster. The historical groups from Russia form a separate cluster. The last cluster includes Livonians and Latgals from Vidzeme. The analysis did not include contemporary series because of some features which have changed in the last ten centuries like Carabelli cusp and reduction of hypocone on M^2. From the ethnic aspect the result would not be objective because most of the changes are epochal. For analysing different features of Pada and for better visualisation of features comparing graphics have been calculated. Graphics give location of features compared to each other and include reduction and Western features according to Eastern features (Fig. 1, 2). The western features include Carabelli cusp, four-cusped M_1 and M_2; the Eastern features include crowding, six-cusped M_1 shovel-shaped I^1(degree 2 and 3), deflecting wrinkle, distal trigonide crest, and finally reduction features reduction of I^2(degree 2 and 3), hypocone reduction on M^2, four-cusped M_1 and M_2. Cluster analysis shows a clear difference between the Estonian groups and Vidzeme's Latgals and Livonians groups, but the graph shows that Eastern features are quite similar in Estonian and Latvian groups, differences occur mostly in Western features. The eastern-reduction graph shows the concentration of Estonian and Latvian groups. The Slavonic groups are placed separately on both graphs.

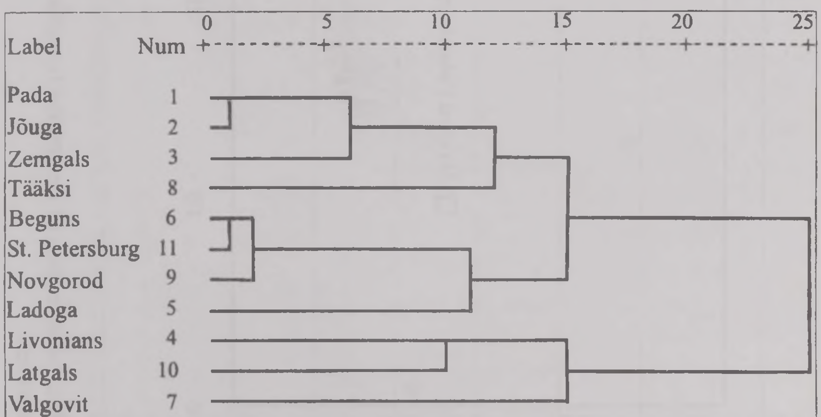

Figure 1. Cluster analysis of groups from the end of the Iron Age from Estonian, Latvian and Russian territories.

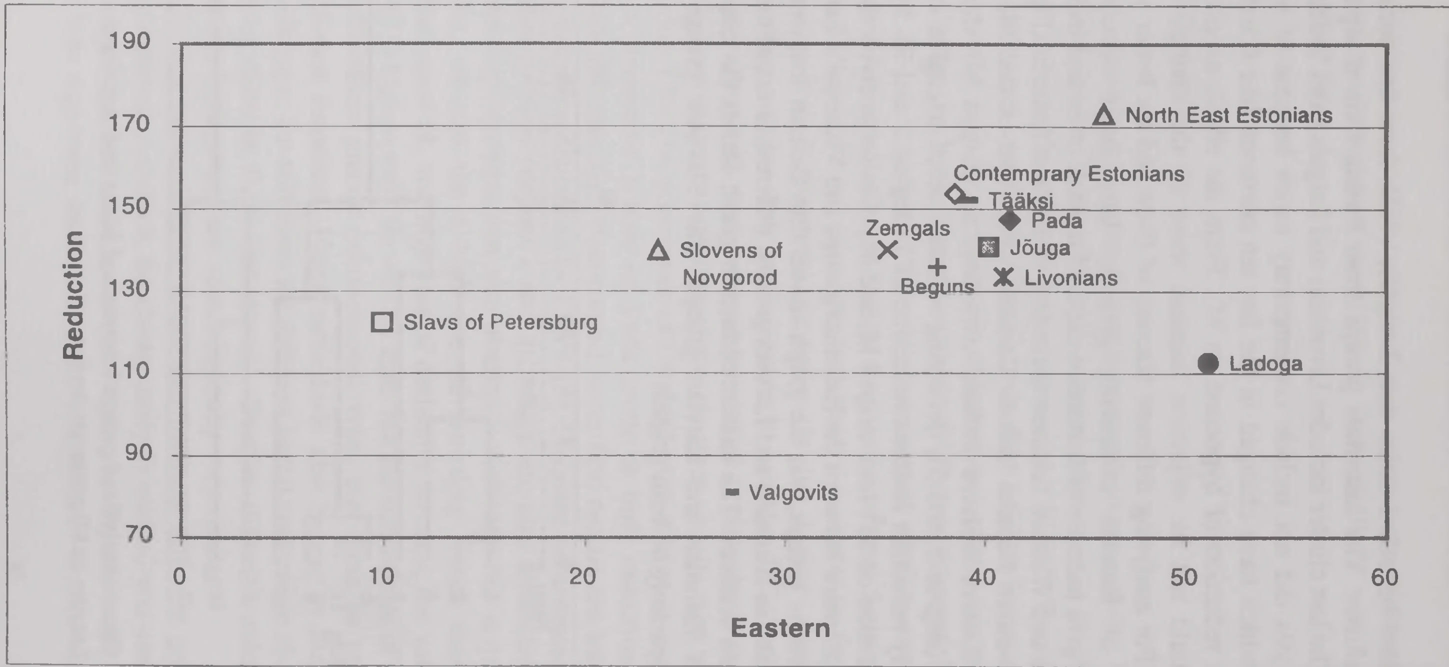

Figure 2. Graphical distribution of the groups from the end of the Iron Age and contemporary Estonians by Eastern and reduction odontological features.

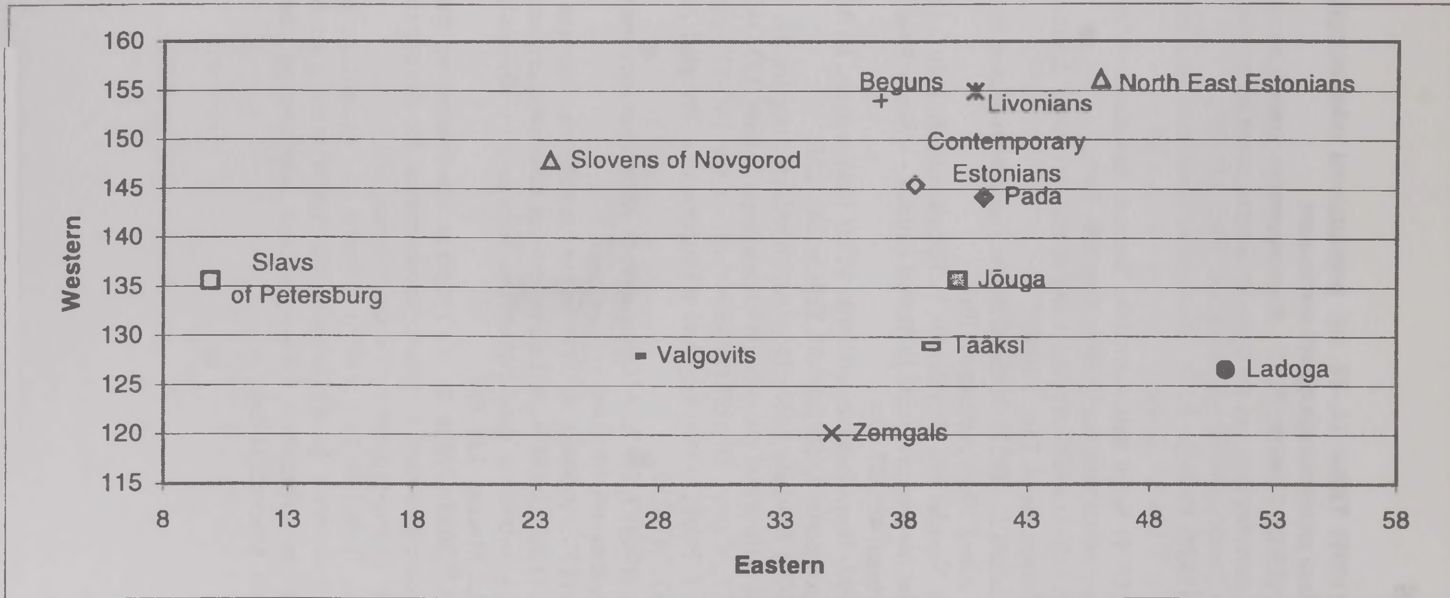

Figure 3. Graphical distribution of the groups from the end of the Iron Age and contemporary Estonians by Eastern and Western odontological features.

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SYSTEMATIZATION OF ANTHROPOMETRIC DATA OF BODY STRUCTURE IF HEIGHT CLASS IS MEDIUM AND BODY WEIGHT IN CLASSES SMALL, MEDIUM AND LARGE. PART I.

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ABSTRACT

The aim of the present survey was to examine a statistical model — the height-weight standard deviation (SD) classes — if all the subjects are from the medium height class with body weight from various classes — small, medium and large. Thirty-five anthropometric variables were measured by the method of R. Martin and twelve skinfolds by the method of T. Lohman.

1255 boys aged 17–18 years from the city of Tartu and Tartu and Põlva counties were recruited in this study. Their anthropometric data were systematized into 3×3 height-weight SD-classes. For the present analysis, the anthropometric data of 463 individuals from three classes with medium height and different weights — small, medium and large were used.

It was revealed that these classes were characterized by significant changes in anthropometric variables. However, there were no changes in heights and height indices. On the contrary, all breadths and depths, circumferences, skinfolds, body composition indices and proportions changed while weight increased from small to medium to large. Weight increase was accompanied by an increase in bone, muscle and fat mass. Relative bone mass decreased, relative muscle mass remained unchanged and fat percentage increased.

Key words: body height, body weight, height and weight SD classes

INTRODUCTION

Constitutional typology is well known to be a useful tool not only in obtaining individual diagnoses but also in identifying the average typology of a given population in order to establish the relationship between physique and motor performance. Still, there is no universally accepted schema for classification of anthropometric data [26].

The Women's Clinic at the University of Tartu has been studying the body structure of young nondelivered women from 1974 up to now [12, 13]. By statistical methods it has been proved that the structure of woman's body is a well-correlated system, in which the leading role belongs to height and weight. Over fifty per cent of the variability of other anthropometric characteristics is the result of different height and weight.

In numerous publications [9–11, 14, 15, 17–19, 21, 24–26, 28, 29] H. Kaarma and her pupils have recommended a SD classification of body height and weight into 3×3 SD classes in the following way. Height and weight are divided into three classes: the "medium" class includes the mean value ±0.5 SD; all values of height and weight below these would be classified as "small", and all values over the above mentioned ranges as "large". So we generate nine classes — three classes with harmony between height and weight (small, medium and large); three classes with height dominating over weight and three classes with weight class dominating over height. All the publications have included exact statistical analysis, which shows that the classes with harmony between height and weight have statistically proven differences by Sheffe test, and also three alliance classes with weight class dominating and alliance class with height class dominating have statistically significant differences.

The purpose of this study was to examine body structure in the "medium" height classes, which rank by weight into classes "small", "medium" and "large". We hypothesized that the height changes are small and nonsignificant but, on the contrary, changes in breadths, depths, circumferences and skinfolds are significant in so defined classes.

MATERIAL AND METHODS

The sample considered in this paper includes 463 boys at the age of 17–18 years from the city of Tartu, and Tartu and Põlva counties. For anthropometric investigation the subjects were dressed only in cotton briefs. The anthropometric variables measured were as follows: body weight and height; seven heights — height to suprasternale notch, *processus xiphoideus* height, umbilical, symphyseal, iliospinale, *acromiale* and *dactylion* heights; ten breadth and depth measurements — biacromial, chest, waist and bicristal breadths, chest and abdomen depths, elbow, wrist, femur and bimalleolar breadths; circumferences — head, neck, chest, plus at maximum inspiration and at maximum expiration, waist, pelvis, hip, proximal and midthigh, calf and ankle, arm, arm circumference flexed and tensed, forearm and wrist circumferences; skinfolds — chin, chest, midaxillary, suprailiac, supraspinale, abdominal, subscapular, biceps, triceps, thigh and calf. From these anthropometric variables projective upper limb length (acromiale minus dactylion), sternum length (suprasternal minus processus xiphoideus), abdomen length (processsus xiphoideus minus symphyseal height) and trunk length (suprasternal minus symphyseal height) were calculated. The measurements were taken according to the method of R. Martin [16, 23]. Skinfolds thiknesses were measured at standardized sites according to Lohman *et al* [20], Heyward and Stolarczyk [7]. Rohrer and body mass index, body surface area by DuBois and DuBois [4], body density by Wilmore and Behnke [30], relative fat percentage by Siri [27], absolute and relative mass of subcutaneous fat were calculated. Local subcutaneous fat and bone-muscle component on the cross-sectional areas of the arm and thigh were calculated according to De Koning, Binkhorst, Kauer and Thijssen [2]. Lower limb length was calculated by the formula of Jatsuta [8] — (iliospinale+symphysiale)/2. Muscle mass was calculated by the method of Martin *et al.* [22], bones mass by Drinkwater *et al.* [3], lung vital and total capacity by Baldwin, Cournand and Richards [1] and rest metabolic rate by Harris-Benedict [6].

For dividing the boys into a 3×3 SD classification, we computed their mean height and weight. The mean height was 179.11±6.39 cm and mean weight 69.22±9.61 kg. For medium height class the lower border was 175.91 cm and the upper border 182.31 cm. For medium weight the lower border was 64.41 kg and the upper border 74.02 kg.

Values below these borders were classified as "small" and values above them as "large". The medium height class included 463 subjects. Statistical significance between three weight classes was assessed by ANOVA test and between classes by t-test for two independent groups. The level of significance was set at $p<0.05$. Statistical package SAS® for Windows, version 6.12, was used for these calculations.

RESULTS

135 subjects were classified as having small weight (60.21±3.11 kg), 213 had medium weight (69.13±2.26 kg), and 115 had large weight (81.22±7.78 kg). The differences between the weight classes were statistically significant ($p<0.001$).

The mean values of all anthropometric variables and calculated indices were compared between the three weight classes.

As can be seen from the Table, there were no significant changes in length measurements — sternum, abdomen, trunk, upper and lower limb lengths (variables 3–7) did not change significantly. Neither were there any changes in relative trunk, abdominal, upper and lower limb lengths (v. 50–53).

All other anthropometric variables increased with increase of the weight class — depths and breadths (v. 8–17), circumferences (v. 18–29), skinfolds (v. 31–41), Rohrer and BMI (v. 42–43), body surface area (v. 44), mean skinfolds, mass of subcutaneous fat, body density, relative mass of fat by Siri (v. 45–49). Changes in the abovementioned variables caused an increase in indices (v. 54–72), indices of proportionality of the limbs (v. 73–81) and proportions of the trunk (v. 82–84). Cross-sectional areas of the limbs (v. 85–90) also increased with weight augmentation. It is remarkable that with weight increase the ratios of the bone-muscle area to fat area on limbs changed — fat area increased more than bone-muscle area (v. 91–94).

Calculated norms of the lung vital and total capacity and rest metabolic rate increased with weight increase (v. 95–97). Muscle mass by Martin *et al.* increased with weight increase, but the relative muscle mass remain unchanged (v. 98–99). More interesting changes happened to bone mass and relative bone mass — absolute bone mass increased with weight increase, but relative bone mass, vice versa, decreased with weight increase (v. 100–101).

Table 1. Basic statistics of anthropometrical measurements, indices and body composition data of 17–18-year-old boys grouped into medium-height and three weight classes

No	Variable	1 small weight n=135 mean	SD	2 medium weight n=213 mean	SD	3 large weight n=115 mean	SD	p-value 1,2,3	1–2	1–3	2–3
1.	weight (kg)	60.21	3.11	69.13	2.60	81.22	7.78	***	***	***	***
	Heights(cm)										
2.	height	178.73	1.65	179.21	1.71	179.65	1.86	***	**	***	*
3.	sternum length	17.16	2.06	17.14	1.92	17.40	2.10	ns	ns	ns	ns
4.	abdomen length	35.17	2.60	35.59	2.54	35.31	2.65	ns	ns	ns	ns
5.	trunk length	52.33	2.07	52.74	2.38	52.71	2.32	ns	ns	ns	ns
6.	upper limb length	79.04	2.69	79.64	2.42	79.70	2.39	ns	ns	ns	ns
7.	lower limb length	94.99	2.39	95.06	2.42	95.26	2.36	ns	ns	ns	ns
	Breadths and depths										
8.	biacromial breadth	38.90	1.27	40.15	1.39	40.98	1.48	***	***	***	***
9.	chest breadth	25.92	1.27	27.16	1.51	28.31	2.39	***	***	***	***
10.	waist breadth	23.74	1.56	24.90	1.52	26.70	2.40	***	***	***	***
11.	bicristal breadth	27.05	1.68	27.29	1.65	27.66	2.36	*	ns	*	ns
12.	chest depth	18.48	1.97	19.23	1.65	20.50	2.01	***	***	***	***
13.	abdomen depth	16.38	1.11	17.34	1.32	18.83	2.24	***	***	***	***
14.	femur breadth	9.06	0.75	9.34	0.58	9.72	0.73	***	***	***	***
15.	ancle breadth	7.47	0.45	7.62	0.42	7.78	0.50	***	**	***	**
16.	elbow breadth	7.15	0.34	7.29	0.38	7.40	0.45	***	***	***	*
17.	wrist breadth	5.75	0.38	5.86	0.37	5.97	0.33	***	*	***	**
	Circumferences										
18.	head circumference	56.20	2.36	57.38	1.38	57.93	1.38	***	***	***	***
19.	minimal neck circumference	34.53	1.17	36.21	1.23	37.99	1.23	***	***	***	***

20.	chest circumference	86.52	3.44	91.54	3.62	98.69	5.85	***	***	***	***
21.	waist circumference	70.27	3.68	74.72	2.81	82.20	7.13	***	***	***	***
22.	pelvis circumference	77.31	2.66	81.60	3.27	88.57	6.86	***	***	***	***
23.	hip circumference	85.99	2.80	90.28	2.96	96.19	6.16	***	***	***	***
24.	proximal thigh circumference	50.93	2.78	55.46	2.74	61.19	6.16	***	***	***	***
25.	midthigh circumference	44.50	2.94	48.05	2.79	52.28	4.28	***	***	***	***
26.	calf circumference	33.93	1.70	36.30	1.56	38.93	2.56	***	***	***	***
27.	ancle circumference	22.14	1.22	23.01	1.02	24.12	1.34	***	***	***	***
28.	arm circumference	25.78	1.68	28.20	1.50	31.72	2.58	***	***	***	***
29.	forearm circumference	24.45	1.30	26.09	1.11	27.90	1.60	***	***	***	***
30.	wrist circumference	16.74	0.66	17.27	0.66	17.92	0.68	***	***	***	***
	Skinfolds(cm)										
31.	chin skinfold	0.38	0.09	0.44	0.21	0.58	0.22	***	***	***	***
32.	chest skinfold	0.43	0.11	0.53	0.16	0.79	0.41	***	***	***	***
33.	midaxillary skinfold	0.52	0.13	0.68	0.22	1.12	0.54	***	***	***	***
34.	suprailiac skinfold	0.71	0.22	0.94	0.32	1.51	0.66	***	***	***	***
35.	supraspinale skinfold	0.46	0.12	0.54	0.17	0.89	0.58	***	***	***	***
36.	abdominal skinfold	0.64	0.19	0.86	0.32	1.51	0.80	***	***	***	***
37.	subscapular skinfold	0.68	0.16	0.85	0.22	1.36	0.61	***	***	***	***
38.	biceps skinfold	0.38	0.14	0.45	0.15	0.70	0.33	***	***	***	***
39.	triceps skinfold	0.65	0.19	0.85	0.28	1.25	0.53	***	***	***	***
40.	thigh skinfold	1.04	0.32	1.34	0.38	1.79	0.65	***	***	***	***
41.	calf skinfold	0.78	0.23	0.92	0.27	1.24	0.41	***	***	***	***
	Indices										
42.	Rohrer index	1.05	0.06	1.20	0.05	1.40	0.14	***	**	***	***
43.	body mass index	18.85	0.99	21.53	0.87	25.17	2.44	***	***	***	***
44.	body surface area (m^2)	1.70	0.11	1.81	0.12	1.94	0.12	***	***	***	***
45.	mean skinfold	0.61	0.12	0.76	0.18	1.16	0.46	***	***	***	***
46.	mass of subcutaneous fat (kg)	9.33	2.13	12.46	3.12	20.38	8.60	***	***	***	***
47.	relative mass of subcutaneous fat (%)	15.46	3.18	18.00	4.32	24.56	7.93	***	***	***	***
48.	body density (g/cm^3)	1.068	0.004	1.065	0.006	1.058	0.009	***	***	***	***

49.	relative mass of fat by Siri(%)	13.45	1.98	14.57	2.53	17.87	4.36	***	***	***	***
	Proportions										
50.	relative trunk length(%)	29.28	1.15	29.43	1.31	29.34	1.28	ns	ns	ns	ns
51.	relative abdominal length	19.68	1.44	19.86	1.41	19.66	1.49	ns	ns	ns	ns
52.	relative upper limb length	44.22	1.48	44.44	1.32	44.37	1.25	ns	ns	ns	ns
53.	relative lower limb length	53.14	1.21	53.04	1.19	53.02	1.16	ns	ns	ns	ns
54.	relative biacromial breadth	21.77	0.78	22.41	0.80	22.82	0.83	***	***	***	***
55.	relative chest breadth	14.50	0.71	15.15	0.84	15.76	1.33	***	***	***	***
56.	relative waist breadth	13.28	0.87	13.90	0.86	14.86	1.34	***	***	***	***
57.	relative bicristal breadth	15.13	0.92	15.23	0.93	15.40	1.29	ns	ns	ns	ns
58.	relative chest depth	10.34	1.10	10.73	0.92	11.41	1.11	***	***	***	***
59.	relative abdomen depth	9.17	0.65	9.68	0.74	10.48	1.25	***	***	***	***
60.	relative femur breadth	5.07	0.42	5.21	0.33	5.41	0.41	***	**	***	***
61.	relative ankle breadth	4.18	0.24	4.25	0.24	4.33	0.27	***	**	***	*
62.	relative elbow breadth	4.00	0.20	4.07	0.21	4.12	0.25	***	**	***	*
63.	relative wrist breadth	3.22	0.21	3.27	0.21	3.32	0.18	***	*	***	*
64.	relative chest circumference	48.41	1.98	51.08	2.07	54.94	3.33	***	***	***	***
65.	relative waist circumference	39.33	2.18	41.71	1.63	45.76	4.04	***	***	***	***
66.	relative pelvis circumference	43.26	1.52	45.54	1.90	49.31	3.88	***	***	***	***
67.	relative hip circumference	48.12	1.58	50.38	1.68	53.55	3.48	***	***	***	***
68.	relative proximal thigh circumference	28.50	1.59	30.95	1.58	34.06	2.40	***	***	***	***
69.	relative calf circumference	18.98	0.96	20.26	0.87	21.67	1.44	***	***	***	***
70.	relative arm circumference	14.42	0.96	15.74	0.85	17.66	1.48	***	***	***	***
71.	relative forearm circumference	13.68	0.74	14.56	0.64	15.53	0.93	***	***	***	***
72.	relative wrist circumference	9.36	0.38	9.64	0.38	9.98	0.39	***	***	***	***
	Limbs proportions										
73.	arm circumference/upper limb length (%)	32.65	2.47	35.44	2.24	39.85	3.72	***	***	***	***
74.	forearm circumference/upper limb length	30.97	1.94	32.79	1.74	35.04	2.26	***	***	***	***
75.	wrist circumference/upper limb length	21.21	1.09	21.70	0.97	22.50	1.11	***	***	***	***
76.	elbow breadth/upper limb length	9.06	0.52	9.15	0.50	9.29	0.61	**	ns	**	*
77.	wrist breadth/upper limb length	7.29	0.56	7.36	0.50	7.49	0.45	**	ns	**	*

78.	proximal thigh circumference/lower limb length	53.66	3.35	58.39	3.32	64.26	4.54	***	***	***	***
79.	calf circumference/lower limb length	35.74	2.00	38.21	1.79	40.89	2.76	***	***	***	***
80.	femur width/lower limb length	9.54	0.78	9.83	0.64	10.20	0.71	***	***	***	***
81.	ankle breadt/lower limb length	7.87	0.49	8.03	0.49	8.17	0.54	***	**	***	*
82.	chest depth/chest breadth	71.52	8.86	71.06	7.59	72.79	8.53	ns	ns	ns	ns
83.	biacromial breadth/bicristal breadth	144.42	10.84	147.64	10.74	149.18	14.04	**	**	**	ns
84.	biacromial breadth/chest circumference	45.02	2.06	43.91	1.98	41.63	2.28	***	***	***	***
	Areas and their proportions										
85.	total cross-sectional area of arm (cm²)	53.12	7.13	63.50	6.75	80.62	13.55	***	***	***	***
86.	bone-muscle rate of the cross-sectional area of arm (cm²)	46.67	6.26	54.67	6.26	65.65	9.31	***	***	***	***
87.	fat rate of the cross-sectional area of arm (cm²)	6.45	1.97	8.82	2.71	14.97	7.08	***	***	***	***
88.	total cross-sectional area of thigh (cm²)	207.16	22.74	245.53	24.34	299.49	41.80	***	***	***	***
89.	bone-muscle rate of the cross-sectional area of thigh	181.35	20.32	209.82	21.05	247.75	29.37	***	***	***	***
90.	fat rate of the cross-sectional area of thigh	25.81	8.18	35.71	10.75	51.74	21.56	***	***	***	***
91.	bone-muscle rate of the cross-sectional area of arm/total cross sectional area of arm	0.88	0.03	0.86	0.04	0.82	0.06	***	***	***	***
92.	fat rate of the cross-sectional area of arm/total cross-sectional area of arm	0.12	0.03	0.14	0.04	0.18	0.06	***	***	***	***
93.	bone-muscle rate of the cross-sectional area of thigh /total cross-sectional area of thigh	0.88	0.03	0.86	0.04	0.83	0.05	***	***	***	***
94.	fat rate of the cross-sectional area of thigh/total cross-sectional area of thigh	0.12	0.03	0.14	0.04	0.17	0.05	***	***	***	***
	Functional indices										
95.	lung vital capacity by Baldwin ml-s	4585.53	41.59	4595.28	44.48	4606.36	49.73	**	*	***	*
96.	total capacity by Baldwin ml-s	5731.91	51.99	5744.09	55.59	5757.95	62.16	**	*	***	*
97.	rest metabolic rate by Harris-Benedict(kcal)	1668.91	44.01	1793.04	37.64	1961.39	107.73	***	***	***	***
	Masses										
98.	muscle mass by Martin (kg)	33.39	3.52	38.75	3.26	45.37	5.64	***	***	***	***
99.	muscle mass by Martin percentage	55.43	4.86	56.04	4.08	55.91	5.29	ns	ns	ns	ns
100.	Bone mass by Drinkwater (kg)	8.92	0.84	9.36	0.76	9.87	0.98	***	***	***	***
101.	Bone mass by Drinkwater percentage	14.85	1.48	13.54	1.09	12.20	1.25	***	***	***	***

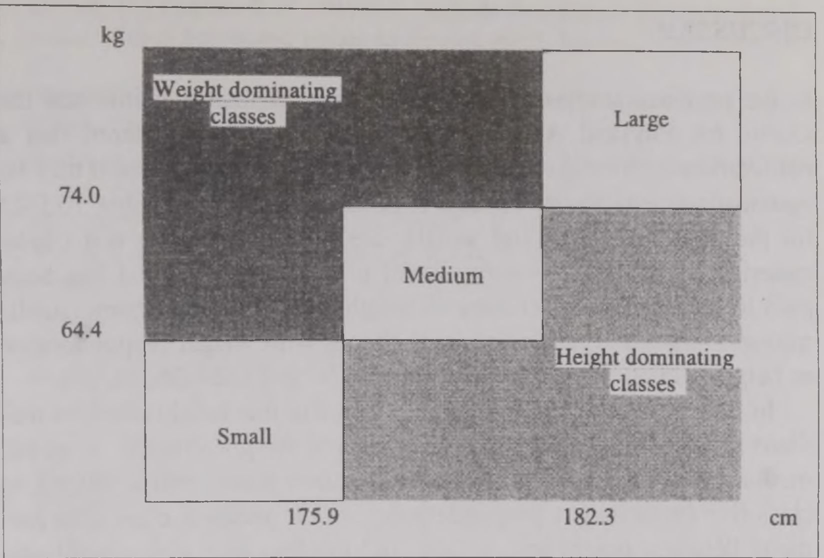

Figure 1. Classification of 17–18-year-old boys by five height/weight SD classes.

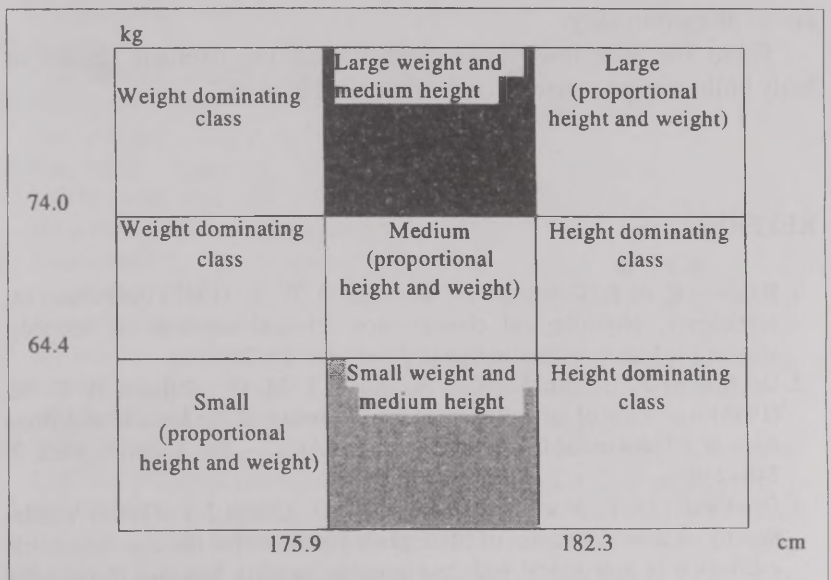

Figure 2. Classification of 17–18-year-old boys by five height/weight SD classes.

DISCUSSION

In the previous studies of Tartu University Women's Clinic and the Centre for Physical Anthropology it has been hypothesized that a multivariate statistical model is useful to reveal that body build may be systematized into classes created with mean height and weight ±0.5SD for the medium height and weight class and leaving the rest of the material outside these values. In all publications attention has been paid to the changes in classes of weight and height harmony (small-medium-large) and in contralateral classes with weight preponderance or height preponderance [9–11, 14, 15, 17–19, 21, 24–26, 28, 29].

In this study we examined the changes in one height class — medium (175.9–182.3 cm) — between three weight classes — small, medium and large. In the five-class system these groups belong to class five (with height preponderance), to the medium class with harmony between height and weight, and to class four with weight preponderance.

Our hypothesis that the three classes created within the medium height class are different by multivariate statistics was fully proved for anthropometric variables, body composition characteristics and indices of proportionality.

There are very few publications concerning detailed studies of body build except a special anthropological atlas [5].

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CONNECTION BETWEEN HEART MEASUREMENTS AND BODY DIMENSIONS OF 15-YEAR-OLD GIRLS

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ABSTRACT

The subjects of the study were 268 practically healthy 15-year old Estonian girls. They were studied anthropometrically and echocardiographically. The aim of the paper is to investigate and describe the mutual dependence between body measurements and heart dimensions, particularly to check the possibility of predicting the expectable values of heart dimensions using the body measurements. To reach the aim several methods of multivariate statistical analysis were used: correlation, factor, linear regression and canonical analysis. As a result the dependence structure of heart measurements as a four-factor structure was found; the most influential predictors for heart dimensions were identified; the best linear regression models for all heart dimensions were calculated and the canonical components, carrying the highest possible correlation between the heart dimensions and body measurements were determined. All computations were made using the standard procedures of STATISTICA and SPSS.

Key words: body measurements, echocardiography, heart measurements of girls

INTRODUCTION

Previous anthropometric investigations have proved that body build is a regular system and body measurements are mutually correlated [3]. The aspect that attracted our attention in the present paper is the relation between the dimensions of internal organs and anthropometric measurements [4]. The most frequent object of research has been the morphometric measurements of the heart [1, 2]. The problem how to establish norms for dimensions of heart in relation to dimensions of body has not been solved yet. Most often the relations between heart measurements and body surface area have been studied; body surface area has also been used to create standards for heart dimensions. It is obvious that one body dimension cannot be sufficient for standardising all heart measurements. The aim of the present paper is to analyse in detail the relations between heart dimensions and anthropometric measurements.

MATERIAL AND METHODS

The sample included 268 practically healthy Estonian girls from different regions of Southern Estonia. Their age varied from 14 years 5 months 29 days to 15 years 5 months 29 days. None of them trained for top-level sports and their sexual maturity corresponded to levels III–IV on Tanner's scale.

The girls were examined anthropometrically; 30 standard body measurements were taken, and several indices, including body surface area (by Du Bois formula) and mass of muscular tissue (by Matiegka formula) were calculated, see Appendix.

The dimensions of heart and blood vessels were studied echocardiographically with a two-dimensional Doppler echocardiograph Sonos 5500. Ten heart dimensions were measured (in millimetres) and, using standard formulae, some indices were calculated from them as follows:

1. Aortic cross diameter (AO),
2. Anterior-posterior diameter of the left atrium (LA);
3. Cross diameter of the right ventricular outflow tract (RVOT);
4. Cross diameter of truncus arteriae pulmonalis (AP);
5. Ventricular septum thickness in diastole at the base of left ventricle (STd_1);
6. Left ventricular posterior wall thickness in diastole at the base of left ventricle (PWd_1)

7. Ventricular septum thickness in diastole at the medium segment of left ventricle (STd);
8. Left ventricular posterior wall thickness in diastole at the medium segment of left ventricle (PWd)
9. Left ventricular maximal cross diameter in diastole (LVEDd);
10. Left ventricular inner diameter in diastole (LVIDd);
11. Left ventricular volume (LVVd, calculated by the area-length ellipsoid volume formula);
12. Left ventricular mass (LVMASS, calculated according to Penn convention using Devereux' and Reichek's formula);
13. Relative left ventricular posterior wall thickness in diastole (RPWT).

    Ratios LVIDd/BSA and LVMASS/BSA, where BSA is the body surface area (see Appendix) were also used in study.

To investigate the mutual relations between heart and body dimensions several methods of multivariate statistics — correlation analysis, factor analysis, canonical analysis and linear regression analysis were applied, using packages STATISTICA and SPSS.

RESULTS

The structure of mutual dependence of heart measurements was studied using correlation analysis on the basis of linear (Pearson) correlation coefficients. The following circumstances served as the reasons for the choice:

- All measurements are continuous numeric variables without outliers and heavy tails, hence suitable for multivariate linear analysis.
- The classical multivariate methodologies used in the study rely on the concept of linear dependence.

Nearly all correlation dependencies between different heart dimensions were positive. In general, the dependencies were not strong (in most cases 0.2–0.3), but in more than of 70% cases significant at the level of 0.05; see Figure 1, where the frequency distribution of correlation coefficients of all heart dimensions (their number is $(3 \times 14)/2=91$) is represented.

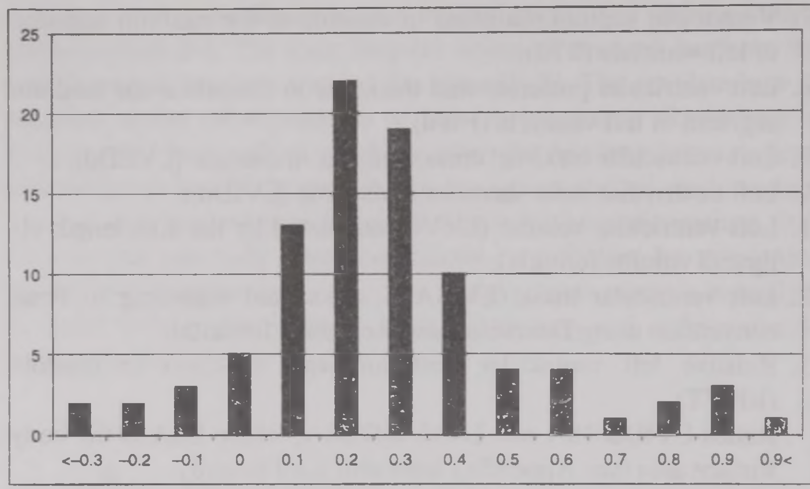

Figure 1. Frequency distribution of correlation coefficients between heart dimensions.

From the Figure the following circumstances became evident:

- Among the dimensions there exists a small group of very tightly correlated variables;
- Some variables (especially ratios) have negative correlations with other variables; it may be not a random effect.

To analyse the dependency structure more deeply, factor analysis of heart dimensions was used (Method of Principal Components and Varimax rotation).

The Factor analysis of heart dimensions gave 4 factors; see Table 1, where loadings >0.5 are bold.

The four-factor structure has a description level of 69.4%, and from the values of communalities it follows that 12 variables out of 15 had a description rate over 50%. Using some ratios together with initial measurements will not affect the results, as the denominator BSA (*body surface area*) used in the last two variables does not belong to the set of heart dimensions. The interpretation of the results of factor analysis is the following,

- The first factor — *Ventricular mass factor* — is very strongly correlated with the measurements of *septum thickness* (STd_1, STd) and with calculated *absolute and relative mass* (LVMASS, LVMASS/BSA).

- The second factor — *Ventricular size factor* — is strongly correlated with *ventricular diameters* (LVEDd, LVIDd, LVIDd/BSA) and *ventricular volume* (LVVd).
- The third factor — *Heart wall thickness factor* — is correlated with *left ventricular posterior wall thickness* (PWd, RPWT), but also with *calculated mass of left ventricle* (LVMASS).
- *RVOT-LA* factor is correlated with variables RVOT and LA.

Table 1. Factor analysis of heart dimensions

Variable	1. Factor	2. Factor	3. Factor	4. Factor	Communality
AO		0.416	0.323		*0.280*
LA		0.201		**0.683**	***0.528***
RVOT				**0.697**	***0.547***
AP	0.335	0.356		0.245	*0.300*
STd_l	**0.739**			0.341	***0.670***
PWd_l	0.430		0.265		*0.290*
STd	**0.906**				***0.831***
PWd	0.300		**0.907**		***0.926***
LVEDd		**0.789**		0.239	***0.687***
LVIDd		**0.942**			***0.933***
LVVd		**0.936**			***0.926***
LVMASS	**0.785**		**0.546**		***0.954***
RPWT	0.247	–0.334	**0.881**		***0.948***
LVIDd/BSA		**0.571**	–0.374	–0.377	***0.634***
LVMASS/BSA	**0.847**		0.437		***0.932***

Three variables — AO, AP and PWd_l — have rather low description via factors introduced (communalities have values 0.28, 0.30 and 0.29 correspondingly and no loadings >0.5 exist).

Dependencies between body measurements and heart dimensions. The correlations between heart dimensions and body measurements (see Appendix) were somewhat smaller compared with the correlations between the heart measurements themselves. From all mutual correlations 62% were significant (at the level of 0.05). Table 2 presents the body measurements that have the largest number of significant correlations with heart dimensions.

Table 2. Body measurements correlated with the largest number of heart dimensions

Body measurements	Heart dimensions		Body measurements	Heart dimensions	
	Number	Correlation		Number	Correlation
X27	15	0.254	X18	13	0.248
X24	14	0.240	X22	12	0.225
X26	14	0.267	X7	12	0.241
X29	14	0.289	X20	12	0.253
X30	14	0.258	X2	12	0.267
X1	13	**0.302**	X28	12	0.260
X23	13	0.269	X4	12	**0.313**
X32	13	0.235	X9	11	0.245
X17	13	0.264			

Table 2 gives the body measurements significantly ($p<0.05$) correlated with more than 10 heart dimensions (out of 15). The second column shows the number of significantly correlated heart dimensions and the third column the average value of significant correlations.

The following regularities appeared:

- The thorax measurements (*chest circumferences* X26, X27, X28, X29, *chest breadth* X24, *chest depth* X23) are significantly correlated with most heart dimensions.
- Several circumferences such as *calf* (X30), *waist* (X32), *upper arm* (X17, X18), *wrist* (X22), *neck* (X2) *circumferences* are positively correlated with most heart dimensions.
- *Weight* (X1), *trunk height* (X4) and *mass of muscular tissue* (X9) have relatively high correlations with many heart dimensions.
- From all height measurements only *trunk height* (X4) has significant correlations with most heart dimensions.
- Skinfolds are not significantly correlated with most heart dimensions.

Linear models for prediction of heart dimensions by body measurements. As all heart dimensions are correlated with several body measurements, it is possible to build multiple linear regression models for predicting the expected size of heart dimensions by body measurements. Table 3 presents the optimal linear models calculated using the step-wise procedure. Only significant ($p<0.05$) predictors are indicated with the sign of the corresponding regression coefficient (– if the coefficient is negative). The order of arguments in the model is the same as in step-wise inclusion procedure. The second column of the Table gives the determination coefficient R^2. All the models also include the intercept.

Table 3. Linear models for prediction of heart dimensions by body measurements

Heart dimension	R^2	Variable 1	Variable 2	Variable 3	Variable 4	Variable 5
AO	0.095	X4	X29			
LA	0.209	X1	–X3	–X11		
RVOT	0.176	X29	X33	–X25		
AP	0.195	X23	–X11	X3	–X14	
STd_1	0.159	X29	X16	X33		
PWd_1	0.168	X16	X27	–X10	X31	
STd	0.094	X27	–X21	X29	X12	
PWd	0.141	X29				
LVEDd	0.326	X4	X23	X5		
LVIDd	0.266	X4	X5	X23	–X11	
LVVd	0.274	X4	X5	X23	–X11	X6
LVMASS	0.212	X27	X16	X15	–X8	X29
RPWT	0.078	X13	–X33			
LVIDd/BSA	0.392	–X4	X23	–X25		
LVMASS/BSA	0.148	–X10	X27	–X8	X15	–X19

From Table 3 it follows that:

- In general, the models have a rather low determination coefficient (varying from 0.095 up to 0.392; the corresponding multiple correlation coefficient has the range 0.31–0.63). Hence the heart dimensions are moderately predictable by body measurements.

- The best models, having the determination rate of about 30%, predict the *ventricular size dimensions* LVEDd, LVIDd and LVVd (determined by the second *heart factor*).
- In the formally best model that describes the variable LVIDd/BSA, *the body surface area* has a negative coefficient, reflecting the definition of the ratio (BSA=X4 by definition).
- The most effective explanatory variable is *the body surface area* (X4), being the first predictor in 5 cases out of 15. The regression coefficient for X4 is positive in all cases except the ratio LVIDd/BSA.
- Almost all models for heart dimensions contain at least one thorax measurement — *chest circumference* (X27, X29), *chest depth* (X23) — or two of them. In all cases the regression coefficients are positive.
- *Weight* (X1) is a significant predictor for LA. *Mass of muscular tissue* (X9) did not appear in any model as a significant predictor.
- *Trunk height* (X5) is a significant predictor for LVIDd and LVVd. Other body height and length measurements did not appear in any models as significant predictors.
- From all the skinfolds *the waist skinfold* (X11) has the largest influence on heart dimensions; the regression coefficient is negative in all the cases.

Comparison of the determination coefficient and communality gives some information about the description level of heart dimensions by body measurements on the one hand and by other heart dimensions on the other hand, see Figure 2.

It is easily visible that in the case of all heart measurements the communality (see Table 1) is about three times larger than the determination coefficient R^2, calculated by the linear models (see Table 2). From here it follows that the connection between heart measurements is much stronger than the connection between body measurements and heart dimensions.

Factor analysis of body measurements can be used with the aim of restricting the number of explanatory body measurements in models. The fact that anthropometric measurements are correlated and form well interpretable factors is commonly known. We used the anthropometric measurements as initial variables and extracted the following four factors (using Principal Components method and Varimax rotation):

- *Body mass factor* (description rate 32%) has largest loadings in such variables as *weight* and several *circumferences*, but also in *Rohrer index* and *the mass of muscular tissue* (X9).
- *Body fat factor* (description rate 21%) is correlated with all skin-folds, circumferences and also with the relative amount of fat (X25).
- *Body height factor* (15%) has loadings in *height* and other measurements of height/length.
- *Thorax factor* (5%) is correlated with *thoracal index* (X33) and chest measurements, especially chest depth (X23).

These four factors determined about 75% from the variability of all body measurements.

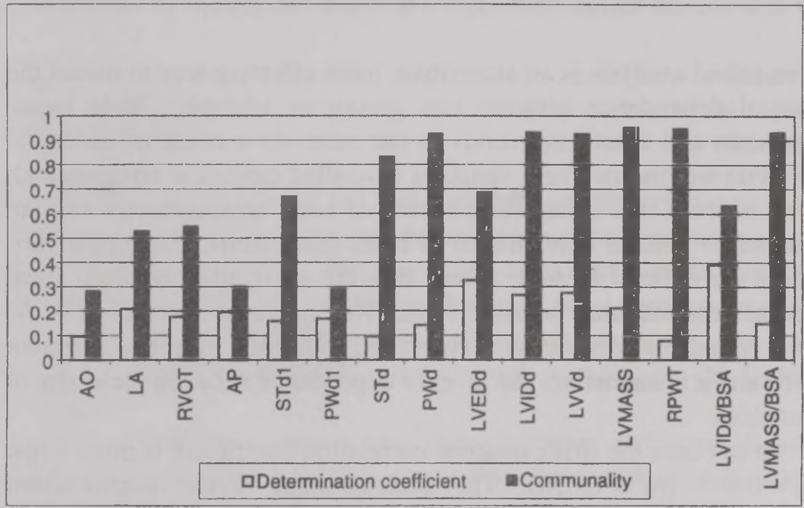

Figure 2. Comparison of determination coefficients and communalities.

Mutual dependence between body measurements and heart dimensions can be modelled using the factors from both data sets. The regression models for heart factors by body factors are given in Table 4.

Table 4. Regression coefficients for predicting heart factors by body factors

	Ventricular mass factor	Ventricular size factor	Heart wall thickness factor	RVOT-LA factor
Body mass factor	0.154	**0.272**	**0.219**	**0.454**
Body fat factor	–0.152	–0.122	**0.317**	0.042
Body height factor	**–0.163**	**0.167**	**0.180**	**0.343**
Thorax factor	–0.079	0.172	–0.144	0.081

Most of the regression coefficients are significant, but their prognostic power is not very high. Somewhat surprising is the fact that *the heart factors of larger numbers* have stronger connections with body factors. The reason is the optimisation rule of factor analysis: the factors are defined to model in the best way the correlations *between the variables of the same group*, and hence the models are not optimal to describe the mutual correlations between two groups of variables.

Canonical analysis is an alternative, more effective way to model the mutual dependence between two groups of variables, body measurements and heart dimensions in our case. As a result of canonical analysis we find two new variables (so-called canonical components). One of them is a linear combination of body measurements and the second — a linear combination of heart dimensions. These new variables are defined in such a way that the correlation between them reaches the maximal possible value. This maximal correlation is *the first canonical correlation* between the variables from two different sets, and it characterises the level of dependence between these sets of variables.

In our case the first canonical correlation coefficient is quite large: $\rho_1 = 0.809$ ($\rho_1^2 = 0.654$). The corresponding linear combinations include the following variables:

- From the heart dimensions LVIDd, LVVd, LVIDd/BSA (with a negative coefficient) and LVMASS/BSA. Hence, *the first canonical component of heart dimensions* is quite close to *the second heart factor* and can be interpreted as the *heart ventricular volume component.*
- The first canonical component of body includes the variables *height*, *Rohrer index* and *weight* (with a negative coefficient);

hence, it can be interpreted as *the body build component* that differentiates pycnomorphic and leptomorphic body types.

The second canonical correlation has the value $\rho_2 = 0.662$ ($\rho_2^2 = 0.44$), and the canonical components include the following variables:

- From the heart dimensions: RPWT, LVIDd and PWd_l (the last one with a negative coefficient). The second canonical component of heart dimensions is close to the *third heart factor* and can be interpreted as the *ventricular wall thickness component.*
- From the body measurements: *thoracal index, chest depth and height, also some circumferences. The factor can be interpreted as the body size component.*

The third canonical correlation is almost equal to the second one, $\rho_3 = 0.662$ ($\rho_3^2 = 0.44$). The existence of three pairs of significantly correlated canonical components demonstrates the existence of three independent regularities connecting the body measurements and heart dimensions.

DISCUSSION

We found that, in spite of the fact that the heart dimensions are not highly correlated, factor analysis demonstrates the strong inner structure of these dimensions. We succeeded to extract four factors that describe about 70% of mutual variability of heart dimensions. The factors as ventricular mass factor, ventricular size factor and ventricular wall thickness factor have a well interpretable biological content.

The correlations between body measurements and heart dimensions are, in general, somewhat lower than the correlations between heart dimensions, but when calculating the mutual correlations between 34 body measurements and 13 heart dimensions, we found that 65% of them were statistically significant ($p<0.05$, $N<250$). From the body measurements having significant positive correlations with most heart dimensions the most remarkable are *the body surface area* and several chest measurements, especially *chest circumferences* measured in different ways. The last result proves that the thorax constitutes a complete whole, including the heart as a part of it.

As all heart dimensions are more or less correlated with body measurements, we attempted to build linear regression models for predicting heart dimensions from body measurements. In most cases the determination level was rather modest, R^2 varied in the range of 0.1–0.4 (correspondingly $0.31<R<0.63$) in the case of optimal models with all significant terms. The best models we found described *ventricular diameters* and *ventricular volume*, the most effective predictor for these dimensions is the *body surface area.* Another group of heart dimensions — *cross diameter of right ventricular outflow tract* (RVOT), *cross diameter of truncus arteriae pulmonalis* (AP), *ventricular septum thickness in diastole* (STd_l and STd), *ventricular posterior wall thickness* (PWd_l and PWd) were predicted at the level of 0.1–0.2 and the effective predictors were different *chest measurements.* The latter result is in good agreement with the conclusion made on basis of mutual correlation analysis. Comparing the values of communalities (that characterise the prognostic power of heart dimensions) and determination coefficients (that characterise the prognostic power of body measurements) we can say, that the prognostic power of body measurements is, in general, one third of the prognostic power of heart dimensions for predicting the values of heart dimensions.

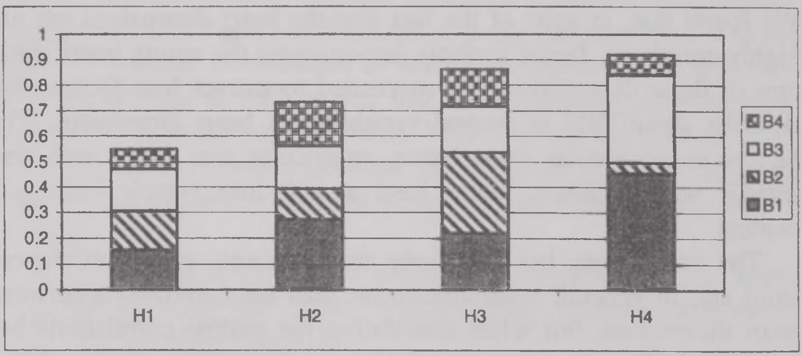

Figure 3. Absolute values of regression coefficients in predicting the heart factors (H) by body factors (B).

To improve the prognostic power of body measurements, the body factors were used instead of initial variables. When the linear regression models for predicting heart factors were expressed via body factors, the description level did not improve significantly. In connection with this step, some interesting effects occurred. One might expect that different body factors are effective for predicting different heart factors, but the result was quite opposite: the body factors served as predictors for all heart factors almost uniformly. The second unexpected effect was that the description level of heart factors was inverse proportional to the factor number, see Table 4 and Figure 3.

As the factors are orthogonal and standardised, it is possible to make some conclusions about the correlations between the body factors and heart factors:

- *The body mass factor* is correlated with *the RVOT-LA factor of the heart*; but also with *the ventricular size factor.*
- *The body fat factor* is correlated with *the ventricular wall thickness factor.*

The most effective tool for solving the problem posed is canonical analysis. Using the canonical components — the specially designed linear combinations of body measurements and heart dimensions — we reached the highest value of canonical correlation 0.81. The corresponding canonical components were from the heart side the *heart ventricular volume component* and from the body side the *body build component.* Thus, canonical analysis proved that body build influences heart dimensions. In a similar way, the second and third pair of canonical components were extracted that proved the existence of several independent regularities between heart dimensions and body measurements.

As a result, we proved, that:

- Heart dimensions are mutually correlated and form a four-factor structure;
- Heart dimensions are correlated with body measurements;
- Heart dimensions can be predicted by body measurements using linear regression models;
- Heart factors can be predicted by body factors;
- There exist canonical body components and canonical heart components (formed as linear combinations) that confirm the existence of high correlations between heart dimensions and body measurements.

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5. Appendix

The list of body measurements and their denotations:

Symbol	Measurement
x1	KAAL Weight
x2	KAELAY Circumference of neck
x3	KAEY Circumference of upper arm
x4	KEHAP Body surface area
x5	KEHATYVI Trunk height
x6	KOHTSG Abdomen depth
x7	KOHUL Abdomen breadth
x8	KOHUY Abdomen circumference
x9	LIHASMASS Mass of muscular tissues
x10	NABAK Umbilical height
x11	NVKOHT Abdomen skin fold
x12	NVOLGE Forearm skin fold
x13	NVOLGT Triceps skin fold
x14	NVREIS Thigh skin fold
x15	NVRIND Chest skin fold
x16	OLAL Shoulders breadth
x17	OLGMAX Upper arm circumference flexed and tensed
x18	OLGMIN Upper arm circumference relaxed
x19	PEAKAEL Head-neck height
x20	PUUSAL Hips breadth
x21	PUUSAY Hips circumference
x22	RANDMEY Wrist circumference

Symbol	Measurement
x23	RINDSG Chest depth
x24	RINNAL Chest breadth
x25	RVPR Relative mass of subcutaneous fat (%)
x26	RY Upper chest circumference
x27	RYALT Lower chest circumference
x28	RYMIN Upper chest circumference in maximal expiration
x29	RYMAX Upper chest circumference in maximal inspiration
x30	SAAREY Calf circumference
x31	SUBRASTR Suprasternal height
x32	TALJEY Waist circumference
x33	TORAKALI Thoracal index
x34	KASV Height
x35	ROHRER Rohrer index

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PHYSICAL TRAINING AND REMODELLING OF HEART

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ABSTRACT

To determine the influence of physical training on remodelling of the heart, eighty healthy young male Estonians were studied somatometrically and echocardiographically. The study population was divided into two groups. The first group included 56 army cadets at the age of 19.1±1.3 years. There were no active top athletes among them. Their PWC_{170} was 2.9±0.48 w/kg. The second group consisted of 24 Estonian top athletes aged 23.3±5 years. It included decathlonists and nordic skiers who belonged to the national team, and rowers and wrestlers who were among the first ten in the list of classification in Estonia. Their PWC_{170} 3.9±0.32 w/kg.

In absolute values the heart size and left ventricle mass of the athletes was larger, but in values adjusted to BSA and heart indices there was no significant difference between the two groups. Neither was there any difference in left ventricle physiological parameters between the two groups at rest. We are of the opinion that the difference in heart parameters between top athletes and the general population is not an influence of exercising but is primarily caused by genetic and selectional factors. Balanced exercising in different events does not cause any evident cardiac general remodulation.

Key words: physical training, top sport, remodulation of heart, echocardiography,

BACKGROUND

Remodelling of the heart is a term used to describe a complex series of structural changes in the heart. The identification of cardiac remodelling is used as a marker and predictor of cardiovascular events [2, 6, 8, 11, 13]. Heart size may predict heart failure. Cardiac remodelling is progressive and often continues long after the initiating of event has manifested itself [4]. The Framingham study showed that age is not predictive for remodelling of heart in healthy men [8]. The left ventricular mass and heart's geometry is a complex phenotype that is influenced by interacting genetic and environmental factors [15].

Stress caused by physical exercise is one of the important predisposing factors in the remodelling process of the heart [14]. It has been presumed that physical training induces physiological increase of left ventricular mass and remodelling of ventricular geometry [3, 10].

Our study was undertaken to determine the relationships between geometry, left ventricle mass and physical training in healthy young male Estonians.

MATERIAL AND METHODS

1. Study population

A total of eighty healthy young male Estonians, divided into two groups, were studied. Group I consisted of 56 army cadets at the age of 19.1±1.3 years. The group represented all cadets actually serving in the region. There were no active top athletes among them. 50% of cadets had exercised systematically twice a week before service. Less than two months had passed from the beginning of the service. All cadets were normally developed; their PWC_{170} was 2.9±0.48 w/kg. Group II included 24 Estonian top athletes at the age of 23.3±5 years. Distribution by sport events and average age in the group is presented in Table 1.

In comparison with other subgroups of top athletes, nordic skiers were significantly older ($p<0.05$). Skiers as well as decathlonists belonged to the national team and had exercised systematically 10–15 years. Rowers and wrestlers belonged to the first ten in the list of classification in Estonia and had exercised systematically about

5–6 years 5 times per week. Physical working capacity (PWC_{170}) of top athletes was 3.9±0.32 w/kg.

Table 1. Distribution of studied top athletes in subgroups according to different events

Discipline	N	Age
Decathlonists	8	23.6±3.8
Rowers	5	19.3±1.9
Wrestlers	5	20.0±4.4
Nordic skiers	6	29.2±4.1

2. *Methods*

Somatometric measurements were taken according to the recommendations of the Canadian Society of Exercise Physiology [5]. Morphometry of the heart was investigated with Aloka SSD 700 System according to ACC [12].

The following values and indices were measured and calculated:

- left ventricular inner diameter in diastole ($LVID_d$) and systole ($LVID_s$);
- left ventricular intracavity long axis in diastole (LAX_{in});
- right ventricular diameter of inflow tract (RVIT) and outflow tract (RVOT) in diastole;
- thickness of intraventricular septum in diastole (ST_d) and in systole (ST_s);
- movement amplitude of intraventricular septum (ST_{ex});
- thickness of posterior wall of left ventricle in diastole (PW_d) and systole (PW_s);
- movement amplitude of posterior wall of left ventricle (PW_{ex});
- three diameters of left atrium (LA_1, LA_2, LA_3);
- two diameters of right atrium (PA_1, PA_2)
- left ventricle volume in diastole (LVV_d) and in systole (LVV_s) in clinostasis and in orthostasis by area-length formula;
- increasing of thickness of intraventricular septum in systole (ST%)

$$ST\% = \frac{ST_s - ST_d}{ST_d}\%$$

- increasing of thickness of posterior wall in systole (PW%)

$$PW\% = \frac{PW_s - PW_d}{PW_d} \%$$

- mass of left ventricle (LVMASS) by Devereux formula;
- mass of left ventricle adjusted to body surface area (BSA) (LVMASS/BSA);
- mass of left ventricle adjusted to weight (LVMASS/kg);
- relative thickness of posterior wall of left ventricle (RPWT)

$$RPWT = \frac{2 \times PW_d}{LVID_d};$$

relative mass of left ventricle (RLVMASS)

$$RLVMASS = \frac{RVMASS}{LVV_d};$$

- volume of left ventricle adjusted to BSA (LVV_d/BSA);
- volume of left ventricle adjusted to weight (LVV_d/kg).

We examined the following physiological parameters characterising heart's work at rest:

- heart rate in clinostasis (HR) and in orthostasis (HR_0)
- stroke volume (SV),
- stroke index (SI=SV/BSA),
- cardiac output in clinostasis (CO) and in orthostasis (CO_0),
- cardiac index in clinostasis (CI=CO/BSA),
- time of isometric relaxation (IR)
- time of deceleration of speed of filling of left ventricle (DT).

Statistical analysis was performed using the statistical package STATISTICA.

RESULTS AND DISCUSSION

As Table 2 shows, top athletes differ significantly from the general population in main somatometric indices. At the same time no difference was established between athletes in subgroups (Table 3).

Table 2. Somatometric characterization of subjects

Parameter	Athletes N=24		Cadets N=56		Significance
	X	δ	X	δ	
Height (cm)	185.7	5.85	178.4	6.16	0,05
Weight (kg)	82.8	8.84	70.9	7.02	0,05
Body surface area (S) (m^2)	2.08	0.19	1.78	0.06	0,05
Body mass index (BMI)	24.00	1.78	22.26	2.04	0,05

Table 3. Somatometric characterization of athletes according to different events

Parameter	Decathlonists N= 8		Rowers N=5		Wrestlers N=5		Nordic skiers N=6		Significance
	X	δ	X	δ	X	δ	X	δ	
Height (cm)	187.2	6.0	189.8	3.6	181.1	6.7	184.6	3.5	2:3
Weight (kg)	87.7	7.2	83.9	4.3	79.4	13.9	77.8	3.8	–
Body surface area (BSA) (m^2)	2.15	0.12	2.13	0.05	2.0	0.19	2.0	0.7	–
Body mass index (BMI)	25.0	0.8	23.3	1.42	24.1	3.0	22.8	0.54	1:4

Physiological parameters of the left ventricle in clinostasis and in orthostasis at rest (Table 4) demonstrated that the difference in studied parameters between groups was evident only in HR data. We explain it with the different influence of sport activities and exercising. At the same time parameters characterising left ventricle systolic (ST_{ex}, ST%, PW_{ex}, PW%, SI, CI) and diastolic (IR, DT) function had no significant difference. Athletes had lower CI in comparison with controls ($p<0.05$), which shows their greater reserve of heart function.

The diameters of both ventricles (RVIT, RVOT) were bigger in athletes ($p<0,05$) in comparison with controls, but no difference was measured in long axis. In absolute values, left ventricle mass was bigger in the athletes group in comparison with controls, but in values adjusted to BSA and in the thickness of left ventricle walls no significant difference was noticed between the subgroups of athletes and in comparison to the control group.

Table 4. Left ventricle physiological parameters at rest

Paramcters	Cadets		Athletes	
	X	δ	X	δ
HR (beat/min)	67.1	13.9	56.8	4.8*
HR_0 (beat/min)	71.4	12.5	58.1	7.3*
SV (ml)	79.4	23.1	76.9	26.1
SI (ml/m^2)	44.7	12.2	37.1	12.6
CO (l/min)	5.1	1.4	4.3	1.0
CO_0 (l/min)	4.1	1.1	3.8	0.9
CI ($l/min/m^2$)	2.8	0.8	2.1	0.5*
ST_{ex} (mm)	9.5	1.5	10.0	2.8
PW_{ex} (mm)	12.2	2.2	14.4	2.5
ST % (%)	40.9	3.8	34.7	2.3
PW % (%)	66.4	3.4	54.6	2.6
IR (sec)	0.072	0.01	0.052	0.02
DT (sec)	0.177	0.02	0.149	0.04

Table 5. Heart measurements of subjects

Parameter	Cadets N=56		Athletes N=24	
	X	δ	X	δ
Left atrium (mm)				
LA_1	30.3	2.9	35.0	5.6*
LA_2	38.5	3.5	37.5	5.4
LA_3	31.0	4.1	33.2	4.7
Right atrium (mm)				
RA_1	33.2	3.2	42.2	3.8*
RA_2	36.0	3.4	39.4	3.5*
Right ventricle (mm)				
$RVIT_d$	34.8	5.7	36.6	6.9
$RVOT_d$	28.4	2.9	33.6	3.4*
Left ventricle (mm)				
$LVID_d$	49.0	4.3	52.3	4.8*
$LVID_s$	32.0	3.8	35.9	6.0*
LAX_{in}	74.0	6.7	75.4	5.5
ST_d	10.4	1.5	10.9	1.9

Parameter	Cadets N=56		Athletes N=24	
	X	δ	X	δ
ST_s	17.5	1.8	14.4	1.7
PW_d	10.1	1.4	10.6	1.9
PW_s	15.5	2.1	17.2	2.1
Left ventricle volume (ml)				
LVV_d	117.0	39.0	132.5	35.4*
LVV_s	43.1	12.6	55.5	21.8*
Left ventricle mass (g) (LVMASS)	183.3	37.4	223.1	53.7*

* p<0,05

Table 6. Heart measurements of athletes according to different events

Parameter	Decathlonists N=8		Rowers N=5		Wrestlers N=5		Nordic skiers N=6		Significance
	X	δ	X	δ	X	δ	X	δ	
	1		2		3		4		
Left atrium (mm)									
LA_1	38.1	2.0	32.2	8.1	33.7	3.2	30.4	3.6	1:2,4
LA_2	33.1	4.4	41.2	5.5	36.8	4.0	41.2	4.0	1:2,4
LA_3	30.2	4.0	34.0	1.8	32.6	3.5	37.4	4.9	1:4
Right atrium (mm)									
RA_1	40.6	3.0	41.8	4.,6	41.4	4.5	46.2	1.9	4:1,3
RA_2	35.8	3.6	35.,0	3.1	35.6	1.9	38.2	4.1	–
Right ventricle (mm)									
$RVIT_d$	41.7	5.8	34.2	2.1	31.0	4.3	36.6	6.6	1:3
$RVOT_d$	34.3	2.1	30.7	1.8	33.1	3.8	35.5	4.4	2:4
Left ventricle (mm)									
$LVID_d$	52.9	4.2	48.6	3.0	50.0	3.,8	56.4	5.2	4:2,3
$LVID_s$	36.9	6.1	32.2	3.2	32.7	3.7	40.2	5.9	4:2,3
LAX_{in}	77.2	3.1	78.5	6.4	67.5	2.8	76.0	5.4	3:1,2,4
ST_d	10.7	1.1	11.1	1.0	11.8	3.2	11.3	1.9	–
ST_s	14.4	1.9	14.0	1.5	14.5	3.4	15.1	0.8	–
PW_d	10.2	1.,4	10.7	2.6	11.0	2.8	11.4	1.1	–
PW_s	16.9	2.0	17.1	0.8	18.0	2.0	16.7	2.1	–

Parameter	Decathlonists N=8		Rowers N=5		Wrestlers N=5		Nordic skiers N=6		Significance
	X	δ	X	δ	X	δ	X	δ	
	1		2		3		4		
Left ventricle volume (ml)									
LVV_d	133.9	26.4	95.8	35.4	122.8	16.2	157.4	32.1	4:2,3
LVV_s	59.7	2.4	36.7	2.8	43.8	11.3	54.5	3.2	4:2,3
Left ventricle mass (g) (LVMASS)	213.4	34.8	197.0	48.6	222.3	83.1	261.2	26.8	–

Table 7. Relative parameters and indices of the left ventricle

Parameters	Cadets		Athletes	
	X	δ	X	δ
LVMASS/BSA (g/m^2)	102.7	19.0	107.0	24.0
LVMASS/kg (g/kg)	2.7	0.43	2.7	0.6
RPWT	0.40	0.07	0.41	0.08
RLVMASS(g/ml)	1.53	0.31	1.84	0.9
LVV_d/BSA(ml/m^2)	65.6	12.8	63.9	17.8
LVV_d/kg (ml/kg)	1.77	0.31	1.62	0.47

According to individual analysis, increased intraventricular septum thickness values (ST_d>11 mm) were recorded in 17% of total in the control (cadets) group and in 22% of total in the athletes group. Increased thickness of posterior wall of left ventricle values (PW_d>12 mm) was recorded in 11% of total in the control and in 19% of total in the athletes group, which is approximately the same relation that we can see in population studies [9].

We have to emphasise that index RPWT (Table 7), which shows the accordance of thickness of posterior wall of left ventricle to the inner diameter ($LVID_d$), was very stable both in controls and athletes — in the range of 0.37–0.45.

Neither had the index RLVMASS, which reflects the accordance of mass and volume of the left ventricle, any significant difference between the control and athletes groups.

Coming to the values of heart measurements heart in subgroups of athletes, we see that the only essential difference is in left ventricle volume, which in nordic skiers is significantly larger in absolute values as well as when standardised to BSA. ($p<0.01$). Nonetheless, heart volume and thickness of walls are in physiological balance, and individual analysis did not reveal any initial symptoms of left ventricle dilatation.

We are fully aware of the fact that the groups studied were relatively small to make far-reaching conclusions. Besides that, the absence of general morphometric differences between athletes performing different disciplines allows us to draw the conclusion that balanced exercising in different events does not cause any evident general remodulation of the heart. Larger volume of left ventricle in nordic skiers should be explained mainly by selectional factors and as a genetic presympton, without which they would not have reached top level in skiing, not as an influence of exercising. Absence of physiological dilatation of the heart in nordic skiers should be also proved by the absence of other remodulation markers in the left ventricle [7].

Our medical experience and analysis of the collected data showed that there is no reason to compare influence of exercising on heart morphometrical values in general population and top level athletes. The same understanding is becoming more and more evidential from other studies [1]. Left ventricular geometry, particularly left ventricular mass, is familial trait [14]. The remodulation of heart influenced by training should be recorded and evaluated individually in dynamic of longitudinal observations.

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BIOLOGICAL MATERIAL AROUND DMBA IMPLANTS REDUCES TUMORIGENESIS

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ABSTRACT

DMBA-containing pellets were implanted below the spleen into the abdominal cavity of rats to give rise to local epithelial and mesenchymal malignant tumours. Two types of DMBA-containing intraabdominal implants were compared — DMBA-containing pellets surrounded by biological material (adrenal) and uncovered DMBA pellets. The time of formation of tumours, their size and histological type, reactive changes in the pellet and around it were recorded. Mesenchymal and epithelial tumours of different size and different histological types arose singly or combined in one and the same experimental animal. Biological material slowed down the speed of tumour formation and decreased the diversity of tumour types, and combinations increased the amount of lymphocytic infiltrate and inhibited the process of organisation. The experimental model can be applied for testing of different cancerogenesis preventive measures.

Key words: DMBA implants, local tumorigenesis, rat model, reactive changes, foreign body.

INTRODUCTION

Experimental 7,12-Dimethylbenz(a)anthracene (DMBA) induction of cancerogenesis is well known and thoroughly investigated with the use of special experimental models. DMBA can be administered intragastrically through a probe, by local cutaneous and mucosal application, by bronchoscopical submucosal treatment, intravenously, orally with food, by subcutaneous injections, with local intraductal mammary injections or by intramuscular injections into the neck region. Different methods for implanting cancerogenic foreign substances [1] and transplants in subcutaneous tissue [2, 3], in the spleen [4], in sublingual submucosa [5], in the bladder [6] and in the pylorus [19] have been described in experimental research.

Carcinogen pellets have been made using gelatine [8] or wax [6, 9]. Some authors have found that small doses of cancerogenic substances applied during a long term, can cause cancer much more efficiently than a single large dose given on one occasion [10, 11]. Therefore various soluble and insoluble materials including lipid matrices, particularly stearyl alcohol, cholesterol [3, 12, 13] and carbon particles [1, 3, 12] have been added to carcinogenic substrates to reduce the speed of polycyclic hydrocarbons release into the tissue.

A few authors have transplanted DMBA in biological material such as the trachea [3] or ovarian tissue [4]. Shiba *et al.* demonstrated that a higher incidence of dysplastic and neoplastic lesions was induced in the tracheal mucosa when the rate of release of DMBA had been lowered [3]. To produce malignant granulosa cell tumours, Nishida *et al.* autografted ovarian tissue containing DMBA into the spleen [4].

Tumours which arise after DMBA application originate from epithelium (carcinomas) [3, 7] and also from mesenchyma (sarcomas) [5, 4].

Usually lymphocytes are involved in antitumour immunity [21], and the intensity of immunologic reactions can affect the destiny of cell transformation [14]. Inflammatory changes have been described in DMBA models before the development of tumours [15], and an inverse relationship between the number of lymphocytes and tumour formation has been found [16]. On the other hand, in the process of foreign body tumorigenesis the inflammatory reaction is caused by the presence of a foreign body and it usually inhibits tumour formation [17]. How the inflammatory processes may intervene the combined tumorigenesis has to be elucidated.

The aim of the present study was to induce tumours, using a rat model for implanting either DMBA-containing pellets in biological material or uncovered DMBA pellets into abdominal cavity. The effects of biological tissue on the development of tumours: the time needed for tumorigenesis, tumours dimensions, histological types and simultaneous reactive changes in implants and surrounding tissues, were studied.

MATERIALS AND METHODS

Study design

Two different experimental series were carried out, altogether on 150 white male and female rats. Tumours were induced by a cancerogen, DMBA. The reactive DMBA (C18 H10 $(CH3)_2$) was purchased from Fluka AG, Buchs SG in Switzerland. Beeswax, whale's fatty alcohol, activated carbon and a cancerogenic substance were blended, by means of warming, into a mixture. A special instrument with two halves of hollows for filling with mixture was used to shape pellets of a strictly equal diameter (2 mm) and mass (3.7 mg), each containing 0.038 mg of DMBA. An experimental model, using a foreign material encapsulated in a biological material, was applied [15].

In the first group the animals underwent bilateral adrenalectomy under ether anaesthesia. The removed adrenals were enucleated in vitro by the Evans method [18]. After the parenchyma had been removed from the organ, the DMBA pellet was inserted into the cavity to be surrounded by the adrenal capsule on all sides, lying in a biological chamber. Then both adrenals were transplanted into the abdominal cavity below the spleen, at the level of the upper apex of the left kidney (Group I).

Similar DMBA-containing pellets (without a biological chamber) were implanted just to abdominal cavity below the spleen, at the level of the upper apex of the left kidney in 72 rats without their adrenal enucleation (Group II).

The control group consisted of 50 rats. They were operated in a similar manner but the implanted pellets did not contain any DMBA. The adrenals of the rats were not enucleated either.

The animals were sacrificed after intervals of 3–4 months, 6–7 months, 9–10 months and 12 months after the implantation of the pellets. Three dimensions of the tumours were measured in centimetres and a scoring system with three levels: 1 — only microscopically diagnosed tumours; 2 — tumours of medium size (up to 13 cm); 3 —

large tumours (14–33.5 cm) was developed. Autopsy tissue samples for further histological investigation were taken from the pellet or local tumour tissue and the surrounding tissue.

Histological and immunohistochemical investigation

The tissue samples were fixed in 10% solution of neutral formaldehyde and embedded in paraffin. Histological sections were made and stained with haematoxylin and eosin in routine manner, with widely used picro fuchsin and haematoxylin after van Gieson's method, or with alcian blue.

To assess the diagnosis of sarcomas immunohistochemical staining for vimentin and desmin was performed using the streptavidin biotin (Strept ABC/HRP, DAKO Corp, Denmark) indirect staining method.

Histotopograms

The particles of pellets (foreign material), zones of adrenocortical regeneration, sclerotic connective tissue, granular tissue and lymphocytic infiltration areas around the pellet were depicted on histotopograms drawn according to the method suggested by A. Truupõld [19]. The fields of vision were scanned horizontally and vertically under a microscope with an ocular network and a preparation shifter (object-lens 8 × 0.20; ocular 7). The results of the observations (the pellet, adrenocortical regenerate, connective tissue, sclerosis, lymphocytic infiltration, granular tissue, degenerations) were drawn on a graph paper where 64 cm^2 corresponds to one field of the ocular network in the sequence they were observed under the microscope. A computerised map with areas bearing differentiating markers was drawn from these histotopograms (Figure 1). The image analysing system Image Pro 3.0 was used to analyse the maps. All fields of the maps were automatically scanned. The computer program read the map and produced the percentage for each object in the squares on the map.

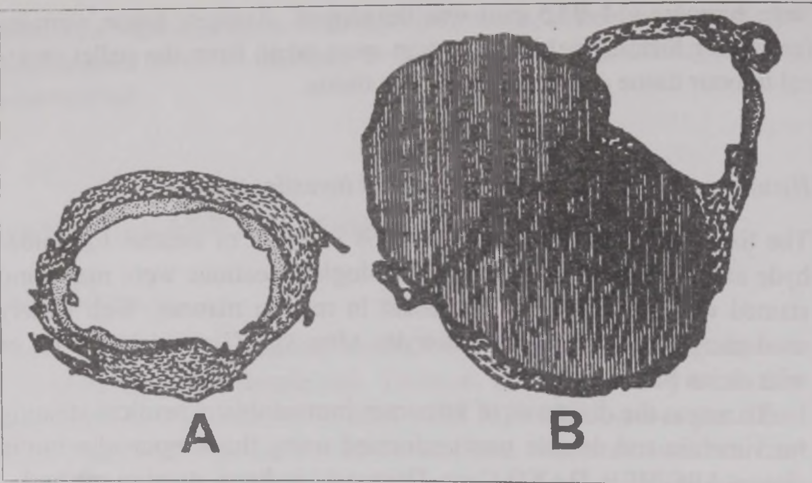


Figure 1. Histotopogram. 2 transplants 3–4 months after the beginning of the experiment (Group I). Labels: white — foreign body; striped — adrenocortical regenerate; wavy — connective tissue; dotted — lymphocytic infiltrate.

Statistics

Microsoft Excel 5.0/7.0, Sigma Statistic program, 2×2 Statistic Tables and Wilcoxon Test were used for statistical evaluation.

RESULTS

Tumorigenesis

DMBA (both in Groups I and II) induced 51 tumours in 100 experimental white rats. In Group I, where the pellets of DMBA were placed in adrenals as a biological chamber and transplanted into the abdominal cavity, there were nine rats with tumours out of 28. In Group II, where the uncovered DMBA pellet was used, there were 42 rats with tumours out of 72 (Table 1). Thus the tumour prevalence was significantly lower in Group I than in Group II ($p < 0.05$).

The first tumours were diagnosed 6–7 months after grafting the DMBA pellets. At that time the number of rats with tumours was significantly lower in Group I ($p < 0.01$). No difference between the groups in the number of tumours was found in rats sacrificed 9–10 and 12 months later (Table 1).

Table 1. Number of histological type of tumors by microscopic evaluation after DMBA pellet grafting into abdominal cavity

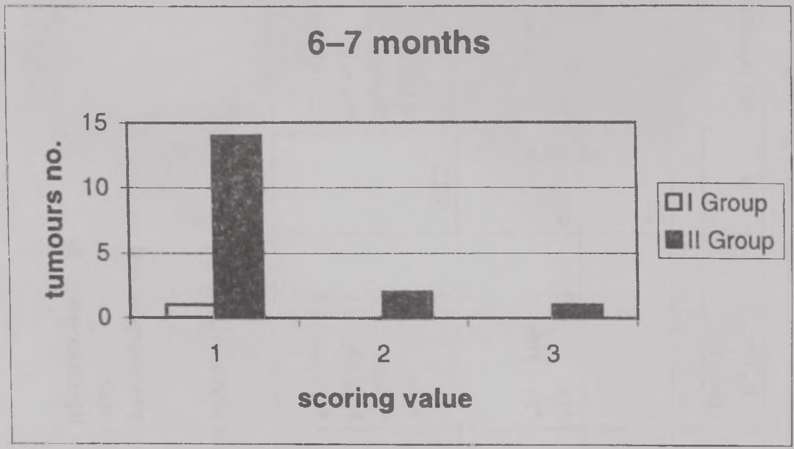
Method	n	3–4 months	n	6–7 months		n	9–10 months		n	12 months		Total n of tumours
					n			n			n	
Control Group n = 50	8	–	14	–		6	–		22	–	–	–
I Group n = 28	0/3	–	1/11[a]	*fs	1	4/9	*fs *fs + rms	3 1	4/5	*fs *fs+adc+sc	3 1	9/28[a]
II Group n = 72	0/17	–	17/19[a]	*fs *rms *fs+rms+a dc *fs+adc *pleos	10 3 1 2 1	10/14	*fs *rms *pleos *fs+adc *fs+rms	5 1 2 1 1	15/22	*fs *pleos *lipos *fs+adc *fs+adc+rms	10 2 1 1 1	42/72[a]

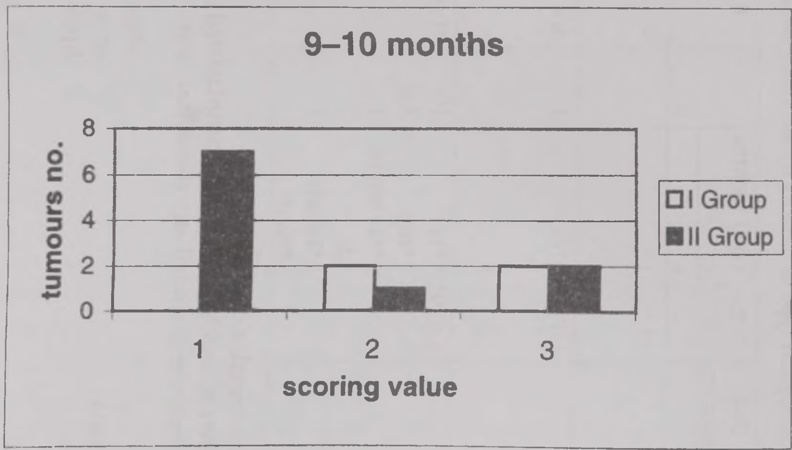
n — number of tumours / number of rats in group
I Group — DMBA pellets in enucleated adrenals transplantated into abdominal cavity
II Group — DMBA pellets transplantated into abdominal cavity

fs — fibrosarcoma
rms — rhabdomyosarcoma
adc — adenocarcinoma
pleos — pleomorphic cell sarcoma
sc — scirrhus
lipos — liposarcoma

[a] $p < 0.01$

According to the scoring results of tumour size (Figure 2), tumorigenesis was significantly lower in Group I, than in Group II ($p < 0.01$) after 6–7 months. After 9–10 and 12 months of the experiment Groups I and II did not display any difference in tumour size.





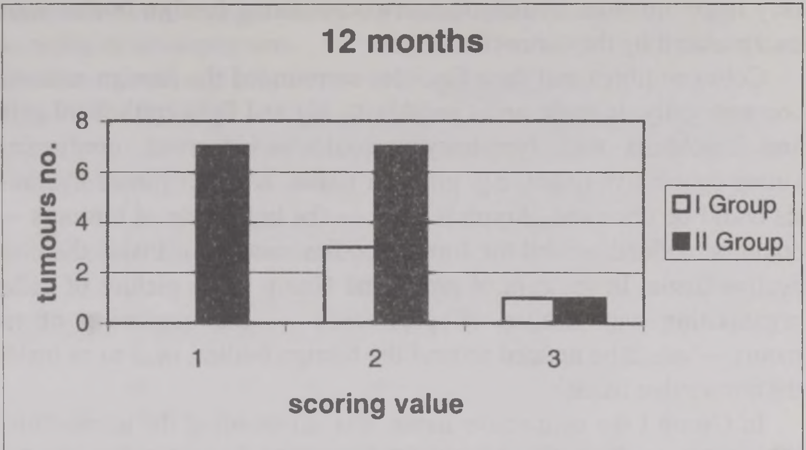


Figure 2. Scoring of tumours size in DMBA tumorigenesis after different time.

The tumours were nodular, of dense consistency, the surfaces of cut slices were whitish-greyish-pinkish with brownish and reddish nidi, at places with necrotic nidi and haemorrhage and even vacuoles filled with fluid or pus. Some larger tumours had spread into the peritoneal and retroperitoneal cavities as well as into the thoracal cavity, coalescing with spleen, intestine, left kidney and mesenterium.

Microscopically the tumours were of different histological types (Table 1). The diagnoses of fibrosarcoma and rhabdomyosarcoma were confirmed by histochemical reactions. In both groups the main type was fibrosarcoma (41 out of 51). There were eight rhabdomyosarcomas. Several combined tumours were diagnosed: fibrosarcoma with rhabdomyosarcoma, adenocarcinoma, scirrhus. In one case a liposarcoma was found. One more anaplastic tumour type was present in four cases — pleomorphic cell sarcoma. In Group II there were more different tumour types singly or in combinations than in Group I (Table 1).

Reactive changes around the implants

The pellets were either intact or were divided into segments by connective tissue. The foreign bodies presented themselves microscopically as structureless black mass, yet the pellet could not be found in very large tumours. Usually the areas containing foreign bodies were encapsulated by the connective tissue.

Collagen fibres and their fascicles surrounded the foreign material concentrically. In some areas polyblasts, big and light epithelioid cells and fibroblasts with lymphocytes could be observed, confirming young connective tissue, e.g. granular tissue. At other places hyalinosis could be observed. Atypical cells — the beginning of tumours — could be noticed around the foreign bodies, next to or inside the connective tissue. In the control group and Group II the picture of pellet organisation was similar. Atypical cells — the beginning of tumours — could be noticed around the foreign bodies, next to or inside the connective tissue.

In Group I the connective tissue was surrounding the adrenocortical regenerate. The adrenocortical regeneration formed nodes, the differentiation of proliferated cells into a glomerular zone and a fascicular-reticular zone was observed. In control group and Group I there was less granular tissue than in Group II both in animals with and without tumours (Table 2). Organisation, i.e. proliferation of connective tissue was more markedly present in the experimental groups than in the control group (data not shown) as we noticed also in our previous paper [20].

Lymphocytic infiltration around the pellet in all periods was statistically higher in Group I as compared with the control group ($p < 0.01$).

Particularly, in Group I the lymphocytic infiltration rate in the rats was remarkably lower in the case of arising tumours (4.07, 0 and 5.08%) than without it (8.79, 8.24 and 18.16%) (Table 2).

Table 2. Reactive changes (%) by implanting DMBA containing pellet according to histotopograms

		Median / Range			
Time	Group	Granular tissue		Lymphocytic infiltration	
		Without tu	With tumour	Without tu	With tumour
3–4 months	Control	1.00/0–5.69		0*	
	I	0		7.97/2.71–13.24	
	II	12.09/0–36.74		3.45/0–20.79	
6–7 months	Control	1.64/0–13.36		1.25/0–8.41*	
	I	0	30.47/0–60.95	**8.79**/0–23,6	**4.07**/0–8.15
	II	6.75/0–13.5	3.03/0–12.85	5.05/2.34–7.77	2.79/0–10.63
9–10 months	Control	3.08/0–15.4		0.26/0–1.29*	
	I	0	0	**8.24**/1.95–13.19	**0**
	II	3.32/0–9.96	8.13/0–57.85	4.57/0–9.45	1.52/0–6.64
12 months	Control	0.42/0–5.03		0*	
	I	0	0	**18.16**/18.16	**5.08**/0–10.16
	II	16.66/0–61.78	1.75/0–6.66	4.61/0–10.55	3.24/0–19.17

* P < O.O5 Control Group versus Group I

DISCUSSION

We found that 0.038 g of DMBA could induce tumours which develop around the DMBA pellet in a period of 6–7 months from the start of the experiment. Our experiment induced mesenchymal and epithelial types of tumours, sometimes occurring together in one and the same experimental animal. The most frequent histological form encountered was fibrosarcoma. This is in accordance with previous studies, as tumours developing after DMBA implantation, originate either from the epithelium [3, 7] or from the mesenchyma [4, 5]. Intrasplenic DMBA grafting surrounded with biological material (ovarium tissue) has been carried out by Nishida, T. *et al.* and observed two different histological types of tumours [4].

There was no literature comparing the results of tumorigenesis and reactive changes with and without biological material. We found that grafting a DMBA pellet under the edge of spleen in a biological chamber (adrenal) or uncovered, induced the same types of local tumours. However, the number of tumours was significantly lower with biological material. This finding could be explained by the stronger immune reaction, induced by biological material.

The organisation process in its different stages from granulation tissue to hyalinosis as well as lymphocytic inflammation could be observed in the study. To understand these findings we have developed a method — histotopogram analysis.

As to reactive changes, there was more cellular infiltration around the implants with biological material, i.e. in Group I. It can be speculated that in animals with high lymphocytic infiltrate no tumours arose, particularly at the beginning of experiments. Further, in the process of tumour development the infiltration level was even less in the preparations with tumour than in the preparations without tumour. R. A. Ruggiero *et al.* have found that inflammatory reaction due to a foreign body inhibited the development of a tumour, yet the tumour in its turn reduced the inflammatory reaction induced by a foreign body [21]. Our study confirmed both findings.

In Group I there was less connective tissue and sclerosis. The connective tissue, surrounding adrenocortical regenerate, has been described in our previous studies [22]. Seemingly the regenerating biological material slows down the process of organisation of foreign material and thus tumorigenesis is also slower. In Group I tumorigenesis developed more slowly, only 5.6% of tumours formed in Group I and 94.4% in Group II in the 6–7 months of the experiment. Most of the tumours started later than 9 months after the implantation.

We compared two rat models of tumorigenesis and found that biological material with its reactions slows down DMBA-induced local tumours. When DMBA is administered systemically (a widely used model), there is a risk of mammary tumours [23]. This model enables one to study more precisely the modulating role of inflammatory processes, e.g. infections and vaccinations, on development of local tumours.

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BODY BUILD STRUCTURE OF 15–19-YEAR-OLD SWISS GIRLS: BASED ON G. GRÜTZNER'S DATA FROM 1928

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ABSTRACT

Data from the literature on anthropometric measurements on 225 Swiss school girls aged 15–19 years, which had been published in 1928, were regarded using the same methodology that has successfully been applied in female body structure research by the Centre for Physical Anthropology at the University of Tartu in their earlier studies. The results proved that, once again, height and weight were the leading characteristics as these two variables, alone or conjoined, produced high predictive values ($0{,}24 < R^2 < 0{,}97$) in more than 90% of the other measurements.

A comparison of the data of the Swiss girls from the mid-twenties with their Estonian counterparts from the mid-nineties showed that in the latter group almost all dimensions had increased.

Key words: anthropometric measurements, body build, schoolchildren

INTRODUCTION

From May 1923 until March 1926 Gertrud Grützner from the Institute of Anthropology at the University of Zürich, Switzerland, collected somatometric data from 15–19-year-old girls who were attending a secondary school in Zürich. Most of them (73.3%) came from the canton of Zürich or neighbouring cantons. Her aim was to contribute to the scanty knowledge of the growth and bodily proportions of young girls as there were only few data available for this age group at that time. The results of her work were published in 1928 [1].

Since then anthropometry has made considerable progress in evaluating data and has especially improved by using weight-height classifications for somatotyping. In the last decade a series of publications has convincingly established and contributed to the notion that only height and weight form exclusive parameters for a reliable description of human body build as they account for 50% of the variability of all other measurements. Along with other populations, this has also been shown to be true for 15-year-old schoolgirls [2] and 18-year-old girls [3].

The aim of the present investigation was, firstly, to check whether in this contingent of girls of different ethnic origin a weight-height classification would characterise their body equally well and, secondly, to see what developmental differences were evident between Swiss girls from the mid-1920s and Estonian girls from the mid-1990s. The Centre for Physical Anthropology at the University of Tartu has been engaged in this type of research from 1974 and has long-term experience concerning correlations between anthropometric characteristics, body build structure and the model of the body as a whole. It keeps a large anthropometric data base and has the technical facilities for data handling and statistical processing. These were indispensable prerequisites for the present study to be performed at that institution.

MATERIAL AND METHODS

The Swiss sample studied by Grützner consisted of 225 girls from four age groups: 15 years (n = 73), 16 years (n = 54), 17 years (n = 51) and 18 years (n = 47). The age was counted in full years (e.g., a girl belongs to the age-group of 15 years from her 15th birthday up to her 16th birthday). Besides body weight, the data base contains 32 different measurements, which were taken according to the classical methods of Martin [4], the length of the lower limb according to Martin's method recommended later [5], and a further 48 relative measurements and indices. Upper limb length was calculated as the sum of upper arm plus forearm plus hand lengths.

The data are not fully independent insofar as some girls were measured a second and even a third time when they were recruited for the next age group. However, this fact does not cause bias in the averages, and the bias in correlations is not remarkable either, as the number of repeated measurements was quite small.

To compare the Swiss girls with girls of the same age groups from Estonia, the data pool of the Centre of Physical Anthropology, University of Tartu, was accessed. There were 1065 girls from the corresponding four age groups: 15 years (n=219), 16 years (n=274), 17 years (n=358) and 18 years (n=214). These data had been collected in 1995.

For statistical evaluation of Swiss girls 30 anthropometric measurements were used.

The inter-ethnic comparisons between the groups are based on 12 equivalent measurements from both data-sets.

Statistical analysis of the Swiss girls was performed using the following methods:

1. Calculation of averages and standard deviations of weight x(w), SD(w) and height x(h), SD(h) and forming five relative size groups of girls in the following way:

- (1) Small: [height < x(h) – 0,5 SD(h)] and [weight <x(w) – 0,5 SD(w)];
- (2) Medium: [(x(h) – 0,5 SD(h) = height < x(h) + 0,5 SD(h)] and [x(w) – 0,5 SD(w) = weight < x(w) + 0,5 SD(w)];
- (3) Large: [height = x(h) + 0,5 SD(h)] and [weight = x(w) + 0,5 SD(w)];
- (4) Pycnomorphous: {[height < x(h) – 0,5 SD(h)] and [weight = x(w) – 0,5 SD(w)]} or {[(x(h) – 0,5 SD(h) = height < x(h) + 0,5 SD(h)] and [weight = x(w) + 0,5 SD(w)]};
- (5) Leptomorphous: {[height = x(h) – 0,5 SD(h)] and [weight <x(w) – 0,5 SD(w)]} or {[(x(h) + 0,5 SD(h) = height] and [x(w) – 0,5 SD(w) = weight < x(w) + 0,5 SD(w)]}.

2. Calculation of basic statistics (averages, standard deviations) of all anthropometric measurements in the given size groups.
3. Using one-factor ANOVA for comparison of averages of anthropometric measurements

- between groups (1) – (3)
- between groups (4) and (5),
- between age groups

as well as for significance testing of differences between group means.

4. Correlation analysis of measurements (used in model building) and linear regression analysis for defining models of anthropometric measurements by age, weight and height.
5. Linear and polynomial regression analysis and smoothing (using the method of moving average) to model the dynamics of height and weight by age (measured in days).
6. To compare the anthropometric measurements of Swiss girls with the corresponding data of coeval Estonian girls, the t-test was used in all age-groups.

The calculations were made using the SAS-system. In all cases the significance level $p = 0.05$ was used.

RESULTS

First we estimated, by age groups, the mean values and standard deviations of the 30 measurements used in the present paper (see Table 1). These include height, weight, length of trunk, upper and lower limbs, feet and hands; biacromial and spinal breadth, distance between nipples, and circumferences of chest, upper arm and thigh.

A number of measurements did not show any gradual increase by age groups. Still, weight ($r = 0.204$) and height ($r = 0.144$) were somewhat related to age (see Fig. 1 and 2).

In many length measurements there were no statistically relevant differences between age groups, especially not in the dimensions of the upper and lower limbs. However, considerable growth was noticed in circumferences and breadth measurements. This suggests that in girls of that age the growth of length measurements decelerated earlier than the growth of circumferences and breadth measurements.

The measurements showing the strongest correlations with all others were height and weight. Height was related to other length measurements ($r = 0.5$–0.8), breadth measurements ($r = 0.2$–0.4) and circumferences ($r = 0.19$–0.2). Weight had closest correlations with circumferences ($r = 0.8$), to a lesser extent with breadth and length measurements ($r = 0.4$–0.5).

Table 1. Basic statistics of anthropometric measurements of 15–19-year-old Swiss girls (n=225)
(all measurements are in cm; body weight is in kg; means and standard deviations are listed; significance level p<0.05)

No	Variable	Years								Significance
		15		16		17		18		
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
1	Height	159.78	6.04	159.86	5.26	162.54	5.41	161.4	4.94	+
2	Weight	52.42	7.59	51.45	5.24	56.46	6.41	54.63	6.60	+
3	Suprasternal height	130.45	5.84	130.44	4.71	132.70	4.62	131.81	4.34	+
4	Umbilical height	96.55	4.55	96.37	4.19	97.85	3.83	97.21	3.94	–
5	Symphyseal height	81.64	4.12	80.51	3.75	82.24	3.76	82.75	3.59	+
6	Mammilar height	115.54	5.54	115.38	5.24	117.08	4.77	115.92	4.58	–
7	Acromial height	130.41	5.42	130.53	5.05	133.12	4.98	131.94	4.45	+
8	Iliospinal height	89.69	4.48	89.40	4.14	90.47	3.79	89.95	3.99	–
9	Tibial height	42.25	2.52	42.39	2.39	42.95	2.13	42.41	2.62	–
10	Sphyrion height	6.83	0.80	6.89	0.77	7.31	0.72	7.17	0.75	+
11	Span	162.30	7.45	161.64	6.26	163.32	5.98	163.05	5.09	–
12	Sitting height	80.24	3.76	79.79	3.02	81.97	2.55	81.50	2.71	+
13	Trunk length	49.13	2.65	49.76	2.20	50.46	2.43	49.06	2.11	+
14	Biacromial breadth	33.76	1.49	33.63	1.58	34.35	1.73	34.35	1.43	+
15	Breadth of nipples	19.80	2.03	19.74	1.70	20.19	1.74	20.14	2.06	–
16	Cristal breadth	27.10	1.60	27.33	1.33	28.36	1.50	28.09	1.56	+
17	Spinal breadth	22.04	1.74	22.08	1.59	22.59	1.70	22.89	1.60	+
18	Upper limb length	71.30	3.12	71.09	2.39	71.73	2.64	71.31	2.53	–
19	Upper arm length	31.17	1.58	31.04	1.21	31.14	1.26	31.13	1.07	–

No	Variable	Years								Significance
		15		16		17		18		
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
20	Forearm length	23.25	1.15	23.22	1.00	23.55	1.09	23.38	1.01	–
21	Hand length	16.85	0.87	16.83	0.71	17.04	0.79	16.80	0.75	–
22	Hand breadth	7.62	0.35	7.61	3.33	7.70	0.32	7.63	0.37	–
23	Lower limb length	86.55	4.14	86.39	3.87	87.19	3.44	86.85	3.68	–
24	Thigh length	44.23	2.26	43.89	1.93	44.29	1.98	44.38	1.90	–
25	Lower leg length	35.38	2.35	35.48	2.20	35.64	1.83	35.24	2.32	–
26	Foot length	24.04	1.27	24.03	9.81	24.43	0.99	24.15	1.09	–
27	Foot breadth	9.73	0.56	9.37	0.53	9.52	0.52	9.63	0.47	+
28	Chest circumference	80.16	5.24	80.09	3.60	82.87	3.87	81.48	3.71	+
29	Upper arm circumference	22.67	1.87	22.56	1.40	23.66	1.69	23.35	1.47	+
30	Thigh circumference	53.15	4.96	52.86	3.84	55.48	3.89	54.28	3.86	+

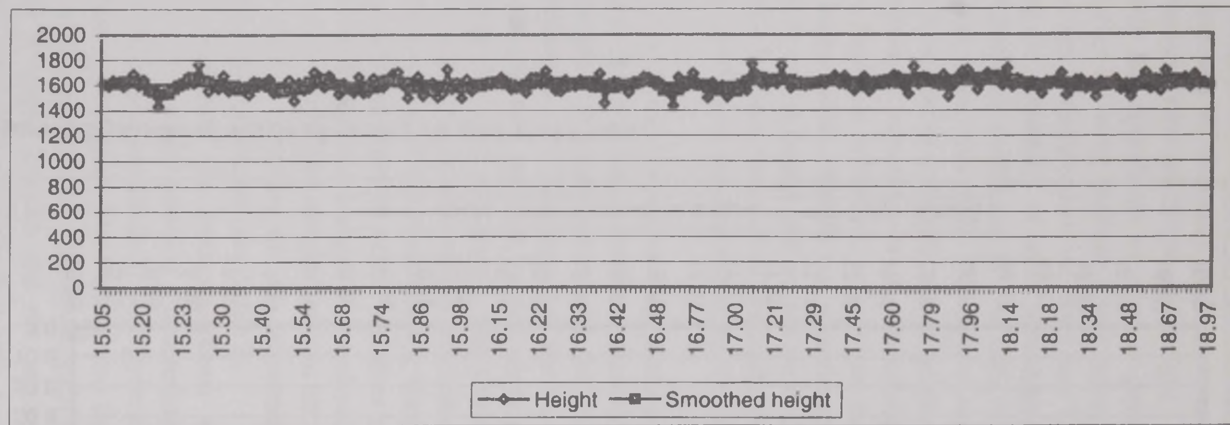

Figure 1. Dynamics of height of Swiss girls aged 15–19 years.

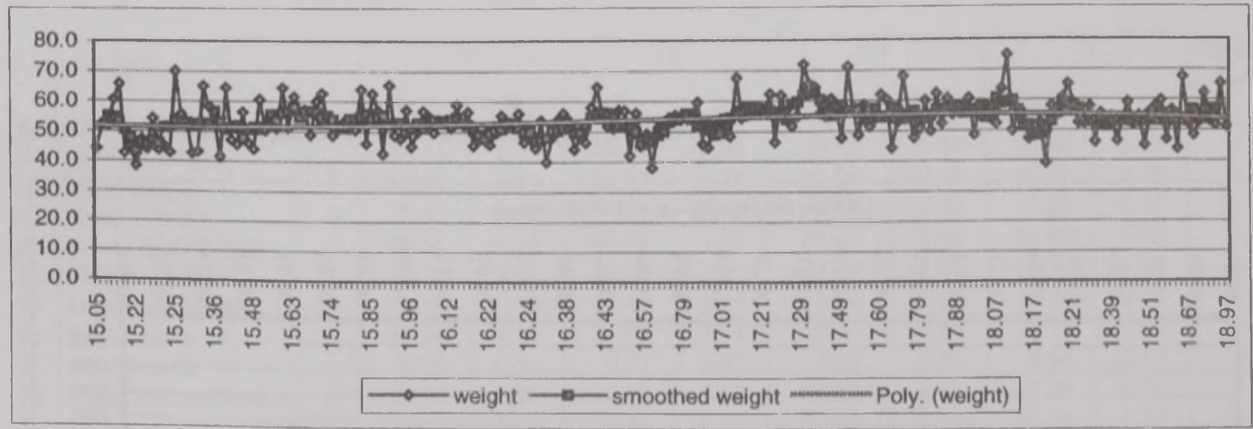

Figure 2. Dynamics of weight of Swiss girls aged 15–19 years.

From the fact that all anthropometric measurements depend significantly on height and weight, we can conclude that the body build structure consists of mutually well correlated variables, where the leading characteristics are height and weight.

To check this hypothesis we tried to predict the values of all the other variables by using multiple linear regression models with height, weight and age as independent variables (see Table 2). These arguments determined the variability of other measurements within 22–97% (by multiple correlation coefficient R^2); in 64% of cases the level of determination was more than 50%. The only exception was spinal breadth that showed very weak correlations with height, weight and age.

All regression equations were statistically significant. From the arguments the most influential was height that was significant in 25 out of 28 cases (89%). Weight was significant in 43% of models. Age in combination with height and weight proved to be significant in five models only. In more than half of the models the absolute value of the regression coefficient corresponding to age was less than 0.005 (see Table 2).

This led us to the conclusion that, when attempting to classify anthropometric characteristics, the basic classification could be a 5-class SD-classification of height and weight, which is well known from our earlier publications [6]. The impact of age was also taken into consideration here. Namely, we first formed separate 5-class height-weight classifications for each age group, and thereafter the corresponding classes of all age groups were united into one classification.

The primary aim of this classification was to demonstrate the possible systematic changes in other variables in the case of different magnitudes of height and weight. In the classes of small, medium and large not only height and weight but also all the other characteristics showed a gradual increase, and all differences between classes 1–3 were statistically significant (see Table 3).

While comparing the pycnomorphous and the leptomorphous classes, we also noticed essential characteristic differences between a number of variables (see Table 3). The pycnomorphs were shorter and heavier than leptomorphs. The former also had bigger breadth measurements and circumferences. However, gain in foot and hand breadth as well as in spinal breadth did not reach statistical significance. Nonetheless we might conclude that such a classification was appropriate for systematising that kind of material.

Table 2. Regression models for antropometric measuresments by age, height and weight
Statistically significant ($p<0.05$) parameters are bold; regression coefficients for age and weight <0.0001 and for height <0.005 are represented as 0

No	Predicted variable	Regression model				R^2
		Intercept	Age	Height	Weight	
3	Suprastenal height	–6.552	0	**0.86**	0.0049	**0.97**
4	Umbilical height	–17.609	–0.001	**0.72**	–0.0234	**0.87**
5	Symphyseal height	–16.276	–0.001	**0.62**	–0.0272	**0.73**
6	Mammilar height	–21.521	0	**0.91**	**–0.1607**	**0.80**
7	Acromial height	–9.444	0	**0.87**	0.0260	**0.92**
8	Iliospinal height	–14.993	–0.1326	**0.67**	–0.0061	**0.77**
9	Tibial height	–14.508	0	**0.35**	0.0150	**0.66**
10	Sphyrion height	–0.238	0	**0.03**	**0.0357**	**0.22**
11	Span	30.091	**–0.0003**	**0.80**	0.0802	**0.71**
12	Sitting height	19.073	0	**0.36**	**0.0797**	**0.53**
13	Trunk length	9.403	0.0001	**0.24**	0.0295	**0.37**
14	Biacromial breadth	18.391	0	**0.07**	**0.0891**	**0.28**
14	Breadth of nipples	15.296	0	–0.02	**0.1585**	**0.29**
16	Cristal breadth	14.795	0.0001	**0.04**	**0.1068**	**0.33**
17	Spinal breadth	21.027	0	–0.02	**0.0758**	**0.08**
18	Upper limb length	6.700	**–0.0001**	**0.40**	0.0171	**0.70**
19	Upper arm length	4.505	**–0.0001**	**0.17**	–0.0010	**0.51**
20	Forearm length	0.501	0	**0.14**	0.0137	**0.57**
21	Hand length	1.358	0	**0.10**	0.0031	**0.46**
22	Hand breadth	4.593	0	**0.01**	**0.0191**	**0.25**
23	Lower limb length	–7.219	–0.1107	**0.60**	–0.0051	**0.73**
24	Thigh length	5.908	–0.0163	**0.25**	–0.0218	**0.41**
25	Lower leg length	–14.040	0	**0.31**	–0.0203	**0.59**
26	Foot length	3.475	0	**0.12**	**0.0322**	**0.58**
27	Foot breadth	4.882	0	**0.02**	**0.0310**	**0.28**
28	Cest circumference	77.605	0	**–0.17**	**0.5818**	**0.70**
29	Upper arm circumf.	23.290	**–0.0001**	**–0.08**	**0.2416**	**0.71**
30	Thigh circumference	56.753	**–0.0001**	**–024**	**0.6829**	**0.88**

Table 3. Basic statistics of anthropometric measurements of 15-19 year-old Swiss girls grouped into 5 height-weight classes (n=190)
(all measurements are in cm, body weight is in kg; means and standard deviations are listed; significance level p<0.05)

No	Variable	1 Small (n=39)		2 Medium (n=44)		3 Large (n=28)		Sig-nifi-cance	4 Pycnomor-phous (n=26)		5 Leptomorphous (n=53)		Sig-nifi-cance
		$\overline{x}$	SD	$\overline{x}$	SD	$\overline{x}$	SD		$\overline{x}$	SD	$\overline{x}$	SD	
1	Height	154.09	3.89	160.60	1.69	168.41	3.85	+	161.15	1.29	163.56	3.76	+
2	Weight	46.08	3.76	53.56	2.44	62.03	5.08	+	61.02	4.27	49.42	4.54	+
3	Suprasternal height	125.52	3.69	131.13	1.54	137.75	3.55	+	131.52	1.53	1433.66	3.36	+
4	Umbilical height	92.27	3.49	97.04	1.66	102.12	2.78	+	97.06	2.15	98.99	3.02	+
5	Symphyseal height	78.03	3.56	81.48	1.86	85.88	2.90	+	82.16	2.00	83.89	3.14	+
6	Mammilar height	110.94	4.33	116.08	2.13	121.03	3.96	+	115.13	2.45	119.27	3.52	+
7	Acromial height	125.45	3.75	131.13	2.21	138.37	3.92	+	131.53	1.91	133.71	3.53	+
8	Iliospinal height	85.60	3.17	89.64	1.62	94.79	3.10	+	89.98	2.75	91.70	3.37	+
9	Tibial height	40.14	2.14	42.58	1.25	45.08	1.98	+	42.50	1.81	43.39	2.19	–
10	Sphyrion height	6.58	0.65	6.95	0.80	7.49	0.65	+	7.11	0.91	7.10	0.80	–
11	Span	156.16	6.82	163.05	2.79	168.15	4.01	+	164.49	3.04	164.66	4.29	–
12	Sitting height	77.99	2.57	81.16	2.24	83.86	3.06	+	81.92	2.73	81.26	2.82	–
13	Trunk length	47.62	1.70	49.67	1.81	51.87	2.84	+	49.36	1.79	49.73	2.19	–
14	Biacromial breadth	32.97	1.24	33.87	1.42	35.16	1.06	+	35.15	1.41	33.84	1.60	+
15	Breadth of nipples	18.59	1.52	20.22	1.54	20.77	1.33	+	21.89	1.60	19.40	1.92	+

16	Cristal breadth	26.52	1.29	27.71	1.62	28.96	1.09	+	28.58	1.84	27.49	1.33	+
17	Spinal breadth	21.77	1.52	22.73	1.93	22.93	1.66	+	22.80	1.97	22.02	1.40	–
18	Upper limb length	68.27	2.57	71.37	1.40	74.19	1.66	+	71.70	1.58	72.56	2.17	–
19	Upper arm length	29.89	1.31	31.20	1.00	32.14	0.86	+	31.35	0.91	31.66	1.14	–
20	Forearm length	22.19	0.94	23.38	0.69	24.50	0.64	+	23.45	0.81	23.74	0.95	–
21	Hand length	16.20	0.72	16.77	0.58	17.55	0.61	+	16.90	0.69	17.16	0.67	–
22	Hand breadth	7.48	0.26	7.63	0.36	7.92	0.27	+	7.71	0.30	7.57	0.34	–
23	Lower limb length	82.74	2.93	86.64	1.62	90.97	2.81	+	86.98	2.75	88.45	3.13	+
24	Thigh length	42.53	1.54	43.99	1.27	45.85	1.68	+	44.53	1.97	45.08	1.79	–
25	Lower leg length	33.50	1.95	35.62	1.22	37.59	1.88	+	35.39	1.46	36.25	2.09	+
26	Foot length	23.13	0.91	24.16	0.82	25.30	0.83	+	24.57	0.75	24.39	0.97	–
27	Foot breadth	9.17	0.47	9.50	0.49	9.91	0.44	+	9.57	0.59	9.38	0.48	–
28	Chest circumference	78.15	3.93	81.68	2.70	84.02	3.82	+	85.66	4.22	78.66	3.09	+
29	Upper arm circumference	22.24	1.61	23.20	1.15	24.37	1.35	+	24.49	1.34	21.83	1.51	+
30	Thigh circumference	50.89	4.01	54.07	1.88	58.03	3.05	+	58.48	3.16	50.62	3.17	+

Finally, we compared the anthropometric variables of the girls from secondary schools of Tartu (aged 15–19, measured in 1995) with the Swiss girls measured in 1923–1926, i.e. approximately 70 years earlier. We were able to compare twelve dimensions that had been measured on both samples. The comparison showed (see Table 4) that the Estonian girls had bigger height and weight, all other measurements were also larger in all age groups. The only measurement that did not show significant differences in any of the age groups was upper limb length.

Table 4. Comparison of anthropometric characteristics of 15–19-year-old Estonian and Swiss girls
(all measurements are in cm, body weight in kg; group sizes; means, standard deviations and significance of the differences of means between ethnic groups (p<0,05) are listed)

No	Variable	Swiss girls			Estonian girls			*p*
		n	mean	SD	n	mean	SD	
	15 years old girls							
1	Height	73	159.78	6.04	219	165.80	5.68	+
2	Weight	59	52.42	7.59	219	56.71	7.38	+
3	Suprasternal height	73	130.45	5.28	219	134.85	5.11	+
4	Umbilical height	73	96.55	4.55	219	100.19	5.20	+
7	Acromial height	73	130.41	5.41	218	135.13	5.25	+
8	Iliospinal height	66	89.69	4.48	218	95.02	5.45	+
14	Biacromial breadth	73	33.76	1.49	219	34.50	1.73	+
18	Upper limb length	71	71.30	3.12	218	71.75	3.12	–
23	Lower limb length	66	86.55	4.14	217	89.99	4.33	+
28	Chest circumference	70	80.16	5.24	219	81.59	4.39	+
29	Upper arm circumference	69	22.67	1.87	218	25.18	2.14	+
30	Thigh circumference	67	53.15	4.96	219	56.78	4.37	+
	16 years old girls							
1	Height	54	159.8	5.26	274	166.58	5.98	+
2	Weight	52	51.45	5.24	274	59.69	9.26	+
3	Suprasternal height	54	130.44	4.71	274	135.52	5.65	+
4	Umbilical height	54	96.37	4.19	274	100.34	4.88	+
7	Acromial height	54	130.53	5.05	274	135.74	5.49	+
8	Iliospinal height	52	89.41	4.14	274	95.09	5.07	+
14	Biacromial breadth	54	33.63	1.58	274	34.87	1.81	+

No	Variable	Swiss girls			Estonian girls			*p*
		n	mean	SD	n	mean	SD	
18	Upper limb length	53	71.09	2.39	274	71.71	4.26	–
23	Lower limb length	52	86.39	3.87	274	90.02	4.30	+
28	Chest circumference	54	80.09	3.60	274	83.19	5.39	+
29	Upper arm circumference	54	22.56	1.40	274	25.80	2.57	+
30	Thigh circumference	54	52.86	3.84	274	57.99	4.91	+
	17 years old girls							
1	Height	51	162.54	5.41	358	166.54	5.70	+
2	Weight	47	56.46	6.41	358	58.81	7.79	+
3	Suprasternal height	51	132.70	4.62	355	135.37	5.00	+
4	Umbilical height	51	82.24	3.76	356	84.50	4.39	+
7	Acromial height	51	133.12	4.98	357	135.64	5.22	+
8	Iliospinal height	50	90.47	3.79	355	94.10	5.03	+
14	Biacromial breadth	51	34.35	1.73	357	34.96	1.67	+
18	Upper limb length	51	71.72	2.74	356	71.93	3.50	–
23	Lower limb length	50	87.19	3.44	353	89.29	4.31	+
28	Chest circumference	51	82.88	3.87	356	82.78	4.65	–
29	Upper arm circumference	51	23.66	1.69	356	25.66	2.41	+
30	Thigh circumference	50	55.48	3.89	356	57.70	4.65	+
	18 years old girls							
1	Height	47	161.40	4.94	214	166.37	6.60	+
2	Weight	47	54.63	6.59	214	58.62	7.97	+
3	Suprasternal height	47	131.81	4.34	213	135.39	5.52	+
4	Umbilical height	47	82.75	3.59	210	84.81	4.54	+
7	Acromial height	47	131.94	4.45	213	135.38	6.01	+
8	Iliospinal height	47	89.95	3.99	211	91.88	5.29	+
14	Biacromial breadth	47	34.35	1.43	213	35.15	1.59	+
18	Upper limb length	47	71.31	2.53	211	71.68	4.24	–
23	Lower limb length	47	86.85	3.68	209	88.32	4.37	+
28	Chest circumference	46	81.48	3.71	213	82.95	5.04	+
29	Upper arm circumference	47	23.35	1.47	212	25.89	2.34	+
30	Thigh circumference	46	54.28	3.86	211	58.15	4.52	+

DISCUSSION

The results of the study showed that the Swiss girls' anthropometric structure of the body as a whole consists of statistically significantly correlated variables that are most closely related to height and weight. Height and weight are the leading characteristics of the system as they determine the variability of all the other characteristics within 57% as average. Therefore, a suitable classification for systematising separate characteristics is a height-weight classification. In the present study a 5-class classification was used, and it proved to be appropriate for these purposes.

The Centre for Physical Anthropology at the University of Tartu has been engaged in body structure research from 1974. Different populations have been studied, and their body structure has been found to be, in principle, similar. The possibilities of classifying 15–19-year-old girls have been published by us earlier.

Furthermore the anthropometric characteristics of Estonian girls were compared with the same characteristics of Swiss girls. We found that the Estonian girls, who were measured 70 years later, exceeded their counterparts in all dimensions. It was interesting to see that the difference in measurements varied with age (see Figure 3). This difference between Estonian and Swiss girls reached its highest value, about 5%, at the age of 16 years, and decreased during the following years. It seems that due to acceleration Estonian girls reach their final shape earlier, at the age of 16 in most cases, but Swiss girls from the mid-1920s gained in size during the ages of 17 and 18 as well.

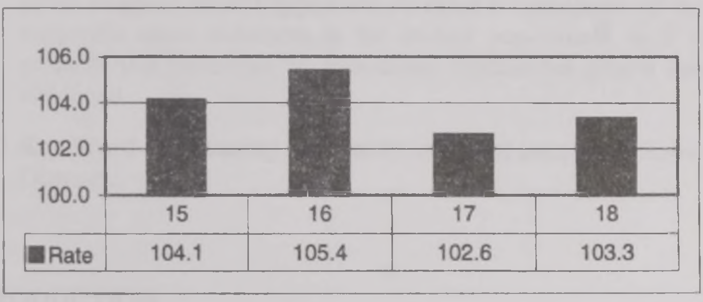

Figure 3. Average rate of measurements Estionian girls/ Swiss girls of different age.

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FLUCTUATING ASYMMETRY IN TWO LITHUANIAN AND DANISH MEDIEVAL AND EARLY MODERN SAMPLES

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ABSTRACT

Fluctuating asymmetry (FA) is a deviation from perfect symmetry of bilateral structures of an organism, when differences between the sides are distributed randomly. It is one of the mostly used unspecific stress indicators. However, despite numerous studies, the question about the causes and meaning of FA still remains, especially in paleopopulational research. The aim of this study was to evaluate fluctuating asymmetry in two medieval populations — Subačiaus St. in Vilnius (Lithuania) and Tirup (Denmark). 13 craniological and osteological measurements were used to estimate FA. Results revealed higher level of FA in Subačiaus St. sample. The major difference between populations was detected in the total average magnitude of fluctuating asymmetry. A comparison between FA level and earlier obtained incidence of linear enamel hypoplasia revealed a coincidence of the two unspecific stress indicators in the studied populations. It is highly probable that Subačiaus St. individuals experienced greater stress in childhood.

Key Words: fluctuating asymmetry, medieval population, Lithuania, Denmark

INTRODUCTION

Recently a lot of studies of human living conditions and health in the past and at present have used unspecific stress markers, such as Harris lines in tubular bones, dental enamel hypoplasias, fluctuating asymmetry of different morphological structures, etc. Fluctuating asymmetry (FA) is a deviation from perfect symmetry of bilateral structures of an organism, when differences between the sides are distributed randomly [9]. All bilaterally symmetrical structures in the organism, e.g. teeth or long bones, should develop mirror images of one another because of equal initial genetic information and epigenetic canalisation during morphogenesis. The failure of an individual to buffer against developmental disturbances results in fluctuating asymmetry [9]. It is believed that FA could reflect a magnitude of developmental instability and thus could be a good indicator of an individual's living conditions.

FA is one of the most often used unspecific stress indicators. A lot of studies have been conducted in order to access FA of various structures: teeth [1, 9, 14, 15, 23], hand bones [19], bones of the skull [22], anthropometrical measurements [18, 20, 30], dermatoglyphic characters [3, 5, 12].

The majority of studies discuss the causes of FA. There is still no agreement whether the magnitude of FA depends more on intrinsic or extrinsic factors. Some authors argue that there is a considerable genetic component, which determines the level of fluctuating asymmetry [12, 20]. It is believed that homozygous or high-inbred individuals should be more asymmetrical than heterozygous [11, 21]. However, some studies of twins and inbred populations have shown no remarkable differences according to zigosity. The latter studies argue that it is epigenetic environmental factors that are most responsible for changes in asymmetry level [1, 6].

The importance of environmental factors in FA level has been confirmed by numerous experimental studies [7, 10, 26]. The general assumption is that an increase in the magnitude of FA reflects a prolonged exposure of the organism to stress factors, e.g. infections, malnutrition, drugs, cold, noise, etc. Various studies of ancient and contemporary human populations [14, 15, 18, 29] also support the hypothesis that FA level corresponds with the living conditions and morbidity of individuals. Some researchers [25] have made an attempt to connect the magnitude of FA with other non-specific stress markers such as Harris lines and enamel hypoplasia. The results of these analyses have revealed a coincidence of three stress indicators. However, there are also studies that show no increase of FA in stressed populations [2, 27].

Theoretical studies of fluctuating asymmetry point to some methodological problems, particularly the small number of individuals and low accuracy of measurements that might obscure the results [4, 8, 19]. This is often addressed to paleopopulation studies that usually include a small number of individuals. For example, Smith and coworkers [27] have demonstrated that only using a sample of several hundred individuals it is possible to detect the true FA level. Such an assumption makes paleopopulation studies of FA questionable.

In our study we made an attempt to evaluate fluctuating asymmetry in two medieval populations. For this purpose we decided to measure asymmetry of limb and skull bones that are not frequently used in such studies. First we had to detect the magnitude of FA in each population and to perform interpopulation comparison of FA levels. Later we compared results of FA analysis with data on linear enamel hypoplasia for the same populations.

MATERIAL AND METHODS

The analysis was performed on two medieval / early modern populations. Subačiaus St. in Vilnius (Lithuania) is an urban orthodox cemetery dated to the 16–17th centuries, excavated in 1998 by A. Vaicekauskas. Tirup (Denmark) is a rural parish cemetery dated to the 12–14th centuries, excavated in 1984 by J. Kieffer-Olsen and investigated by the first author during her stay at Odense University.

Only adult individuals, whose sex and age at death had been determined by other researchers using conventional morphological criteria, were used. All bones affected by disease, trauma and great postmortal erosion were excluded from analysis. In total, 90 individuals from Subačiaus St. and 92 individuals from Tirup were included in the study.

Thirteen craniological and osteological measurements accepted in literature were taken. These were: 5 measurements of humerus: maximum length (HL), maximum midshaft width (HMaxMW), minimum midshaft width (HMinMW), head width (HHW) and head height (HHH); 5 measurements of femur: maximum length (FL), sagital midshaft width (FSMW), transversal midshaft width (FTMW), vertical head width (FWHW) and sagital head width (FSHW); and 3 measurements of skull: orbit breath (OB), orbit height (OH) and ramus of mandible height (RMH).

Before estimating FA, the data were assessed for the presence of directional asymmetry (DA), i.e., nonequality of means and variances between sides for each characteristic [9]. To test for DA, paired t-test using the means and variances of left and right bones for each measurement and separately for population was performed.

Fluctuating asymmetry was estimated using two computational methods:

1. FA_{ij} (FA1) — absolute difference between sides R – L, scaled on the mean total size of the trait 0.5 (R + L). When significant DA estimates are obtained, these are subtracted from the signed individual differences in each respective sample. Thus, the formula for calculating the individual FA is as follows:

$$FA_{ij} = \left| \left[\frac{(X_{ijR} - X_{ijL})}{0.5(X_{ijR} + X_{ijL})} \right] - \frac{1}{n} \sum_{i=1}^{n} \left[\frac{(X_{ijR} - X_{ijL})}{0.5(X_{ijR} + X_{ijL})} \right] \right|$$

where X_{ijR} and X_{ijL} are the j-trait values of the *i*th individual on the right and left bones, respectively, and FA_{ij} is the value of FA at trait j in the *i*th individual. The use of this formula results in the averages of the signed differences of the two sides becoming zero, and eliminates any effects due to directional asymmetry [9]. Because FA_{ij} was not normally distributed, all statistical comparisons required non-parametric tests [18]. Kruskal-Wallis's one-way analysis of variance (ANOVA) was used for this purpose. Mean FA_{ij} (FA1) values are provided only for illustrative purposes.

2. FA6 — variance of R – L differences for each trait:

$$FA6 = \frac{\sum (dS_i - DS)^2}{n-1},$$

where

$$dS_i = \frac{2(R_i - L_i)}{(R_i + L_i)}, \quad DS = \frac{1}{n} \sum dS_i,$$

and n is the sample size (Livshits *et al.*, 1988). FA6 measurements were compared by parametric ANOVA tests.

To check the coincidence of FA with other stress markers, we used our earlier data on linear enamel hypoplasia (LEH) in the same two populations (for detailed explanation refer to [24]). All individuals in each population were divided into groups based on LEH expression. According to the severity of LEH, two groups were defined: "unstressed" — individuals with none or mild hypoplasias, and "stressed" — individuals with moderate and severe hypoplasias. According to the number of stress episodes per individual, two groups were defined: "infrequently stressed" — individuals who had 1–2 stress episodes and "frequently stressed" — individuals who had 3 and more stress episodes. The magnitude of FA was detected for each group separately. Then intergroup comparison in FA level was performed.

All statistical analysis was performed using the SPSS statistical package.

RESULTS

Paired t-test revealed five cases of trait directional asymmetry in Subačiaus St. population and 7 cases in Tirup. Prior to estimation of FA, these traits were corrected as described in *Material and Methods*. Next we calculated the correlation of individual FA1 values for each pair of characteristics in both populations separately. This was done to determine whether the studied bilateral traits exhibited independent FA1 values. Most of the obtained correlations were in the range of 0.0–0.20. Hence, the FA of studied bilateral traits may be considered as independent.

There were no statistical differences in FA1 and FA6 measurements according to the age at death in both populations. Thus, the samples were not divided into age groups. No statistically significant differences between males and females were found either in Subačiaus St. or in Tirup. Thus, both sexes in each population were pooled to enhance the sample size.

The observed FA1 patterns, means and variances of each trait in two populations are presented in Table 1. The range of mean FA1 values were similar in both populations: 0.66–3.65% of the total variable size in Tirup and 0.77–3.64% of the total variable size in Subačiaus St. sample. The measurements of long bone midshafts expressed the greatest asymmetry level and variance. The lowest asymmetry and its variation were assessed for measurements of long bone lengths.

Table 1. Fluctuating asymmetry in Subačiaus St. (1) and Tirup (2) populations (MR — mean ranks of Kruskal-Wallis test)

Variable	Group	n	FA1*100	MR	p	FA6*100	p
HL	1	60	0.86	51.75	0.308	1.48	0.687
	2	48	0.92	57.94		1.29	
HmaxMW	1	79	3.59	72.96	0.410	19.22	0.787
	2	61	3.45	67.31		28.61	
HminMW	1	80	3.64	71.47	0.869	39.16	0.855
	2	61	3.39	70.39		23.23	
HHW	1	40	2.46	34.10	0.373	11.65	0.136
	2	24	1.65	29.83		5.09	
HHH	1	66	2.00	50.15	0.288	8.07	0.928
	2	38	1.97	56.58		6.17	
FL	1	60	0.77	68.78	0.955	1.13	0.323
	2	77	0.66	69.17		0.64	
FSMW	1	53	2.64	52.08	**0.022**	16.14	0.078
	2	66	3.65	66.36		21.19	
FTMW	1	54	3.29	68.65	**0.038**	24.25	0.452
	2	68	2.79	55.82		27.66	
FWHW	1	48	1.41	54.58	0.190	5.00	0.838
	2	70	1.39	62.87		3.03	
FFSHW	1	42	1.68	49.60	0.612	4.11	0.176
	2	53	1.41	46.74		2.71	
OB	1	63	1.79	44.98	0.349	5.17	0.093
	2	23	1.15	39.46		3.29	
OH	1	61	1.94	42.22	0.620	7.05	0.828
	2	21	1.75	39.40		5.85	
RMH	1	63	2.31	52.87	0.407	12.52	0.848
	2	46	2.43	57.92		10.14	
Total average	1	90	2.35	100.72	**0.020**	2.21	0.232
	2	92	2.00	82.48		1.61	

Test of homogeneity of variances revealed no significant differences in variation of the traits in two populations. Kruskal-Wallis test results were significant only in two cases: FSMW mean and mean rank was higher in Tirup ($p = 0.022$), and FTMW revealed greater mean and mean rank in Subačiaus St. sample ($p = 0.038$). Since the differences in FA1 magnitudes for each characteristic were negligible, we decided to compare differences in the total average magnitude of FA. The results show greater mean rank and mean of FA1 in Subačiaus St. sample. This difference was statistically significant ($p = 0.020$).

Differences in the magnitude of FA in stressed and unstressed groups of individuals (defined by LEH) were almost insignificant (Table 2). In Subačiaus St. population stressed individuals displayed greater means and mean ranks of FA1 according to 10 out of 13 characteristics, although, only one of them — OB — was statistically significant ($p = 0.045$). Variances of FA were also greater among stressed individuals, but differences reached significance only for the same OB characteristic ($p = 0.040$). Total average FA1 was greater for the stressed individuals, although the difference is insignificant. There was no clear tendency in differences of FA measurements between stressed and unstressed groups of individuals in Tirup sample. One characteristic (HMMinW) displayed significantly greater FA1 and FA6 values in the unstressed group of this population ($p<0.05$).

The comparison of FA results in groups of individuals with a few (infrequently stressed) and multiple (frequently stressed) stress episodes displayed only one significant case (Table 3). In Subačiaus St. population individuals with multiple stress episodes had greater FA1 and FA6 values for OB ($p<0.05$). There was no clear relationship between the magnitude of FA and the number of stress episodes in either Tirup or Subačiaus St. samples.

Table 2. Fluctuating asymmetry in "unstressed" (1) and "stressed" (2) groups of individuals in two populations (MR — mean ranks of Kruskal-Wallis test)

Variable	Group	Subačiaus str						Tirup					
		n	FA1*100	MR	P	FA6*100	p	n	FA1*100	MR	p	FA6*100	p
HL	1	25	0.74	30.96	0.863	0.97	0.467	23	1.00	22.63	0.511	1.46	0.534
	2	35	0.94	30.17		1.86		19	0.89	20.13		1.25	
HmaxMW	1	31	3.42	35.08	0.317	18.25	0.489	23	2.33	22.78	0.073	17.08	0.067
	2	44	3.84	40.06		21.58		30	4.33	30.23		48.82	
HminMW	1	31	4.26	37.71	0.783	66.27	0.343	23	4.57	33.17	**0.007**	33.06	**0.005**
	2	45	3.28	39.04		22.35		30	2.25	22.27		12.57	
HHW	1	17	2.33	19.53	0.648	10.40	0.809	10	1.63	11.15	0.915	5.57	0.962
	2	23	2.56	21.22		12.86		12	1.42	10.86		3.59	
HHH	1	28	2.14	30.48	0.323	10.45	0.478	14	2.26	17.32	0.867	9.21	0.325
	2	37	1.92	34.91		6.03		19	1.75	16.76		4.39	
FL	1	22	0.73	31.80	0.535	0.91	0.840	31	0.59	31.11	0.195	0.49	0.223
	2	37	0.77	28.93		1.23		37	0.76	37.34		0.84	
FSMW	1	18	2.15	22.97	0.339	10.82	0.269	25	4.41	34.30	0.056	29.16	0.062
	2	32	2.94	26.92		19.92		33	3.01	25.86		16.07	
FTMW	1	18	2.89	25.19	0.769	15.43	0.380	26	2.70	31.04	0.664	14.24	0.708
	2	33	3.59	26.44		28.97		33	3.31	29.18		45.51	
FWHW	1	15	1.01	20.13	0.206	2.92	0.479	25	1.39	31.74	0.929	2.76	0.691
	2	31	1.55	25.13		6.01		37	1.46	31.34		3.49	
FFSHW	1	13	1.72	21.19	0.788	4.35	0.950	22	1.19	20.41	0.121	1.68	0.105

Variable	Group	Subačiaus str						Tirup					
		n	FA1*100	MR	P	FA6*100	p	n	FA1*100	MR	p	FA6*100	p
	2	27	1.69	20.17		4.35		24	1.61	26.33		3.79	
OB	1	26	1.38	26.58	**0.045**	3.50	**0.040**	11	1.08	11.23	0.563	3.51	0.730
	2	37	2.07	35.81		6.09		12	1.20	12.71		3.16	
OH	1	26	1.81	28.60	0.344	6.88	0.746	10	1.72	10.80	0.881	7.65	0.547
	2	35	2.03	32.79		7.34		11	1.77	11.18		4.80	
RMH	1	22	2.27	30.64	0.904	10.82	0.812	22	2.24	21.80	0.869	8.83	0.920
	2	39	2.36	31.21		14.14		20	2.34	21.17		10.03	
Total average	1	32	2.25	40.78	0.520	2.21	0.251	36	1.98	42.25	0.669	1.09	0.730
	2	53	2.14	44.34		2.18		45	1.95	40.00		1.44	

Table 3. Fluctuating asymmetry in "infrequently stressed" (1) and "frequently stressed" (2) groups of individuals in two populations (MR — mean ranks of Kruskal-Wallis test).

Variable	Group	Subačiaus str						Tirup					
		n	FA1*100	MR	p	FA6*100	p	n	FA1*100	MR	p	FA6*100	p
HL	1	18	0.82	31.25	0.828	1.25	0.828	25	0.88	19.96	0.324	1.20	0.449
	2	42	0.87	30.18		1.61		17	1.05	23.76		1.59	
HmaxMW	1	23	3.35	36.61	0.706	16.71	0.463	32	2.91	27.31	0.851	12.28	0.172
	2	52	3.80	38.62		21.39		21	4.31	26.52		57.48	
HminMW	1	23	3.31	38.67	0.962	26.09	0.700	32	3.28	27.41	0.802	24.29	0.939
	2	53	3.84	38.42		47.05		21	3.21	26.38		19.23	
HHW	1	11	2.34	19.45	0.725	10.21	0.898	14	1.60	11.50	0.597	4.89	0.627
	2	29	2.51	20.90		12.51		7	1.34	10.00		4.42	
HHH	1	20	2.66	36.20	0.335	10.95	0.103	19	1.74	15.39	0.255	5.45	0.350
	2	45	1.73	31.58		4.10		14	2.28	19.18		7.92	
FL	1	18	0.78	32.61	0.439	1.07	0.797	37	0.75	36.61	0.336	0.86	0.203
	2	41	0.75	28.85		1.13		31	0.60	31.98		0.49	
FSMW	1	14	3.08	29.54	0.204	15.24	0.753	34	3.73	30.01	0.779	19.69	0.951
	2	36	2.49	23.93		17.51		24	3.44	28.77		20.46	
FTMW	1	14	3.42	26.96	0.770	19.83	0.910	34	2.98	32.71	0.138	16.41	0.952
	2	37	3.32	25.64		27.58		25	3.12	26.32		53.45	
FWHW	1	14	1.38	22.96	0.848	4.02	0.897	36	1.49	33.15	0.378	3.27	0.851
	2	32	1.37	23.73		5.55		26	1.34	29.21		2.73	
FFSHW	1	11	1.77	20.82	0.913	4.64	0.946	29	1.39	22.19	0.370	2.80	0.950

Variable	Group	Subačiaus str						Tirup					
		n	FA1*100	MR	p	FA6*100	p	n	FA1*100	MR	p	FA6*100	p
	2	29	1.68	20.38		4.19		17	1.44	25.74		2.72	
OB	1	21	1.28	24.74	**0.023**	2.96	**0.027**	12	0.98	11.34	0.586	2.48	0.391
	2	42	2.04	35.63		6.22		11	1.32	12.73		4.47	
OH	1	21	2.13	31.57	0.850	7.54	0.460	10	1.95	11.40	0.765	6.95	0.652
	2	40	1.84	30.70		6.57		11	1.57	10.64		5.49	
RMH	1	19	2.72	34.71	0.271	14.05	0.434	24	2.79	24.38	0.077	13.68	0.075
	2	42	2.15	29.32		12.42		18	1.63	17.67		4.26	
Total average	1	26	2.49	47.62	0.252	3.26	0.251	46	2.04	43.13	0.350	1.49	0.288
	2	59	2.29	40.97		1.73		35	1.86	38.20		0.99	

DISCUSSION

The greatest asymmetry in both populations was detected in midshaft measurements of tubular bones. These characteristics also displayed the greatest variation of asymmetry. It seems that diaphysial diameter is characterised by a greater ability for variation in case of developmental disturbance because of bone remodelling.

The results of the present study revealed greater level of FA in Subačiaus St. sample. The major difference between populations was detected in the total average magnitude of fluctuating asymmetry. Population differences in the FA of a particular variable were almost insignificant, although, a clear tendency could be defined for Subačiaus St. population to be more asymmetrical according to the majority of characteristics. However, if sample size is small, there is a great chance to accept null hypothesis on nonexistent difference [27]. Despite this sceptical view we think that our obtained difference in total average magnitude of FA reflects a population difference.

There is still no agreement which factors, genetic or environmental, are more responsible for the FA. Naturally, we cannot totally exclude the impact of population genetic factors. Tirup was a small medieval village, where subsistence of inhabitants was based on agriculture, while Subačiaus St. population belonged to the city. People from villages were more isolated from other communities due to their settled lifestyle. Skeletal material of Tirup individuals displayed features of anatomic variation that are common for homozygous and high-inbred population (J. Boldsen, pers. comm.). It is believed that such individuals should be more asymmetrical because of weaker epigenetic control [11, 21]. However, asymmetry level in Tirup was lower than that of Subačiaus St. Thus, we suppose that it is environmental rather than genetic factors that are responsible for the difference in population asymmetry level in our study.

If greater asymmetry really means a weaker ability of an organism to buffer against developmental disturbances, we might suppose that Subačiaus St. individuals lived under more stressful conditions. Living conditions in medieval towns were highly stressful. Various infectious diseases were widely and easily spread in towns because of the great number of people and their high density [16, 28]. Ordinary citizens were often malnourished [13, 17]. Considering this, it is not surprising that frequent stresses experienced in childhood could weaken individuals' immune system and make them more vulnerable to other stresses in later life. Our earlier study on dental enamel hypoplasia [24] revealed significant differences according to the severity and frequency of LEH in those populations. A greater number of affected individuals were found in Subačiaus St. population. The average degree and number of stress episodes per individual were also higher in Subačiaus St. sample than in Tirup. We argued that the results did express population differences in stress level. It is highly probable that Subačiaus St. individuals experienced greater stress in childhood. Such results correspond with the greater asymmetry level in this population.

It was natural to expect that individuals with more severe and more frequent hypoplasia should display greater fluctuating asymmetry. However, the analysis of FA in 'unstressed' and 'stressed' individuals revealed no significant differences. No certain relation between frequency of LEH and magnitude of fluctuating asymmetry was detected. Only in Subačiaus St. sample there was a clear tendency for 'stressed' individuals to be more asymmetrical, although differences were almost all insignificant, including the total level of asymmetry. Probably analysis of samples of a larger size would reveal a better relation between the frequency and severity of LEH and FA.

Considering all this, it is likely that ordinary medieval citizens were exposed to more chronic stress, which lead to relatively higher morbidity but lower mortality and a higher survivorship. This way it appears that FA could serve as an independent system for checking ontogenetic stress levels in skeletal populations.

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MODELLING FOOD CONSUMPTION IN ESTONIA

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ABSTRACT

The paper studies the dynamics of households' consumption patterns between 1992 and 1996. The data have collected through Household Survey carried out from 1992 to 1996. The present study analyses the consumption of main food components, calculating the consumption in grammes per one household member. It also examines the relationship between the years and the income of the household. The households are divided into income deciles by income per household member. During the analysed period the changes in consumption patterns of different food components vary — the consumption of milk products has decreased, while the consumption of fruit and vegetables has increased. The households with higher income consume more food that those with smaller income.

Keywords: food consumption, income decile classes, linear model, least-square means.

The paper analyses the diet of Estonian households from 1992 to 1996. The data have been collected through household surveys carried out in those years. The number of households interviewed is quite large: 4,099 in 1992, 6,628 in 1993, 6,891 in 1994, 15,792 in 1995, and 17,344 in 1996.

In the present study food consumption is analysed by the main classes, paying no attention to the more detailed classification of food (no separate products analysed). The main food groups are: fruit and vegetables, milk and dairy products, pastry, meat and meat products, sugar and honey, grain products, fish and seafood, fat, eggs and egg products. The relationship between diet and the household's income is studied. Households are divided into deciles by their income, so that the households with the lowest income form the first decile and the households with the highest income the last decile.

In the present study food consumption is defined as average daily food consumption of a household member. Table 1 gives the average food consumption by main food groups for the years studied. As we can see, the consumption of fruit and vegetables has grown during the period, while the consumption of milk products has declined.

Table 1. Average consumption by years

	Fruit	Milk	Pastry	Meat	Sugar	Grain	Fish	Fat	Eggs
92	155.9	262.0	213.8	100.1	49.6	54.5	32.3	28.3	20.0
93	168.0	258.7	206.9	88.5	58.3	46.0	41.8	35.1	20.4
94	178.0	255.0	203.9	87.6	65.1	56.8	42.4	36.7	20.1
95	291.4	219.7	159.6	97.1	52.5	53.4	30.1	29.8	17.4
96	325.6	204.6	146.4	91.9	56.8	56.3	31.4	31.6	16.5
Average	261.1	227.1	171.4	92.4	55.9	53.9	34.2	31.8	18.0

Table 2 provides the general relation between income per one household member and average food consumption. Here we can see that food consumption depends on the income of the household. The average food consumption of all the households in the low income class (i.e. the poorest households) is lower than that of the households in the higher income classes.

Table 2. Average consumption by deciles

Decile	1	2	3	4	5	6	7	8	9	10
Fruit	140.7	196.7	202.1	263.6	203.7	203.9	280.1	333.6	328.0	358.6
Milk	190.3	232.3	248.2	245.4	250.1	242.5	245.2	245.5	246.8	253.6
Pastry	171.2	191.3	196.0	185.9	189.9	186.4	188.7	183.2	183.0	185.7
Meat	56.8	72.4	85.7	84.1	92.2	92.2	100.7	104.6	112.0	129.7
Sugar	37.6	47.6	54.6	54.0	58.5	58.6	61.4	64.8	62.0	65.8
Grain	44.1	56.4	58.6	56.0	53.5	54.8	53.9	52.3	51.7	52.6
Fish	25.7	35.4	41.5	37.2	37.2	37.3	36.1	35.5	34.3	38.0
Fat	24.9	30.5	34.3	32.9	32.3	32.5	32.9	33.4	33.5	35.5
Eggs	12.3	16.3	19.1	18.9	19.1	20.0	19.7	20.5	20.6	22.4

In the following the changes in average daily consumption of each nutrient have been investigated by means of a linear model. The arguments in that model are the year (the period from 1992-1996 has been considered) and the class of income (the income is divided into ten classes, which may be called deciles). The interaction effect of arguments is also included into the model. The arguments are interpreted as categorical variables. Therefore, the model is a two-way unbalanced factor model with 49 parameters. The least-squares means [1] were computed for each effect included into the model. The least-squares estimates of marginal averages are to unbalanced designs as class and subclass arithmetic averages are to balanced designs — they are estimates of the class or subclass marginal averages that would be expected if the design had been balanced. So the least-squares means are more reliable estimates than the subclass arithmetic averages. In addition to each difference in the least-square means it is possible to calculate the probability of significance (p). In the following the difference is said to be statistically significant if $p<0.05$.

As we will see, the relationship between the dependent variable (the average daily consumption of a nutrient) and arguments is not very strong, the squared multiple correlation coefficient (R-square) being between 0.01 and 0.1. The average standard error of the model (Root MSE) is also rather great. Such a model is not appropriate for prediction, but we can use this model to investigate the main trends of average consumption.

The investigated nutrients are presented the order of their share in average daily consumption.

Fruit and vegetables

The overall average daily consumption is 261.1g. For estimation the model 50,719 observations (families) were used. The model is significant ($p<0.0001$), R-square is 0.054, Root MSE is 423.29g. Both factors — the year and the decile — are significant and so are the interactions.

From the least-squares means for different years (Table 1) one can conclude that the average daily consumption of fruit and vegetable is increasing. The changes have been especially rapid in 1995 and 1996. The differences between the years 1994, 1995 and 1996 are statistically significant. The average daily consumption in 1996 (325.0g) is about twice as high as in 1992 (155.9g).

Considering the least-squares means for different deciles (Table 2), we notice a clear trend — the average daily consumption is increasing when the income is increasing. The average consumption in deciles 2, 3, and 5 is similar (differences are not statistically significant), which is also true for the average consumption in classes 8 and 9. The daily average of the 10th decile (358.6g) is more than two times higher than in the first decile (140.7g).

We get a more detailed picture if we look at the least-squares means in all subclasses formed by years and deciles (Table 3, Fig. 1).

Table 3. Average consumption of fruit and vegetables

d-class	1	2	3	4	5	6	7	8	9	10
92	93.6	105.7	105.6	125.9	125	153.6	149.6	162.4	212.2	326.3
93	90.6	119.8	143.3	171.2	161.8	190.5	197.6	199.6	201.3	204.6
94	110.3	145.6	156.5	156.4	138.3	169.2	187.9	204.5	246.4	264.9
95	145.3	158.9	215.0	303.4	216.7	342.9	295.0	401.3	403.9	431.6
96	178.8	288.5	262.4	316.7	277.2	367.4	356.5	429.2	359.3	419.8

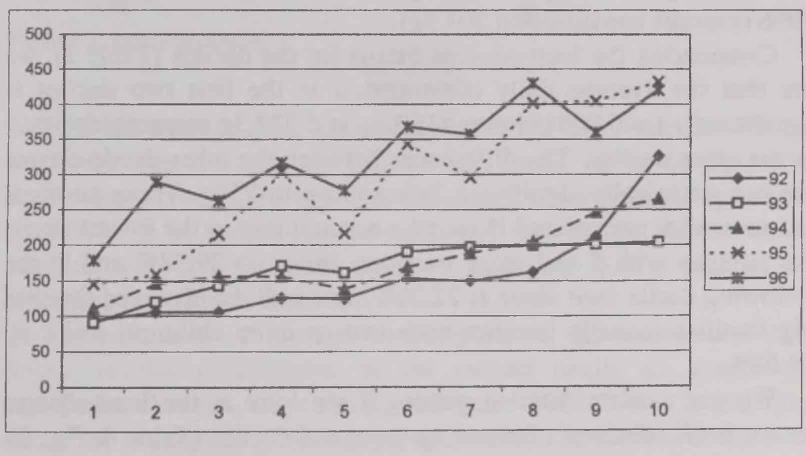

Figure 1. Fruit and vegetables.

The main trend during the period is growth in consumption. We can notice that in 1995 or 1996 there was a significant "jump" of daily averages in all deciles. For the first decile-class the changes between the years are significant from the year 1994, but the daily average of the first decile is always the lowest in the year. In the two highest deciles, the 10th and the 9th, the increase stopped in 1996. In the ninth decile the daily average of 1996 (359.3g) is significantly lower than of 1995 (403.9g), while in the tenth decile the change (from 431.6g in 1995 to 419.8g in 1996) is statistically insignificant.

Dairy products

The overall average daily consumption is 227.1g. For estimation the model 50,723 observations (families) were used. The model is significant ($p<0.0001$), R-square is 0.03. Both factors — the year and the decile — are significant and so are the interactions.

Considering the least-squares means for different years (Table 1), we can conclude that the average daily milk and milk products consumption is decreasing. The differences between the years 1992, 1993 and 1994 are not statistically significant (average consumption is ~258g). The first statistically significant fall ($p<0.0001$) occurred in 1995 (average consumption 218.1g) and the second one ($p<0.0001$) in 1996 (average consumption 203.9g).

Considering the least-squares means for the deciles (Table 2), we see that the average daily consumption in the first two deciles is significantly ($p<0.0001$) lower (190.3g and 232.3g respectively) than in the other deciles. The differences between the other decile-classes are not statistically significant, being close to 250g. These numbers are somewhat unexpected if we take account that in the lowest decile the families with 5 and more members make up 29.38% and in the following decile their share is 22.26%. From all the observed families big families (usually families with two or more children) make up 14.68%.

We get a more detailed picture if we look at the least-squares means in all subclasses formed by years and deciles (Table 4, Fig. 2). Here we can notice two main trends: in deciles four to ten in 1992-1994 the average daily consumption increases together with the number of the decile-class, in 1995–1996 the average daily consumption does not increase together with the number of the decile-class.

Table 4. Average consumption of milk and dairy products

d-class	1	2	3	4	5	6	7	8	9	10
92	236.4	234.1	242.0	241.8	263.6	281.6	278.5	269.0	289.0	283.7
93	175.5	232.9	234.8	296.5	266.0	273.3	276.3	275.6	272.2	283.4
94	180.1	231.9	243.2	259.8	266.4	253.1	252.7	276.6	301.8	285.0
95	189.8	233.8	257.4	225.7	256.0	207.9	228.1	199.6	190.0	208.4
96	169.5	228.9	263.8	203.0	198.4	196.3	190.6	206.8	181.2	207.7

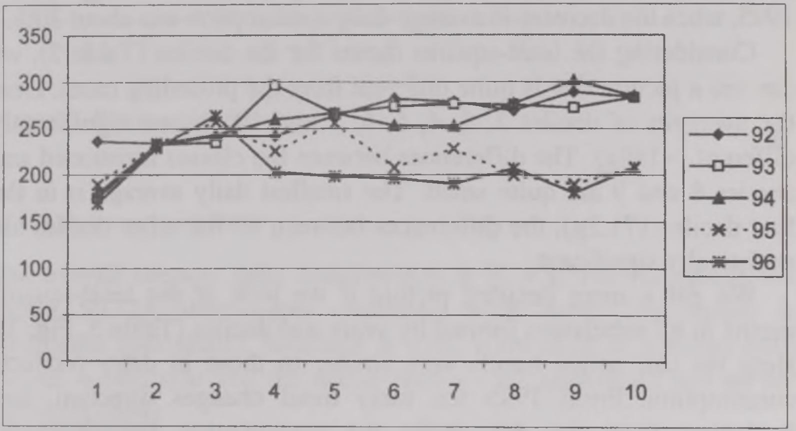

Figure 2. Dairy products.

In 1996 the average daily consumption for the last 7 deciles (~200g) was lower than it was in 1992 in the first decile, i.e. in the class with the lowest income (236.4g). The difference is statistically significant ($p<0.007$). It is appropriate to point out that in the highest decile families with 5 and more members make up 4.84% and in the preceding decile their share is 6.64%.

The behaviour of average consumption in the second and third lowest deciles is different. In the second decile no statistically significant changes occur during the years 1992–1996. In the third decile the average daily consumption increases. In the first decile class it significantly falls in 1993; later changes are not significant.

Pastry products

The overall average daily consumption is 171.4g. For estimation the model 50,723 observations (families) were used. The model is significant ($p<0.0001$), R-square is 0.09, Root MSE is 105.6g. Both factors — the year and the decile-class — are significant and so are the interactions

Considering the least-squares means for different years (Table 1), it must be concluded that the average daily consumption of pastry products is decreasing. The greatest plunge was between 1994 and 1995, when the decrease in average daily consumption was about 20%.

Considering the least-squares means for the deciles (Table 2), we can see a picture that is quite different from the preceding cases. Here the averages of deciles 2, 3, 4, 5, 6, 7 and 10 are not significantly different (~188g). The differences between the classes mentioned and deciles 8 and 9 are quite small. The smallest daily average is in the first decile (171.2g); the differences between all the other deciles are statistically significant.

We get a more detailed picture if we look at the least-squares means in all subclasses formed by years and deciles (Table 5, Fig. 3). Here we can notice trends very similar to those in dairy products consumption. From 1995 the main trend changes direction, and beginning from the 4th decile the consumption has decreased significantly. In the third decile the consumption is very stable, and there are no significant changes during the observed years.

Table 5. Average consumption of pastry products

d-class	1	2	3	4	5	6	7	8	9	10
92	190.4	181.6	202.6	196.7	213.4	231.0	221.9	219.4	231.3	250.1
93	171.4	203.1	197.6	224.3	200.0	212.9	220.8	210.1	217.3	211.5
94	174.5	208.2	194.8	201.5	209.0	209.8	218.2	211.5	211.5	199.8
95	161.9	187.2	189.1	161.0	184.2	147.0	154.7	140.6	134.1	136.3
96	157.9	176.2	196.0	145.9	142.8	131.4	127.9	134.4	120.7	130.5

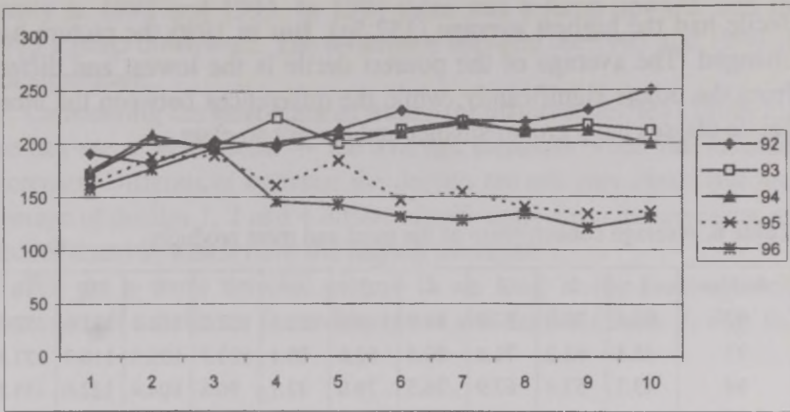

Figure 3. Pastry products.

Meat and meat products

The overall average daily consumption is 92.4 g. For estimation the model 50,723 observations (families) were used. The model is significant ($p<0.0001$), R-square is 0.03, Root MSE is 106.5g. Both factors — the year and the decile-class — are significant and so are the interactions

Considering the least-squares means for different years (Table 1), we can see that the average daily consumption of meat products has changed unevenly. From 1992 to 1993 the average decreased (about 10%), while from 1994 to 1995 the average has increased, reaching almost the level 1992, and in 1996 the average consumption decreased again.

From the least-squares means for different deciles (Table 2), we can see a clear trend — the average increases when the income increases. The differences between deciles 3, 4, 5, 6 are not significant, and same stands for the differences between deciles 7 and 8. But if we compare the averages of the 1st and the 10th classes (56.8g and 129.7g respectively), we can see that the latter is more than twice higher.

We get a more detailed picture if we look at the least-squares means in all subclasses formed by years and deciles (Table 6, Fig. 4). For the first "good" year (1992) it is clear, that the two poorest deciles had a significantly smaller average than classes 5-9, and the tenth decile had the highest average (152.5g). But in 1996 the picture has changed. The average of the poorest decile is the lowest and differs from the others significantly, while the differences between the other decile classes have grown smaller and are not so clear.

Table 6. Average consumption of the meat and meat products

d-class	1	2	3	4	5	6	7	8	9	10
92	62.8	70.9	87.8	84.9	100.9	103.1	102.2	114.1	121.6	152.5
93	45.8	62.2	71.8	80.4	82.6	89.1	103.7	105.3	116.7	127.4
94	43.1	57.8	67.9	76.5	79.0	92.7	96.8	104.4	122.0	135.7
95	68.6	83.1	93.2	86.8	105.4	93.5	108.3	100.8	103.5	128.2
96	63.7	88.0	107.8	91.6	93.2	82.8	92.3	98.1	96.0	104.9

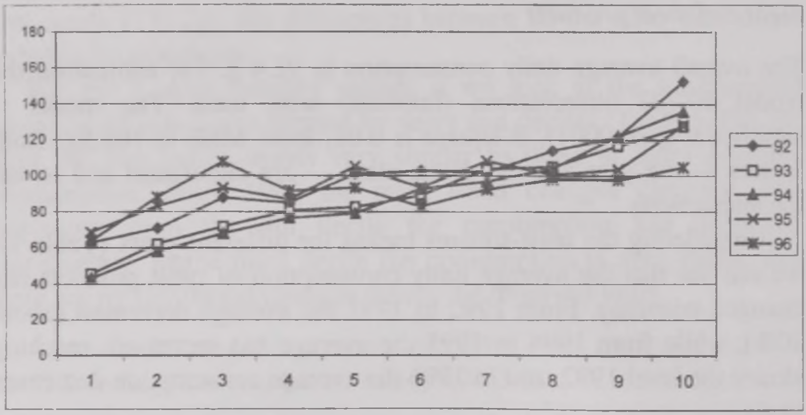

Figure 4. Meat and meat products.

Sugar and honey

The overall average daily consumption is 55.9g. For estimation the model 50,722 observations (families) were used. The model is significant ($p<0.0001$), R-square is 0.01, Root MSE is 131.4g. Both factors — the year and the decile-class — are significant and so are the interactions

From the least-squares means for different years (Table 1), we see that the average daily consumption of sugar did not change significantly in 1992 and 1993. In 1994 there was a jump upward, and in 1995 a jump downward. The difference between the 1995 and 1996 is not significant.

Considering the least-squares means for different deciles (Table 2), we can see a weak trend — the average increases when the income increases. Differences between the deciles are not very clear. But the average of deciles 1, 2 and 4 differs significantly from the averages of deciles 8 and 9, which have the highest averages.

We get a more detailed picture if we look at the least-squares means in all subclasses formed by years and deciles (Table 7, Fig. 5).

Table 7. Average consumption of the sugar and honey

d-class	1	2	3	4	5	6	7	8	9	10
92	29.6	29.3	30.0	34.7	54.2	59.0	56.2	63.3	68.2	71.6
93	32.4	44.0	51.5	64.1	60.3	57.4	73.0	65.0	64.4	72.2
94	36.3	47.6	61.1	68.0	68.1	74.6	66.0	74.8	79.6	75.1
95	40.5	51.4	56.9	49.8	54.1	52.2	58.1	60.2	45.5	56.2
96	49.1	65.5	73.7	53.3	55.9	49.6	53.8	60.8	52.5	53.7

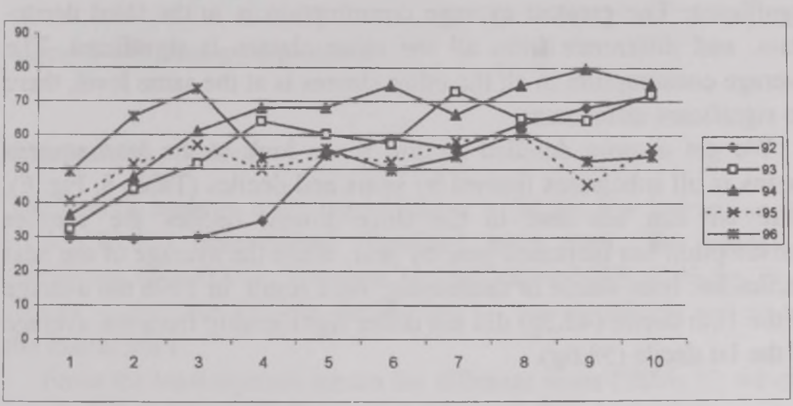

Figure 5. Sugar and honey.

Here the picture is somewhat fuzzy. We may still notice two different (but not very strong) trends. The average increases along with increasing income in the years 1992, 1993, 1994. The average is stable in 1995 and 1996. Only the differences of averages between the first (40.5g) and the eighth (60.2g) decile-class are significant in 1995, and only the difference between the averages of the first (49.1g) and the third (73.7g) decile is significant in 1996.

Grain and grain products

The overall average daily consumption is 53.9g. For estimation the model 50,721 observations (families) were used. The model is significant ($p<0.0001$), R-square is 0.01, Root MSE is 86.9g. Both factors — the year and the decile-class — are significant and so are the interactions

From the least-squares means for different years (Table 1), we can see that the average daily consumption of grain has been very stable. Only the average of 1994 differs from the others significantly; in that year the average consumption was lower. The other differences are not statistically significant

Considering the least-squares means for different deciles (Table 2), we can see a similar picture. The smallest average consumption is, as always, in the first decile, and difference from all the other classes is significant. The greatest average consumption is in the third decile-class, and difference from all the other classes is significant. The average consumption in all the other classes is at the same level; there no significant differences.

We get a more detailed picture if we look at the least-squares means in all subclasses formed by years and deciles (Table 8, Fig. 6). Here we can see that in the three lowest deciles the average consumption has increased year by year, while the average of the next deciles has been stable or decreasing. As a result, in 1996 the average of the 10th decile (42.3g) did not differ significantly from the average of the 1st decile (58.6g).

Table 8. Average consumption of the grain and grain products

d-class	1	2	3	4	5	6	7	8	9	10
92	38.4	45.1	52.8	51.3	49.3	65.7	57.4	56.1	59.1	70.0
93	30.7	45.6	45.3	55.9	44.9	44.8	49.8	47.0	53.3	42.7
94	43.9	61.9	58.6	61.8	62.4	60.4	58.5	55.6	56.5	48.0
95	48.7	59.9	57.5	52.3	57.4	50.7	54.9	49.5	47.6	55.9
96	58.6	69.7	79.0	58.9	53.5	52.5	48.8	53.3	42.3	46.3

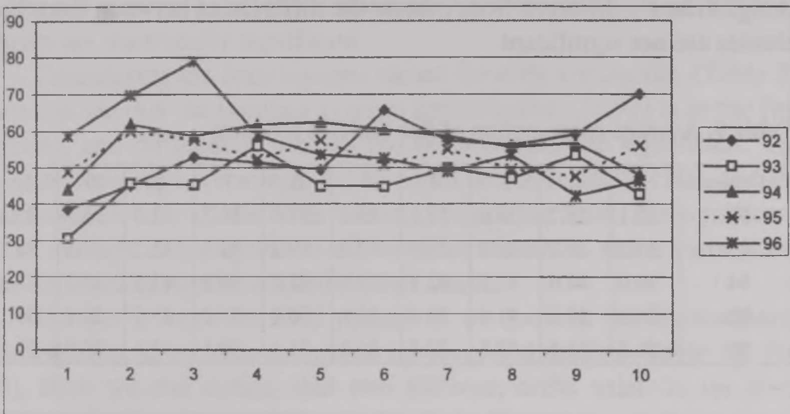

Figure 6. Grain and grain products.

Fish and fish products

The overall average daily consumption is 34.2g. For estimation the model 50,720 observations (families) were used. The model is significant ($p<0.0001$), R-square is 0.02, Root MSE is 56.8g. Both factors — the year and the decile-class — are significant and so are the interactions

From the least-squares means for different years (Table 1), we can see that the average daily consumption of fish jumped upward in 1993, did not change significantly in the following year and then jumped downward almost to the level of 1992.

Considering the least-squares means for different deciles (Table 2), we can see a picture similar to the previous case. The smallest average consumption (25.7g) is, as always, in the first decile, and differences with all the other classes are significant. The greatest average consumption (41.5g) is in the third decile class, and differences with all the other classes are significant. The average consumption in all other deciles is at the same level; no statistically significant differences occur.

We get a more detailed picture if we look at the least-squares means in all subclasses formed by years and deciles (Table 9, Fig. 7). Here it is interesting to note that the average has never been increasing together with incomes. The changes are quite small. Therefore, in 1992 the differences between averages are not statistically significant. In 1996 the greatest average consumption in third decile-class (43.8g) is significantly different from others; the differences between the other classes are not significant.

Table 9. Average consumption of fish and fish products

d-class	1	2	3	4	5	6	7	8	9	10
92	22.1	21.7	38.0	27.8	33.0	37.0	36.3	32.5	36.9	37.4
93	25.2	39.2	42.0	53.6	42.1	49.2	42.4	45.2	37.5	42.1
94	30.0	44.6	42.3	42.1	47.9	42.1	40.6	42.6	43.7	48.3
95	24.8	37.8	41.4	30.0	36.6	26.8	30.9	25.9	26.8	30.1
96	26.3	33.6	43.8	32.5	26.3	31.4	30.1	31.1	26.8	31.9

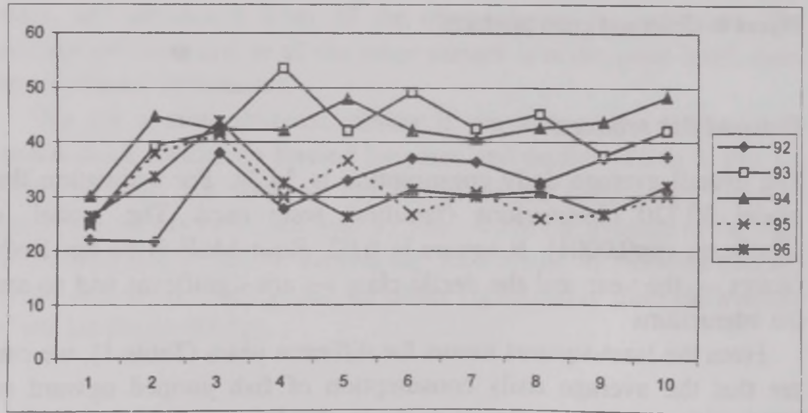

Figure 7. Fish and fish products.

Fat and cooking oil

The overall average daily consumption is 31.8g. For estimation the model 50,724 observations (families) were used. The model is significant ($p<0.0001$), R-square is 0.04, Root MSE is 81.8g. Both factors — the year and the decile-class — are significant and so are the interactions

From the least-squares means for different years (Table 1), we can see that the average daily consumption of the fat and cooking oil has changed unevenly. All the differences between averages of different years are statistically significant.

Considering the least-squares means for different deciles (Table 2), we can see that the smallest average consumption (24.9g) is in the first decile, and differences with all the other deciles are significant. The greatest average consumption (35.5g) is in tenth decile-class and the differences with all the other classes, except the third, are significant. The average consumption in all the other classes is at the same level; no statistically significant differences occur.

We get a more detailed picture if we look at the least-squared averages in all subclasses formed by years and deciles (Table 10, Fig. 8). Here we can notice, that two different drifts exist. In the three lowest deciles the average consumption increases year by year; in other deciles the average consumption is stable or decreasing.

Table 10. Average consumption of the fat and cooking oil

d-class	1	2	3	4	5	6	7	8	9	10
92	19.6	19.5	23.9	27.1	25.7	29.9	31.4	31.0	34.7	39.7
93	23.4	30.3	33.1	37.5	33.9	36.7	34.3	39.7	38.9	40.4
94	24.5	33.8	35.8	37.1	38.6	38.7	38.4	39.5	41.3	39.6
95	26.5	32.4	35.8	30.3	34.0	28.4	28.9	26.8	26.3	28.3
96	30.6	36.4	42.6	32.2	29.2	29.0	28.6	30.3	26.2	29.7

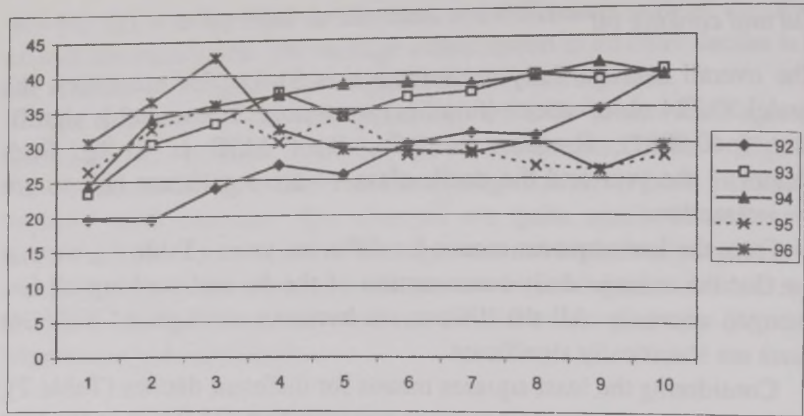

Figure 8. Fat an Cooking Oil.

Eggs

The overall average daily consumption is 18.0 g. For estimation the model 50,754 observations (families) were used. The model is significant (p<0.0001), R-square is 0.03, Root MSE is 19.2g. Both factors — the year and the decile-class — are significant and so are the interactions

From the least-squares means for different years (Table 1), we can see that the average daily consumption of eggs did not change significantly in 1992, 1993 and 1994; after that the average has made two significant jumps downward.

Considering the least-squares means for different deciles (Table 2), we can see that the averages of the two first decile-classes are significantly lower than in other deciles. The greatest average consumption (22.4g) is in the 10th decile, and differences with all the other classes are significant. The average consumption in all the other classes is nearly the same.

We get a more detailed picture if we look at the least-squared averages in all subclasses formed by years and deciles (Table 11, Fig. 9). Here we can notice, that two different drifts exist. In the three lowest decile-classes the average consumption increases with the increase in income, while in other the deciles the average consumption has become more stable by years.

Table 11. Average consumption of eggs

d-class	1	2	3	4	5	6	7	8	9	10
92	13.9	14.6	19.1	17.2	19.6	23.0	23.0	21.2	21.2	27.2
93	11.4	17.6	18.8	22.7	20.4	21.3	20.9	23.2	23.2	24.3
94	11.4	16.2	19.1	20.1	19.7	21.5	20.2	23.4	25.1	24.1
95	13.0	16.4	18.4	17.8	19.8	17.4	18.8	17.3	17.5	18.2
96	11.7	16.8	19.9	16.8	16.2	16.9	15.8	17.2	16.2	18.0

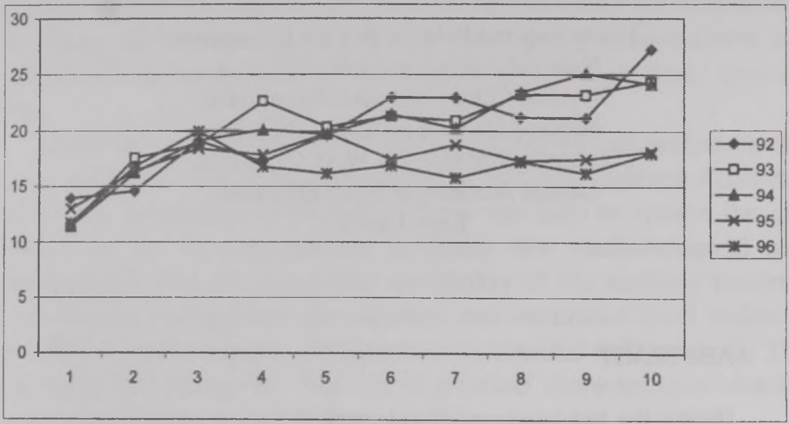

Figure 9. Eggs.

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ANTHROPOMETRIC CHARACTERISTICS OF BODY FUNCTIONAL CAPACITIES AND PHYSICAL FITNESS OF CADETS

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ABSTRACT

During the last ten years of independent Latvian state no data have been collected about the body constitution, physical fitness and functional capacities of military personnel (recruits, officers) of the National Defence Forces of Latvia. The theme of our study was to characterise the body constitution, functional parameters, physical development and physical fitness of the future officers. We measured their body mass, height and lung vital capacity. The evaluation of anthropometric data shows that cadets of NDA had higher anthropometric characteristics than the military personnel of US Army, but there were no differences with the anthropometric data of British Army cadets and Lithuanian future police-officers. We measured heart rate per minute, breathing rate per minute, lung ventilation in litres per minute, gas composition of exhaled air during physical load on treadmill, and fixed sport results in various kinds of physical exercise. The data underwent statistical processing with determination of the mean, standard deviation, standard error, correlation coefficient. The cadets of NDA are well trained (as shown by the main physical working capacity characteristic — maximal oxygen consumption in millilitres per kg of body mass per minute). Our data formed the data base of sport results and physical development, physical working capacity base of officers the National Defence Forces of Latvia. It can be used for staffing units with personnel and determining their individual fighting efficiency.

Key words: anthropometry, body constitution, cadets, Latvia, physical fitness.

INTRODUCTION

Re-establishment of the Republic of Latvia concerned all institutions, including military structures. The new conditions produced a new approach and higher demands to the training process of military specialists.

Under the new conditions the most effective way of perfecting the Defence Forces was to train cadets at the National Defence Academy of Latvia. Evaluation of physical fitness can help to reduce the expenses of the training process, to create new methodological and pedagogical methods to improve the quality of the teaching process. Determining the physical development and endurance level makes it possible to select capable, able persons for specific military units. The necessity of creating the database of physical characteristics of military personnel was dictated by practical requirements.

The theme of our study was to measure the physical development and fitness of the cadets of NDA, to characterise their physical endurance, to fix sport results in various standard physical exercises and in physical load on treadmill in laboratory circumstances, to evaluate the cadets' anthropometric characteristics, to analyse the correlations between body dimensions and physiological functional indicators.

There were no data about the military personnel of the present-day Latvian Army. We have found statistics about military personnel from 1920 [3, 4] and from 1935–1937 [9].

That information concerned military personnel before World War II. Our investigation filled deficiency of information concerning military personnel in 1998–1999. The body constitution characteristics and anthropometric data of military personnel of the USA have been examined by R. S. O'Neil and J. M. Henderson [18], F. J. Kragh and D. Taylor [16], C. K. Haddock *et al.* [12], S. J. Montain *et al.* [17], L. C. James *et al.* [14]. S. Dadelo [8] has examined the statistics about the future police officers in Lithuania. We found facts about young men's body constitution (students of Moscow and St. Petersburg) in the works of V. V. Bunak [19], A. G. Dembo [20] and V. V. Zobkov [21]. Relationships between functional indicators and body dimensions have been described by P. Astrand and K. Rodahl [2], E. Asmussen and K. Hubol-Nielsen [1], W. Dobeln [10], E. Buskirk and H. L. Taylor [6].

We determined the correlation between body constitution and physical functional indicators. We used anthropometric examination, experimental data (of laboratory standard physical load and sport results) and mathematical methods for assessment of the physical state of NDA cadets.

MATERIALS AND METHODS.

We examined healthy persons aged 19–24 years — cadets of the National Defence Academy of Latvia. The whole examined group included 26 persons. They had equal training, service and living conditions.

We used the following research methods:

1. anthropometric examination;
2. the experimental method;
3. the mathematical method.

The anthropometric examination included determination of the main anthropometric parameters (height, body mass, lung vital capacity). We measured height with a heightmeter, weight (body mass) with medical scales, lung vital capacity with a spirometer. We calculated the anthropometric indices according to A. V. Chogovadze [22].

1) weight-height index in g per cm

$$\frac{\text{body mass (g)}}{\text{Height (cm)}}$$

According to A. V. Chogovadze, the standard weight index for men is 385–410 g/cm.

2) vital index in ml per kg

$$\frac{\text{Vital lung capacity (ml)}}{\text{Body mass (kg)}}$$

The standard of vital index according to A. V. Chogovadze is 65–70 ml/kg.

3) relative body mass (%)

$$\frac{\text{Body mass (kg)}}{\text{Individual standard of body mass}}$$

The standard of body mass depends on height. When body height is less than 175 cm, the standard body mass is body height (cm) — 100; when body height is 175–185 cm, the standard body mass is body height (cm) — 105; when body height is over 185 cm, the standard body mass is body height (cm) — 110.

The experimental method included two parts:

1. We fixed sport results in various standard physical exercises:
   1) sprint (100 m);
   2) standing jump;
   3) grenade throwing;
   4) cross country race (3000 m);
   5) arm pumping exercise;
   6) sit-up test;
   7) pull-up to bar.
2. Each person underwent the standard physical load (running test on a horizontal treadmill) in laboratory circumstances. The initial speed on the horizontal treadmill was 2.25 m/s, then it was increased each minute by 0.15 m/s. The subject ran under the control of the experimenter till exhaustion. We used the gas analysis method and multichannel electrocardiographic control with Medgraphic cardiorespiratory diagnostic system cardiO2.

During the test we fixed the following physiological functional parameters:

1) heart rate (beats per min);
2) breathing rate per min;
3) lung ventilation (litres per min);
4) maximal oxygen consumption in ml per kg of body mass;
5) total oxygen consumption in litres per min;
6) O_2 pulse (oxygen pulse), i.e. the ratio between maximal oxygen consumption in ml per kg of body mass and heart rate per min;
7) respiratory coefficient, i.e. the ratio between exhaled carbonic gas in litres per min and consumed oxygen in litres per min.

The mathematical methods of data processing included calculation of the mean, standard deviation (SD), standard error (SE) and correlation coefficients. These were calculated between:

1) the weight-height index and total oxygen consumption in litres per min;

2) the weight-height index and maximal oxygen consumption in ml per min per kg of body mass in threshold zone;

3) weight-height index and maximal oxygen consumption in ml per min per kg of body mass under maximal load (exhaustion moment);

4) lung vital capacity and maximal oxygen consumption in ml per min per kg of body mass in anaerobic threshold zone and under maximal load;

5) weight-height index and running speed on treadmill in anaerobic threshold zone and under maximal load;

6) weight-height index and sprint result;

7) weight-height index and cross country race result;

8) weight-height index and the total of physical exercise results in points (score sum);

9) the vital index (ratio between lung vital capacity in ml and body mass in kg) and sprint result;

10) maximal oxygen consumption in ml per min per kg of body mass and sprint result;

11) maximal oxygen consumption in ml per kg of body mass and strength exercises in points (score sum).

RESULTS

We determined that the cadets' body mass was 76.1 ± 8.9 kg, their height was 182.2 ± 8.2 cm and vital lung capacity was 5.3 ± 0.8 litres (all data mean ± SD). The anthropometric indices characterising body constitution were the following:

- weight-height index: 416.9 ± 8.4 g per cm;
- vital index: 69.0±1.4 ml of air per kg of body mass;
- relative body mass: 103.8%.

The physiological functional characteristic of are were presented in Table 1.

Table 1. Physiological functional characteristics of cadets-officers in rest, anaerobic threshold and the maximal physical load of standard physical exercise on horizontal treadmill (mean ±SE)

Physiological functional parameters		In rest	In anaerobic threshold zone	In the maximal physical load
Heart rate (beat per min)		74.8 ±2.9	180.1±1.5	198.2±1.0
Blood pressure	systolic	124.0±1.9		191.7±3.8
Mm Hg Col	diastolic	77.3±1.7		27.6±5.4
Respiratory rate per min		17.0±0.4	31.2±1.6	40.9±1.5
Lung ventilation litre per min		15.1±0.5	79.2 ±2.3	122.4±3.2
Maximal oxygen consumption in ml per kg per min			39.50±0.63	46.99±0.71
Oxygen consumption in litre per min		0,39±0.02	3.02±0.04	3.45±0.08
Oxygen pulse in ml per min		4.50±0.19	16.85±0.28	18.39±0.36
Oxygen partial pressure in alveolar air in mm Hg Col		113.4±1.33	144.89±0.99	125.8±1.21
Exhaled carbonic gas in litre per min		0.37±0.52	2.75±0.07	3.86±0.09
Carbonic gas partial pressure in alveolar air in mm Hg Col		39.3±0.52	48.89±0.78	51.55±1.25
Respiratory coefficient			0.91±0.01	1.17±0.01
Running speed on treadmill in metre per second			3.38±0.05	4.42±0.05

The cadets' sports results (the mean values) were the following:

1. sprint (100 m) 13.06 s;
2. standing jump 2.47 m;
3. grenade throwing 48.2 m;
4. cross country race (3000 m) 11 min 55s;
5. arm pumping exercise (n) 43;
6. pull up to bar (n) 12.

DISCUSSION

The anthropometric parameters of Latvian military personnel had not been examined for more than 70 years. We found some data concerning military personnel in the papers of Backmann [3, 4] and Derums [9]. During the last seven decades anthropometric parameters have been influenced by acceleration. The body mass in 1920 were about 65 kg (mean values), in 1935 it was 67 kg, but in 1999 it had increased to 77.6 kg Height underwent the following modification: in 1920 a military person was about 171 cm tall, in 1935 their height was about 1.7 cm larger, and nowadays the mean value of height is 182.2 cm.

Some differences were found between anthropometric parameters in the Baltic region and on the American continent. According the data of O'Neil and Henderson [18] the mean height of a military person in the US Army was 69.5 in (176.0 cm) and body mass 162.4 LB (73.7 kg), which was lower than the respective data of the cadets of the National Defense Academy (NDA). The same facts concerning the military personnel of the US Army have been confirmed by Kragh and Taylor [16], Haddock *et al.* [12], James *et al.* [14] and Montain *et al.* [17]. We compared the data of British Army cadets [13] and cadets of NDA. There were no differences in anthropometric parameters between them, like there were no differences between the anthropometric characteristics of cadets of NDA and students of the Law Academy of Lithuania [8]. While comparing our data with the data of students of Moscow Technological Institute [21] and students of St. Petersburg Sport Education Academy [20], we found that cadets of NDA had higher anthropometric characteristics than students of Moscow and St. Petersburg.

By their height, 73% of cadets NDA belonged to the 174–190 cm interval. The body mass of 72% of cadets was between 67–85 kg. Evaluation of anthropometric characteristics revealed that the weight-height index indicated sturdy body constitution (hypersthenic body constitution); 20% of cadets had normosthenic body constitution. Cadets had high vital lung capacity (5.3 litres), and they also had a high level of the vital index, which is an indicator of well-developed chest and good potential capacity of respiratory organs.

Human body physical capacity depends on the state of cardiovascular and respiratory systems [11, 15]. The physical standard test on a horizontal treadmill activates the energy supply of the working muscle groups. We measured the following physiological functional parameters: lung ventilation, respiratory coefficient, heart rate, oxygen and carbon dioxide partial pressure in alveolar air. At the beginning of the physical load muscles receive aerobic energy supply, until physical load increases until a concrete point when muscle energy supply becomes aerobic combined with an anaerobic energy supply component. That interval of energy supply in muscle work (aerobic and anaerobic) is known as the anaerobic threshold zone. Under the maximum physical load (exhaustion moment) muscle work energy supply is anaerobic. The change in the mentioned parameters indicates the aerobic and anaerobic threshold zone where energy supply undergoes transition [2, 6, 7]. Working capacity is influenced by various factors, such as health status, self-confidence, psychophysiological and emotional status. The results for the subjects of the study are presented in Table 1.

The maximum oxygen consumption in millilitres per kilogram of body mass in minute was the most important characteristic of physical working capacity. For cadets that parameter was 46.9 ml per kg in min, which corresponds to the state of a well-trained person. According Kragh and Taylor [16] the maximum oxygen consumption in ml per kg in min for the US Army military personnel (rangers) was 53.0 ml per kg in min, but for Latvian footballers (unpublished data) it was 49.1 ml per kg in min. The parameter of maximal oxygen consumption in ml per kg of body mass in min is the basic parameter of physical endurance.

We revealed dependence between body constitution, sport results and physical working capacity by calculating the correlation coefficient (r). Cadets with a bigger weight-height index utilised more of oxygen in litres per minute in the anaerobic threshold zone ($r = 0.605$; calculus of probability 0.366; coefficient of authenticity 4.47) as well as under maximum physical load (exhaustion moment) ($r = 0.634$; calculus of probability 0.402). There were correlations of medium strength between maximum oxygen consumption in ml per kg of body mass in min and weight-height index in the anaerobic threshold zone ($r = 0.432$; coefficient of authenticity 2.74) and under maximum physical load ($r = 0.348$; coefficient of authenticity 1.74).

As analysis of cadets' sport results shows, cadets with sturdy body constitution were not slower runners. The correlation coefficient between the weight-height index and running speed on treadmill was weak (r = –0.298; coefficient of authenticity 1.46).

Correlation between vital lung capacity and maximum oxygen consumption in ml per kg of body mass in min was weak in the anaerobic threshold zone (r = –0.222; calculus of probability 0.049) as well as under maximum physical load (r = 0.123; calculus of probability 0.15).

There was no correlation between the weight-height index and sprint results (r = 0.169; calculus of probability 0.0027), and between the weight-height index and the total score sum of physical exercises (r = –0.323). The correlation between the weight-height index and cross-country race results had medium strength (r = 0.300; calculus of probability –0.09). There were no correlations between the vital index and sprint results (r = –0.152), between the vital index and cross country-race results (r = –0.046), between the vital index and the total score of physical exercises results (r = –0.105). Weak correlations were found between maximum oxygen consumption in ml per kg of body mass in min and sprint results (r = –0.095), between maximum oxygen consumption in ml per kg of body mass in min and the total score of strength exercises (r = –0.0197), and between maximal oxygen consumption in ml per kg of body mass in min and the total score of physical exercises (r = 0.0002). We found correlations of medium strength between maximum oxygen consumption in ml per kg of body mass in min and cross-country race results (r = 0.302; coefficient of authenticity 1.45). Running speed in laboratory conditions was not a predictor of good sprint results . However, we found a correlation of medium strength between running speed data in the anaerobic threshold zone and cross-country race results (r = –0.556; calculus of probability 0.309). Oxygen pulse correlated with cross-country race results both in the anaerobic threshold zone (r = –0.3005; calculus of probability 0.09) and under the maximum physical load (r = –0.343; calculus of probability 0.118).

Our study revealed that anthropometric methods, which determine the main anthropometric parameters (height, body mass, lung vital capacity) furnished information about physical development. That information was the most acceptable and important for military units.

The experimental method showed that measuring of physiological functional characteristics in laboratory circumstances was important for selecting the persons for specific military units. The most valuable parameter was the maximum oxygen consumption in ml per kg of body mass in min, which correlated with sport results in physical endurance exercises.

The experimental method revealed that the most informative physical exercise was cross-country race (3000 m). The results of cross-country race were an indicator of physical working capacity.

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TRENDS OF HUMAN LIFE SPAN EVOLUTION IN POPULATIONS WHO LIVED AROUND CABYLE

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ABSTRACT

The site of Cabyle attracts attention in studying the evolution of human life span, as it has been inhabited in Antiquity, Late Antiquity and the Middle Ages by populations of different origin. Data from three necropolises of Cabyle, dated in Late Antiquity (secondary graves in Roman mounds necropolis from the IV century and necropolis by the East Wall from the end of the IV–VI c.) and the Middle Ages (XI–XVI c.) have been analysed by methods of paleodemography. Demographic indices have been calculated for populations, which have left the three necropolises. Results show the best life expectancy in the population from the Middle Ages — the highest values for the first age groups and higher values for both sexes of adults. The situation in the population from Late Antiquity, documented from the necropolis by the East Wall, was demographically unfavourable. It was characterized by the highest infant mortality and, respectively, the lowest life expectancy for the first age groups. The population from this necropolis also had lower life expectancy for both sexes in comparison with the necropolis from the Middle Ages. The necropolis by the East Wall is characterized by lower life expectancy for men at the age of Adultus as compared to women of the same age. The structure of the population, which has left the necropolis on the mounds, is not properly represented in the anthropological material from the graves.

Key words: paleodemography, Late Antiquity, the Middle Ages, Cabyle

INTRODUCTION

The site of Cabyle attracts the attention in studying the evolution of human life span as it has been inhabited by populations of different origin in Antiquity, Late Antiquity and the Middle Ages. Mound necropolises from the Hellenistic Age, dated in the III–I c. BC [6] and from the Roman period, dated in the I–II c. AD [5], and necropolises from Late antiquity, one dated from the end of the IV to the beginning of the VII c. AD [10] and another in first half of the IV c. AD [5], and from the Middle Ages, the XI–XIV c. AD [4] have been excavated on the territory of the site. The anthropological material from the Hellenistic necropolis and the Roman mound necropolis does not allow paleodemographic study. This is due to insufficient preservation of bone material after a burial ritual with cremation and fragmentation of investigated parts of mound necropolises. The anthropological material from the two necropolises from Late Antiquity and the necropolis from the Middle Ages has been studied [2, 3, 10, 11] and allows a paleodemographic survey.

According to the archaeological data, the necropolis by the East Wall from the IV–VI c. AD is related to the local population from an Early Byzantine centre [10]. The necropolis of secondary graves with inhumation in the Roman mound necropolis belongs most probably to a barbaric, Gothic population [5]. The medieval necropolis belongs to a Bulgarian village from the Second Kingdom.

MATERIAL AND METHODS

The anthropological material found was divided into five-years age groups and by sexes. An average distribution for five-years age groups was estimated from the number of skeletons aged in the frames of basic anthropological age groups. The result was summed with the number of skeletons within five years age intervals. Demographic indices were estimated for every five-years age interval and for both sexes according to the method of paleodemography [1].

RESULTS AND DISCUSSION

The distribution of the anthropological material between both sexes shows significant differences among the studied necropolises. An extremely high number of infant skeletons has been found in the necropolis of the Late Antiquity population of the city. This is most probably caused by epidemic decease and poor conditions of hygiene and nutrition in the politically unstable period of Late Antiquity, when the native population of the Early Byzantine centre suffered from economic instability and invasions by barbarians. Infant mortality in the Late Antiquity necropolis on the Roman mound necropolis from the IV c. AD is too small to be considered as truthful. The lack of infant skeletons here is probably caused by careless treatment of infant dead by a probable Gothic population, which lived under war conditions. The relatively lower number of skeletons from the age group of Adultus and the higher number of skeletons in the age group Maturus with the presence of skeletons in the age of Senilis and a relatively sufficient number of infant skeletons, representative for infant mortality, point to the most favourable life conditions among the population from the village from the Second Bulgarian Kingdom (Fig. 1).

As it has been already mentioned, extremely high infant mortality can be observed in the necropolis of the Late Antiquity population of the Byzantine town (Fig. 1). The relative number of dead in the first age group in this necropolis (80%) is one of the highest for the investigated necropolises on the Bulgarian territory for all archaeological periods [7, 8]. In the second age group of this necropolis infant mortality reaches its normal limits of 10%. This could be caused by an epidemic infection, which had strongly affected infants from the first age group. Infant mortality around 30%, shown in the necropolis from the Middle Ages, points to the favourable living conditions of the community of the village from the XI–XIV c. AD. The very reduced relative number of skeletons in the first age group in the necropolis from the mounds of the IV c. AD, related to a Gothic population, cannot be considered as representative of infant mortality. Most probably this has been caused by the careless treatment of the dead in this age group and by bad preservation of their skeletons. Such a suggestion is supported by the high relative number of the dead in the next two infant age groups, where in the group of 10–14 years the highest relative

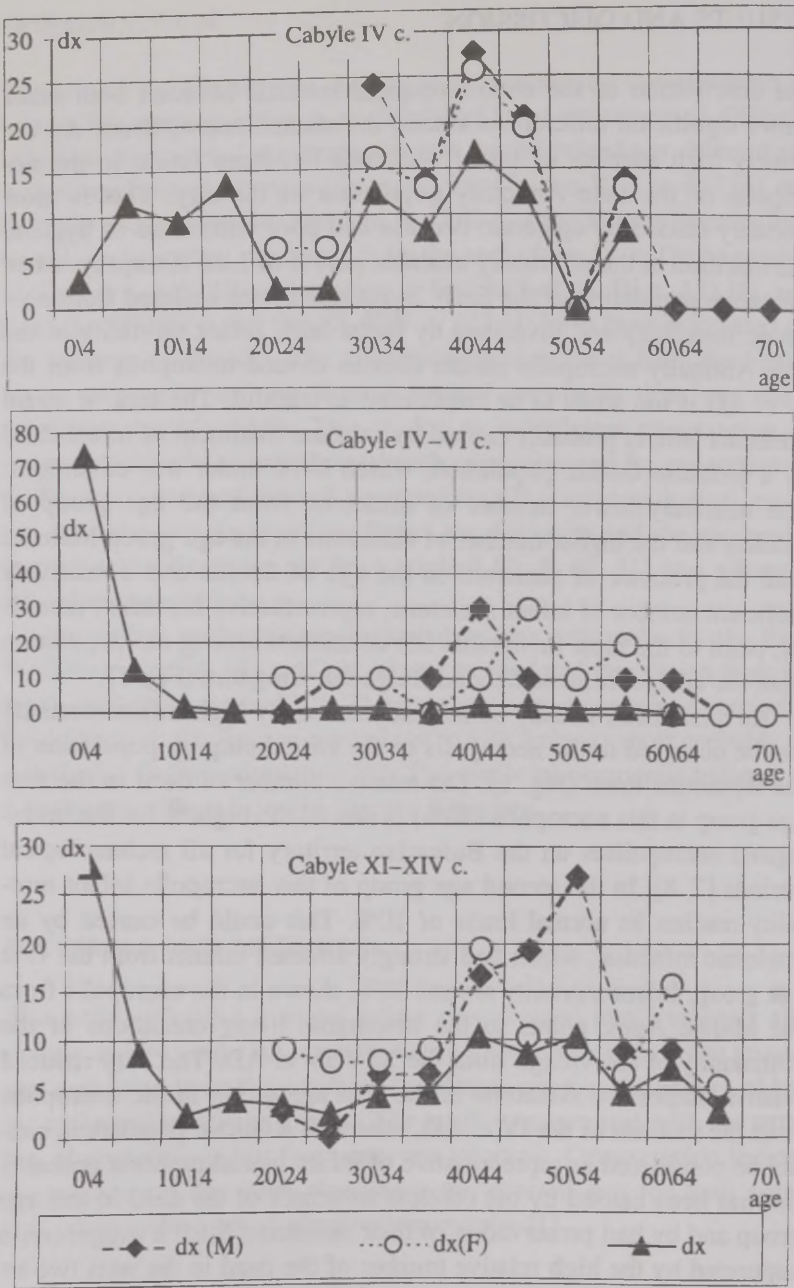

Figure 1. Relative number of dead.

number of the dead is observed. This results not only from the high absolute number of skeletons in this age group, but also from the very reduced number of skeletons in the previous age groups. Nevertheless, the high absolute and relative number of skeletons in the age groups of 10–14 and 15–19 years, in which mortality reaches its lowest values in the other anthropologically studied necropolises, point to the unfavourable living conditions of the population, which had left the necropolis. High infant mortality is a common feature for demographically primitive societies, which is compensated by a high birth rate [9].

In both Late Antiquity necropolises, the lack of young men's skeletons (Fig. 1) can be observed (20–24 years in the necropolis by the East Wall from the IV–VI c. AD and 20–30 in the necropolis on the Roman mounds from the IV c. AD). This could by due to war activity of the populations from the period. For adults of both sexes high values of the relative number of the dead can be observed in the necropolis on the Roman mounds from the IV c. AD. The conditions of the population from the Middle Ages — with stable, relatively low values for the relative number of the dead to the age of 40 years, where a rise of values of this coefficient begins and reaches its peak in a relatively higher age – seem to have been the most favourable. Nevertheless, relatively equal and high values of the relative number of the dead are observed in the data for females in all the three populations (Fig. 1). This feature is observed in all anthropologically investigated necropolises from prehistory to the end of the Middle Ages and is explained by many anthropologists by complications during pregnancy and childbirth [7].

The probability of death (Fig. 2) as well as the relative number of the dead show extremely high values for the age groups of 0–4 and 5–9 years in the material from the necropolis by the East Wall from the IV–VI c. AD. In both necropolises from Late Antiquity the increase of values for probability of death for adults is observed in earlier age groups. The material from the necropolis on the Roman mounds from the IV c. AD, with relatively equal values of this coefficient for both sexes, exhibits a specific situation. In the necropolis from the Middle Ages, the increment of values of probability of death begins at a higher age, and the values of this coefficient reach 1 for both sexes at the oldest age of 65–69 years.

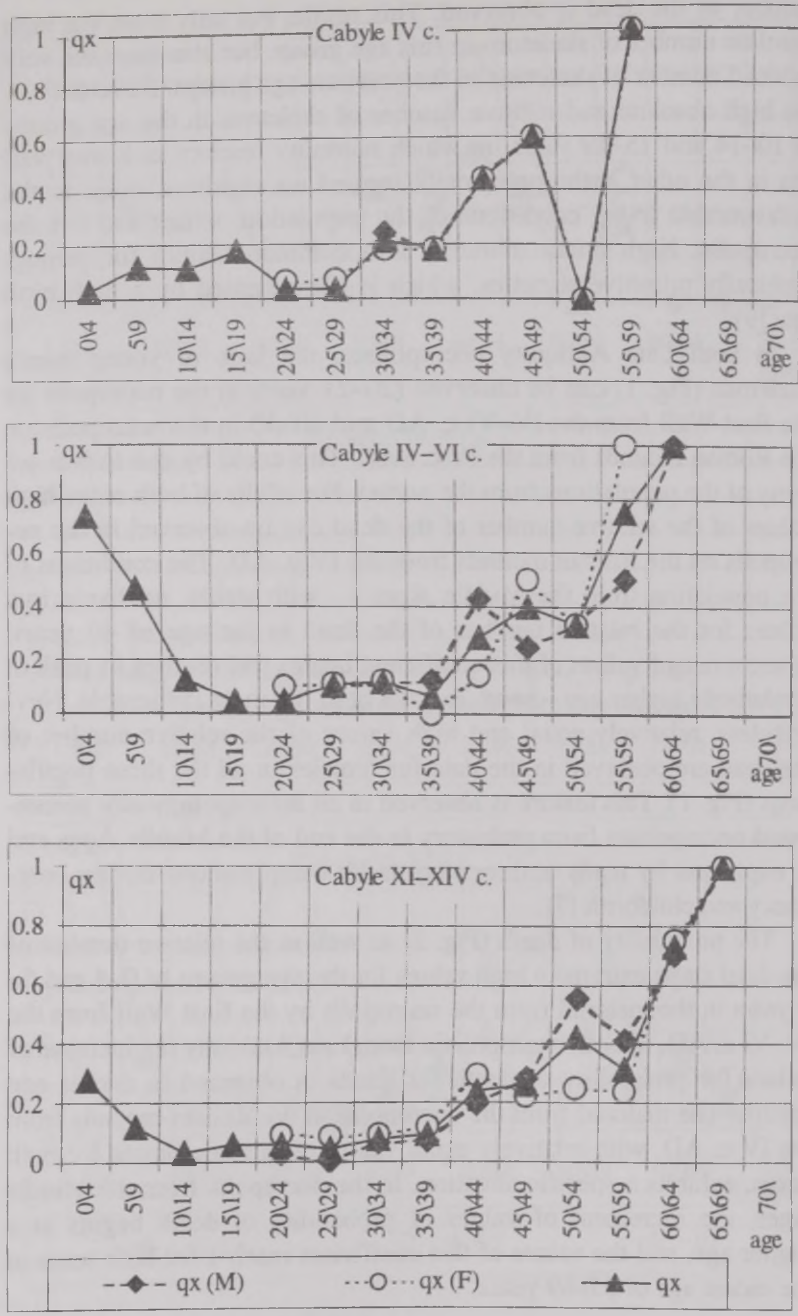

Figure 2. Probability of death.

According to the high values of the relative number of the dead and the probability of death for the first two age groups in the necropolis by the East Wall from the IV–VI c. AD, which define a picture of high infant mortality, the relative number of survived (Fig. 3) in these age groups is extremely low in this necropolis. The situation where nearly 100% of all the newborn survived, as shown in the material from the necropolis on the Roman mounds from the IV c. AD, is not real and is most probably caused by the discussed lack of material. The increase in the mortality of young women is also reflected in the lower values of the relative number of survivals among females in relation to males at younger age. In the populations from Cabyle from the IV c. AD and the IV–VI c. AD the relative number of survivals for males and females has close values in the age group of 40–44 years. In the population from Cabyle from the XI–XII c. AD this feature appears in the age group of 55–59 years. The material from this necropolis shows the biggest percentage of survivals at the age of Senilis — nearly 10% for the age group of 60–65 years and survived in age group of 65–69 years. In the other two necropolises the values of the relative number of survivals reach 0 in the age group of 60–64 years for the necropolis from the IV c. AD and in the group of 65–69 years in the necropolis from the IV–VI c. AD.

The values of average life expectancy (Fig. 4, Table 1) for all age groups and for both sexes express the tendencies discussed above. The high value of 32.8 years for the first age group in the necropolis from the IV c. AD is to be explained by the lack of material and can not be accepted as truthful. Different conditions of infant mortality, shown by the material from the necropolises from the IV–VI c. AD and XI–XIV c. AD lead to distinct differences in life expectancy for first age group. Extremely low life expectancy of 8.3 years was calculated for the first age group from the necropolis of the Early Byzantine town. On the contrary, in the material from the medieval necropolis, a relative high value for average life expectancy in the first age group (28.39 years) was estimated as compared to all anthropologically studied necropolises. The highest value of life expectancy was calculated for the age group of 5–9 years of the medieval population. In all other age groups, values of average life expectancy for this population are higher than in the two populations from Late Antiquity. The lowest values for this coefficient were calculated for the necropolis from

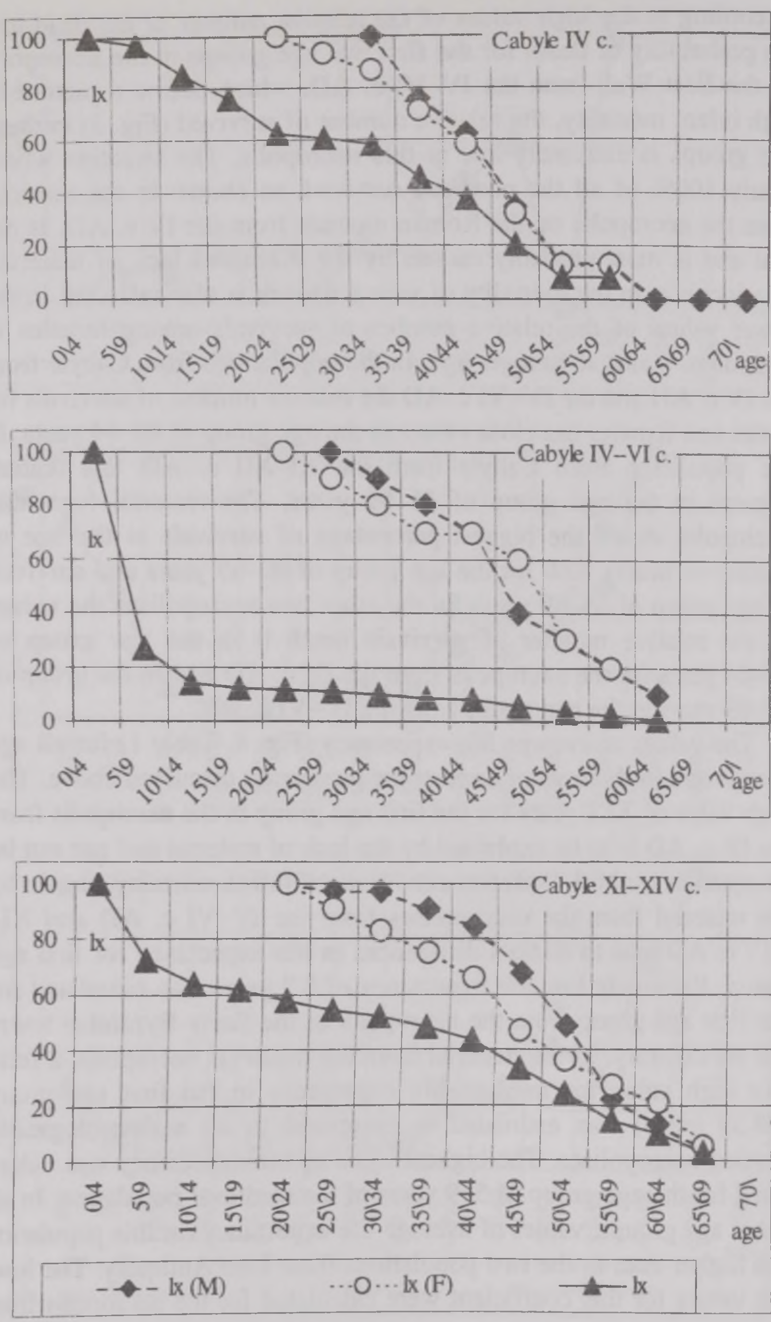

Figure 3. Relative number of survivals.

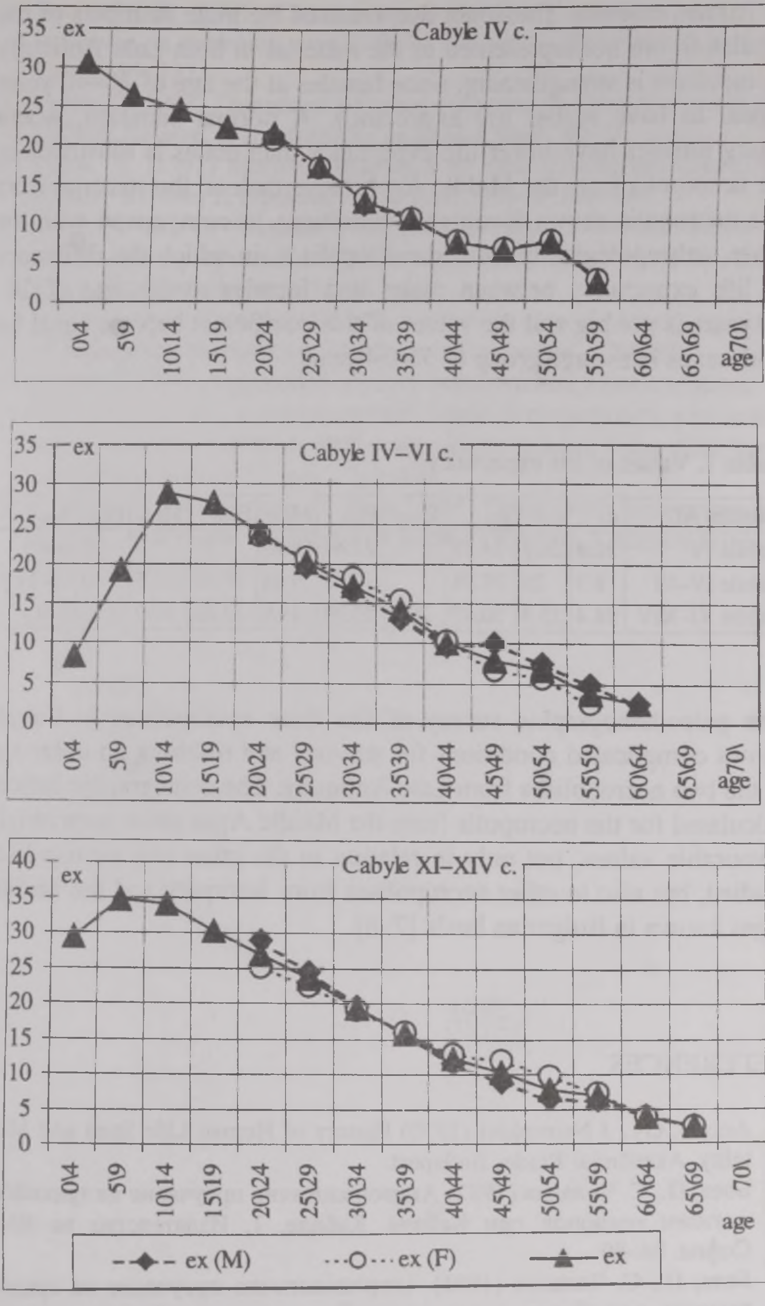

Figure 4. Life expectancy.

the Roman mounds. The doubt that some of the male members of the population are not represented in the material in both Late Antiquity necropolises is strengthening, since females at the age of 20–40 years appear to have higher life expectancy. A normal situation, where young females have lower life expectancy than males is illustrated in the necropolis from the Middle Ages. Nevertheless, the material from this necropolis shows favourable conditions in comparison with the other anthropologically studied necropolises, in which the difference in life expectancy between males and females at the age of 20–29 years is not big and the values of this coefficient become equal for both sexes in the age group of 30–34 years.

Table 1. Values of life expectancy

Century AD	e_0	e_{10}	e_{15}	Me_{20}	Fe_{20}	Me_{40}	Fe_{40}	Me_{60}	Fe_{60}	e_{max}
Cabile IV	32.8	26.7	24.27		21.44	8.45	7.75	0	0	0–4 y.
Cabile IV–VI	8.3	29	27.74		23.5	9.64	10.36	2.5	0	10–14 y.
Cabile XI–XIV	28.4	33.9	30.47	28.8	25.39	11.9	12.82	4.17	3.13	5–9 y.

The paleodemographic survey of the three necropolises in Cabyle shows complicated conditions for survival and reaching an older age in the two necropolises from Late Antiquity. The demographic indices calculated for the necropolis from the Middle Ages show surprisingly favourable values, not only in relation to the other two necropolises studied, but also to other necropolises from Antiquity and the Middle Ages known in Bulgarian lands [7, 8].

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INFLUENCE OF ANTHROPOMETRIC PARAMETERS ON MOTOR ABILITY TEST RESULTS IN 13–15 YEAR-OLD-GIRLS

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ABSTRACT

The aim of the study was to examine the relationships between anthropometry and motor ability test results in 13–15-year old girls (n = 80). In total, nine skinfolds, 13 girths, eight lengths and eight breadth/lengths were measured. The following EUROFIT tests were used: 20 m endurance shuttle-run, handgrip, standing broad jump, flexed arm hang, sit-ups, 10×5 m shuttle run, plate tapping, sit-and-reach, Flamingo balance. It was concluded that the influence of anthropometric parameters on the motor ability level in 13–15-year old girls is not high — about 10–20% of the total variance.

Key words: anthropometry, motor ability, adolescent girls

INTRODUCTION

The first information about the influence of anthropometric parameters on the different motor ability test results was published more than 20 years ago by Malina [5], Bouckaert *et al.* [1] and Slaughter *et al.* [11]. Physical education teachers have frequently noted that the motor abilities in children with small stature in tests which need speed and strength are lower than in children with normal or high body stature. In contrast, the results of the tests which need endurance are relatively low in children who are very tall and have relatively high body mass [2, 9, 10].

There is little information about the influence of body stature and body mass, and especially the influence of different skinfold, girth, length and breadth/length parameters separately on the different motor abilities in children. In our laboratory, we have studied the relationships between the anthropometric profile of 10–12-year old boys (n = 70) and girls (n = 69) measured according to the protocol recommended by the International Society for Advancement of Kinanthropometry [7] and EUROFIT [3] tests results [4]. In total, nine skinfolds, 13 girths, eight lengths and eight breadth/lengths were measured. The influence of anthropometric parameters on motor abilities in prepubertal children was found to be moderate [4]. However, there is lack of data about the relationships between anthropometry and motor abilities in postpubertal girls.

The aim of the present study was to examine the relationships between anthropometry and motor ability test results in 13–15-year-old girls.

SUBJECTS AND METHODS

The subjects of the study were 80 girls aged 13–15 years (13.3±0.6 yrs, 155.3±8.0 cm, 45.2±7.5 kg). The girls were from the small town of Vändra (Estonia), and all of them were ethnic Estonians. Their physical education at school consisted of two physical education classes per week. All the 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. Measurements were performed at school in the morning after emptying the bladder. All the children had a light traditional breakfast. The girls did not exercise before testing.

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 anthropometrical parameters were measured according to the protocol recommended by the International Society for Advancement of Kinanthropometry [7]. In total, nine skinfolds (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, medial calf, midaxilla), 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, iliospinale-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 callipers.

The following EUROFIT tests were used after a short (about 10 min) standardized warm-up (light running, jumping, and stretching exercises): 20 m endurance shuttle-run, handgrip strength, standing broad jump, flexed arm hang, sit-ups, 10×5 m shuttle-run, plate tapping, sit-and-reach, Flamingo balance). All children were familiar with the testing equipment. All the tests were performed in the mornings during the compulsory physical education classes.

Descriptive statistics (mean ± standard deviation [SD]) for each of the dependent variables were determined. Multiple linear regression analysis was used for presenting the influence of the skinfolds, girths, length and breadths/length on different EUROFIT tests results. An alpha level of 0.05 was used.

RESULTS

The mean anthropometric characteristics are presented in Table 1 and the mean EUROFIT tests results in Table 2. Table 3 presents multiple linear regression analysis results, where independent variables denote different EUROFIT tests results and dependent variables all skinfold, girth, length or breadth/length parameters. Our results indicate that the skinfold thicknesses were highly correlated with the results of all the used EUROFIT tests. Bent arm hang results depended on skinfolds within 22.31% of the total variance. The skinfold thicknesses' influence was relatively weak on handgrip strength (8.60%) and Flamingo

Table 1. Anthropometric characteristics of 13–15-year-old girls (n = 80)

	$\overline{X}$ ±SD	Minimum	Maximum
Skinfolds (mm)			
Triceps	11.2±2.4	4	20
Subscapular	8.9±2.1	4	13
Biceps	9.4±2.6	5	17
Iliac crest	8.9±2.0	4	12
Supraspinale	9.3±2.4	5	18
Abdominal	11.5±3.1	6	25
Front thigh	16.5±4.4	8	30
Medial calf	12.9±2.7	6	23
Mid-axilla	8.6±1.8	5	17
Sum of skinfolds	97.0±15.5	61	135
Girths (cm)			
Head	53.4±1.0	50.5	56.2
Neck	28.0±1.3	21.5	30.8
Arm (relaxed)	21.7±1.6	17.3	24.9
Arm (flexed and tensed)	23.2±1.5	18.7	26.4
Forearm	21.2±1.1	17.8	23.7
Wrist	14.8±1.1	12.2	17.6
Chest	72.3±5.1	60.6	84.5
Waist	61.1±3.9	52.5	69.6
Gluteal	73.5±7.2	60.1	91.4
Thigh (1 cm gluteal)	46.7±3.2	38.5	53.5
Thigh (mid tro-tib-lat)	44.2±3.1	37.7	49.8
Calf	31.3±2.7	22.8	35.5
Ankle	21.1±1.3	17.4	24.8
Lengths (cm)			
Acromiale radiale	29.2±2.6	20.3	33.6
Radiale-stylion	22.8±1.7	19.7	28.6
Midstylion- dactylion	15.6±0.8	13.4	17.8
Iliospinale b. ht	47.5±3.8	40.2	54.8
Trochanterion b. ht	39.8±4.2	27.7	48.5
Trochanterion-tibiale laterale	32.8±2.1	29.4	38.3
Tibiale laterale to floor	45.5±2.9	39.4	54.0
Tibiale mediale-sphy. tibiale	32.6±1.9	28.8	36.4

	$\overline{X} \pm SD$	Minimum	Maximum
Breadths/ lengths (cm)			
Biacromial	32.9±2.1	28.1	38.8
Biiliocristal	24.2±2.0	20.6	28.4
Foot lengths	23.2±0.8	21.5	25.8
Sitting height	75.8±3.7	68.4	85.8
Transverse chest	23.5±1.9	20.1	28.4
A-P chest depth	13.8±1.5	10.4	17.4
Humerus	6.1±0.4	5.3	7.1
Femur	8.1±0.5	7.1	9.3

Table 2. Eurofit tests results in 13–15 year-old girls (n = 80)

	$\overline{X} \pm SD$	Minimum	Maximum
20 m shuttle run (min)	6.7±0.9	4	10
Handgrip strength (kg)	14.7±2.4	10	20
Standing broad jump (cm)	154.8±12.9	120	182
Bent arm hang (s)	64.2±141.7	10	612
Sit-ups (x)	20.4±2.9	10	27
10 x 5 m shuttle-run (s)	19.0±1.5	16.4	24.8
Plate tapping (s)	11.8±1.1	9.7	14.3
Sit-and-reach (cm)	25.3±4.3	18	36
Flamingo balance (mistakes)	7.5±2.0	4	13

Table 3. Multiple linear regression analysis results where independent variables are Eurofit tests results and dependent variables skinfolds, girths, lengths, and breadths/lengths parameters ($R^2 \times 100$)

	Skinfolds	Girths	Lengths	Breadths/lengths
20 m shuttle-run	R^2=17.60 p<0.0000	R^2=19.36 p<0.3065	R^2=16.10 p<0.0373	R^2=10.55 p<0.6896
Handgrip strength	R^2=8.60 p<0.0000	R^2=3.82 p<0.1096	R^2=8.87 p<0.2460	R^2=6.22 p<0.3797
Standing broad jump	R^2=14.25 p<0.0000	R^2=24.10 p<0.0172	R^2=17.51 p<0.0000	R^2=21.49 p<0.0209
Bent arm hang	R^2=22.31 p<0.0070	R^2=31.77 p<0.0527	R^2=13.09 p<0.0759	R^2=15.78 p<0.3705
Sit-ups	R^2=10.16 p<0.0000	R^2=7.89 p<0.1987	R^2=14.81 p<0.0009	R^2=3.68 p<0.4281
10 × 5m shuttle-run	R^2=12.87 p<0.0000	R^2=21.83 p<0.0083	R^2=19.88 p<0.0000	R^2=19.85 p<0.0000
Plate tapping	R^2=15.99 p<0.0000	R^2=23.48 p<0.0583	R^2=9.01 p<0.0000	R^2=15.48 p<0.0194
Sit-and-reach	R^2=13.09 p<0.0000	R^2=17.39 p<0.0401	R^2=8.55 p<0.0120	R^2=14.23 p<0.9813
Flamingo balance	R^2=9.79 p<0.0163	R^2=16.91 p<0.1637	R^2=17.69 p<0.1968	R^2=6.59 p<0.0736

balance (9.79%). The girth parameters were highly dependent on the results of the bent arm hang (31.77%) and standing board jump (24.10%). The girth parameters did not influence the results of the handgrip (3.82%) and sit-ups (7.89%) tests. The 10×5m shuttle-run tests were relatively highly dependent on the length parameters (19.88%). The influence of the length parameters was the weakest on the sit-and-reach test results (8.55%). From the breadth/length parameters, the influence was strongest on the standing broad jump results (21.49%) and lowest on the sit-ups test results (3.68%).

DISCUSSION

Our results indicate that the influence of anthropometric parameters on motor ability tests results is relatively weak. As a rule, anthropometric parameters characterized 10–20% of the total variance. One of the explanations of this relatively weak influence is that none of the studied girls was overweight.

In our previous results in 10–12-year-old girls [4], the influence of skinfold thicknesses was relatively strong on the results of handgrip, sit-ups and Flamingo balance tests (20.63–23.78%). Surprisingly, in this study, these tests characterized only about 10% of the total variance (see Table 3). Probably the different results could be explained by differences between the two studies at the maturation level. It is well known that in females body fat mass increases during childhood and continues to increase through adolescence [6]. Pizzamano *et al.* [8] have also indicated that aerobic and anaerobic parameters in adolescents are highly dependent on the anthropometric parameters.

There is not sufficient information available about the influence of girth, length and breadth/length parameters on motor abilities in adolescent girls. Our previous studies [4] of 10–12-year-old girls indicate that there are several differences in these parameters as compared with the 13–15-year-old adolescents of the present study.

It was concluded that the influence of anthropometric parameters on the motor ability level in 13–15-year-old girls is not high — about 10–20% of the total variance.

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CONSTRUCTING GROWTH REFERENCE CURVES

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ABSTRACT

The paper presents an approach to constructing centile curves. The procedure used for normal distributions of a given variable consisted of stepwise smoothing of mean values, standard deviations and "empirical derivative" by the moving average technique. In the case of non-normal distributions, the values of the given variable, corresponding to standard centiles, were read from normal distribution graphs and then subjected to a series of smoothings. Two graphs were presented as examples: body height and handgrip of Polish boys. The presented method is universally applicable, since it does not depend on the type of distribution. By applying serial, overlapping classifications of data, the numbers of points may be increased even several times, which greatly improves data processing.

Key words: centile grids, age-dependent curves

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INTRODUCTION

Designing realistic norms for growth processes has long been a challenge to researchers in many fields. Graphs representing age-related changes in body height and mass are of special interest, since they permit monitoring the course of growth of individual children, detecting possible anomalies in development, etc. The construction of such norms requires the sample to be representative of the population in question, either local (of, e.g., a given urban agglomeration) or nation-wide. In every case, however, the population cannot be considered homogenous with respect to body proportions, due to the existence of diverse somatotypes (see e.g. [2]), various environmental conditions, etc. Thus, the distributions of variables usually deviate from the normal one. This precludes, in most cases, the use of simple statistical measures, i.e. the means and standard deviations, as it would lead to oversimplification and, in effect, distortion of the computed model with respect to real data.

The early attempts at drawing reference curves by eye have been replaced by comprehensive computer-aided computational techniques involving, e.g., polynomials to fit the segments of the growth curve [3]. The most advanced procedures were presented recently by Cole [1], who recommends constructing internationally valid reference curves.

The aim of this study was to design simple procedures for constructing centile scales and curves for normally or non-normally distributed variables, without employing highly sophisticated curve fitting, yet closely reflecting empirical data. As examples of those two kinds of variables, the body height and handgrip values recorded in boys were presented.

MATERIAL AND METHODS

The data presented here were recorded in a cohort of nearly 40,000 boys aged 7–20 years, randomly selected from the general Polish population, and contained in an Excel file. Details concerning sampling, measurement procedures, etc., have been published elsewhere [4]. From that cohort, 2000 boys were selected by applying a random number generator. The data from that sample were arranged by calendar age in order to prepare frequency distributions. Age classes were overlapping in the following way:

7.01–8.00 years, 7.51–8.50 years, 8.01–9.00 years, 8.51–9.50 years, etc. This procedure doubled the number of class distribution curves or means as compared with a single, non-overlapping classification. For the two variables selected for presentation here — body height and handgrip — frequency distributions were obtained for and handgrip — frequency distributions were obtained for every age class, and graphs were prepared using normal (probit) paper.

Standard centile curves were prepared, i.e. for 3, 10, 25, 50, 75, 90 and 97% of the population.

A case of normal distribution (body height)

Percent frequencies for every age class were plotted against mid-class body height on normal paper. The distributions proved reasonably normal, as shown for most classes (Fig. 1). This justified the use of means and standard deviations for every age class (Table 1), which served later to compute standard centile values.

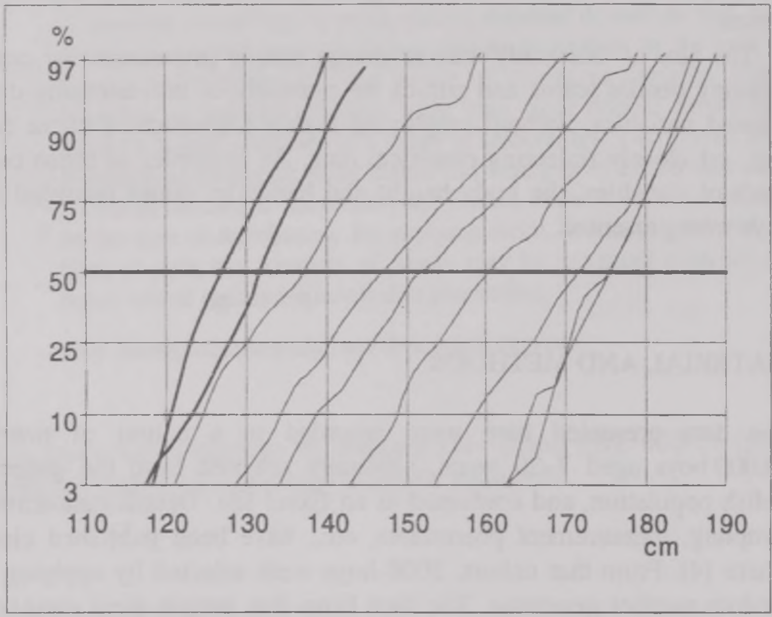

Figure 1. Normal distribution graphs for body height in several age classes.

When plotted against age, neither mean heights nor standard deviations produced smooth enough curves. The following smoothing procedure was employed:

Table 1. Means, standard deviations (SD) and corrected values of body height computed for overlapping age classes of boys (n = 2000)

Age	n	Mean	SD	M	S	d	D	M+D
7.0	–	128.20	7.52	128.13	7.41	2.2	2.13	128.08
7.5	128	130.10	8.06	130.26	7.93	2.13	2.16	130.29
8.0	193	132.52	8.06	132.46	8.25	2.20	2.17	132.42
8.5	182	134.89	8.77	134.62	8.74	2.16	2.18	134.64
9.0	156	136.31	9.14	136.71	9.29	2.09	2.22	136.84
9.5	162	138.89	9.92	139.11	9.91	2.40	2.36	139.07
10.0	177	141.77	10.88	141.65	10.34	2.54	2.48	141.59
10.5	178	144.43	10.58	144.26	10.43	2.59	2.58	144.22
11.0	171	146.42	9.71	146.79	10.40	2.53	2.64	146.89
11.5	178	149.56	10.84	149.57	10.79	2.78	2.78	149.57
12.0	180	152.49	11.40	152.49	11.17	2.92	2.94	152.52
12.5	190	155.23	11.70	155.64	11.37	3.15	3.12	155.62
13.0	207	158.97	11.30	159.01	11.19	3.37	3.21	158.85
13.5	193	163.00	10.63	162.29	10.85	3.28	3.13	162.13
14.0	175	165.22	10.60	165.12	10.55	2.83	2.89	165.19
14.5	185	167.32	10.50	167.71	10.16	2.59	2.64	167.76
15.0	190	170.73	9.53	170.22	9.50	2.51	2.36	170.07
15.5	171	172.90	8.77	172.27	8.74	2.05	2.00	172.21
16.0	125	173.60	7.74	173.72	7.95	1.45	1.59	173.86
16.5	100	175.17	7.25	174.96	7.33	1.24	1.29	175.01
17.0	116	175.96	6.90	175.96	6.90	1.00	1.07	176.03
17.5	125	176.90	6.25	176.95	6.63	0.99	0.93	176.90
18.0	115	178.08	6.65	177.77	6.71	0.82	0.74	177.69
18.5	99	178.63	6.94	178.28	6.87	0.51	0.51	178.28
19.0	75	178.35	7.17	178.45	7.07	0.17	0.30	178.58
19.5	57	178.53	7.07	178.54	7.16	0.10	0.20	178.65
20.0	–	178.67	7.33	178.88	7.34	0.34	0.12	178.66

Legend: M — Means, smoothed by moving average; S — Standard deviations smoothed by moving average; d — Differences between consecutive M means; D — Smoothed d values; M+D — “Reconstituted” M means

Mean body heights were smoothed by the conventional 5-point moving average M values). Next, the differences between the consecutive smoothed means were computed (d; "raw numerical derivative") and smoothed by moving average (D values). From these smoothed differences, corrected means were obtained by consecutive additions, starting from the first smoothed mean (M+D). All these values are shown in Table 1. Raw and smoothed differences are shown in Fig. 2.

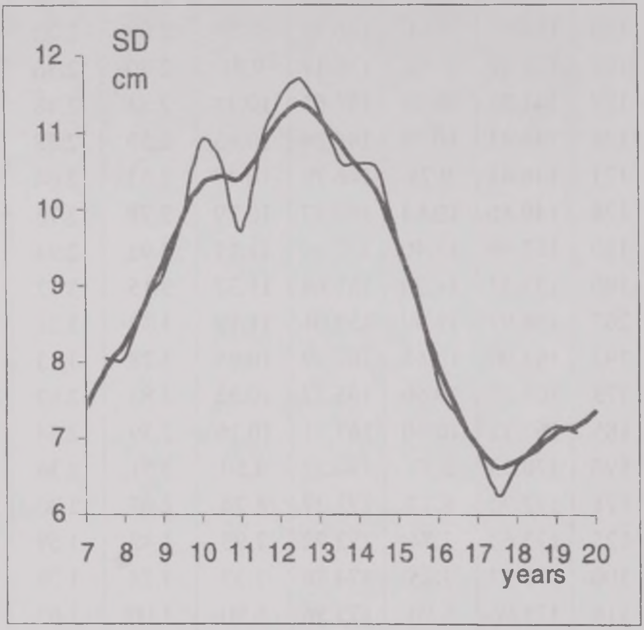

Figure 2. Raw and smoothed standard deviations for body height in all age classes.

Standard deviations were processed twice by moving average (SD1 and SD2), which produced a sufficiently smooth curve (Fig. 3).

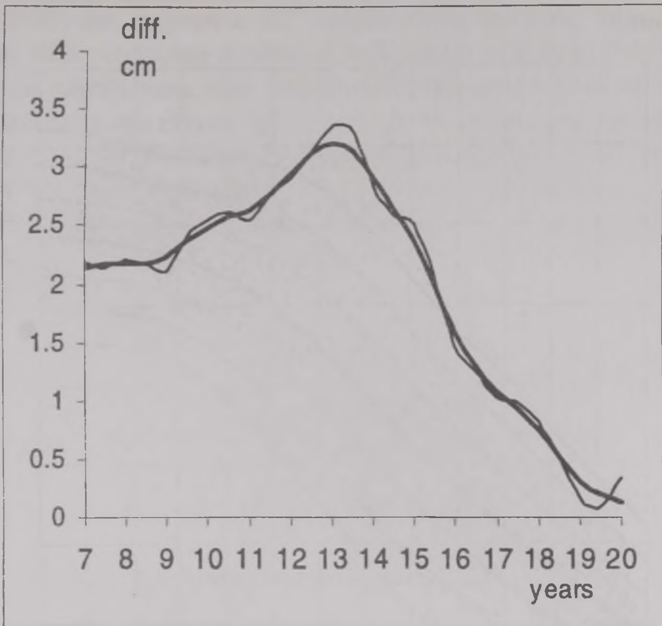

Figure 3. Raw and smoothed differences in mean body heights between consecutive age classes ("raw numerical derivative").

Finally, to the recomputed means (M+D) the smoothed standard deviations, multiplied by appropriate *t* values (t×SD2), were added and plotted against mid-class age values The resulting centile graph is shown in Fig. 4.

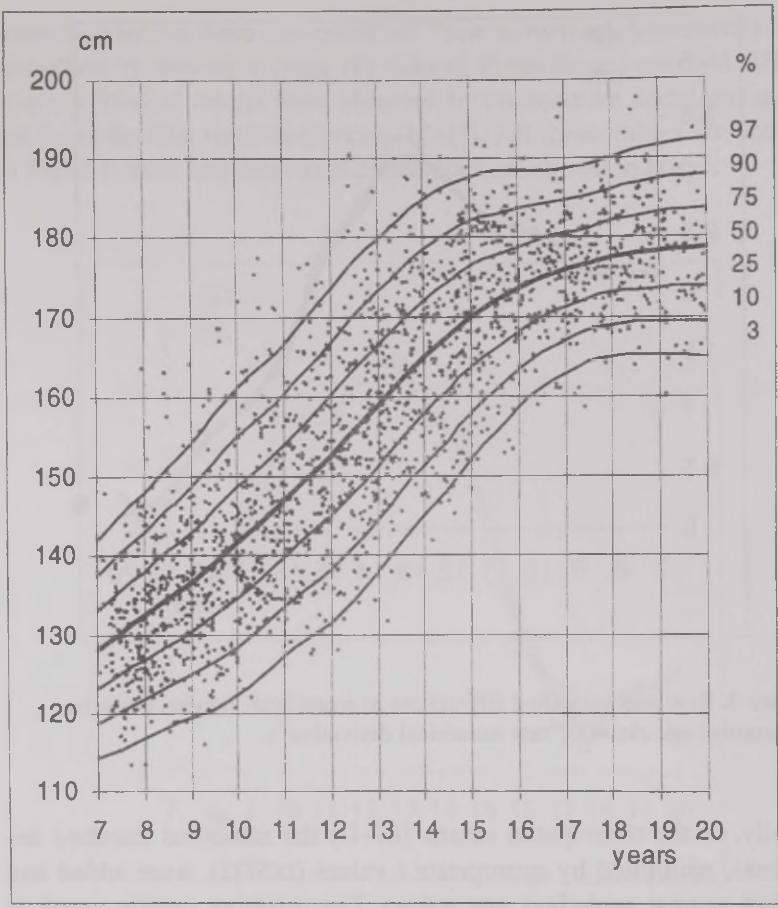

Figure 4. Centile grid for body height of Polish girls with individual values shown. A random sample (n = 2000) from a national cohort of 36,000 subjects.

A case of non-normal distribution (handgrip)

Distributions of handgrip values in various age classes (Fig. 5) show distinct non-normalities; therefore, centile curves cannot be computed from the means and standard deviations. Instead, argument values (in this case — kg) were read from the curve plotted on normal paper (this can be easily done in Excel, as shown in these graphs) for every age class separately. From all 7 values (for centiles 3, 10, 25, 50, 75, 90 and 97) the respective 50^{th} centile value (median, M) was subtracted, thus producing a table of differences (Table 2). Differences for given centile were then smoothed (in this case twice) by moving average across age classes (Fig. 6). Next, M values were smoothed by moving average. The sums of smoothed M's and respective smoothed differences produced the centile curves (Fig. 7). In order to verify the goodness of fit, individual points were plotted in the centile graph.

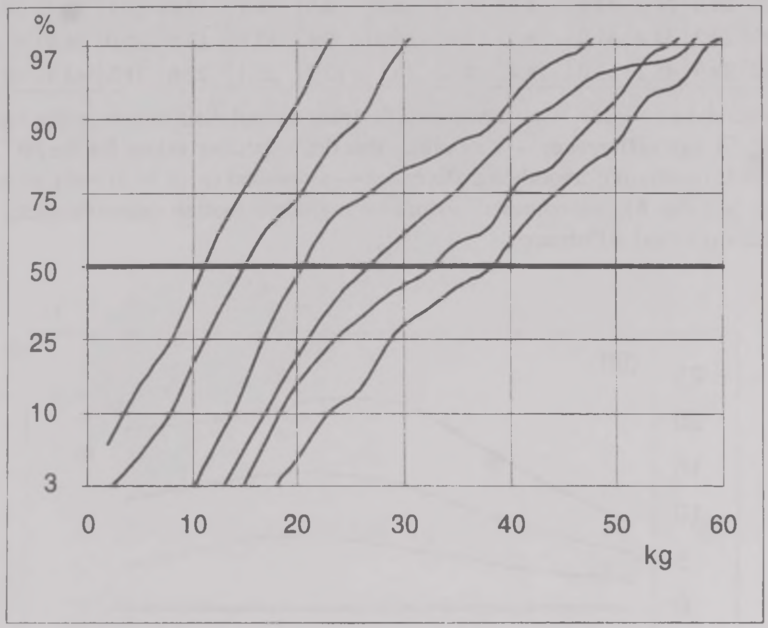

Figure 5. Normal distribution graphs for handgrip values in several age classes.

Table 2. Handgrip values (kg) read from normal distribution graphs plotted for age classes 10.5, 12.5 and 13.5 years, and the respective corrected values

	Raw values			Raw differences			Smoothed differences			"Recombined" values		
%	10.5	12.5	13.5	10.5	12.5	13.5	10.5	12.5	13.5	10.5	12.5	13.5
3	2.6	11.0	13.1	−12.9	−9.6	−13.8	−10.5	−12.5	−14.3	5.1	9.8	12.8
10	7.7	13.4	16.5	−7.8	−7.2	−10.4	−7.4	−9.2	−10.7	8.2	13.1	16.4
25	11.3	16.1	20.9	−4.2	−4.5	−6.0	−3.9	−5.4	−6.3	11.7	16.8	20.8
50	15.5	20.6	26.9	0	0	0	0	0	0	**15.6**	**22.3**	**27.1**
75	20.0	26.9	33.8	4.5	6.3	6.9	4.5	6.1	7.0	20.1	28.4	34.1
90	24.2	34.4	41.9	8.7	13.8	15.0	9.4	12.6	13.9	25.0	34.9	41.0
97	29.9	45.2	53.0	14.4	24.6	26.1	15.9	21.1	22.6	31.5	43.4	49.7

Legend: raw values — obtained directly from normal distribution graphs (see Fig. 5); raw differences — raw values less the respective values for the 50th centile (medians); smoothed differences — smoothed twice by moving average (see Fig. 6); "recombined" values — smoothed median values (bolded) plus smoothed differences

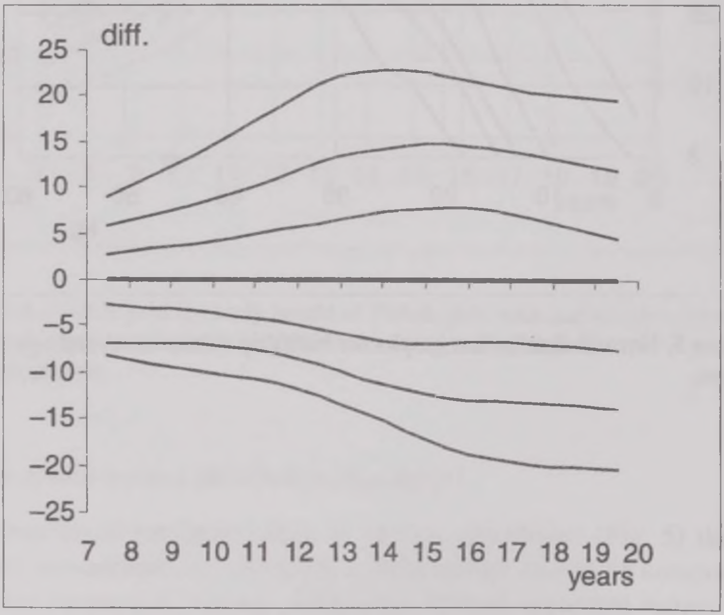

Figure 6. Smoothed differences between the mean and given centile values for body height in all age classes.

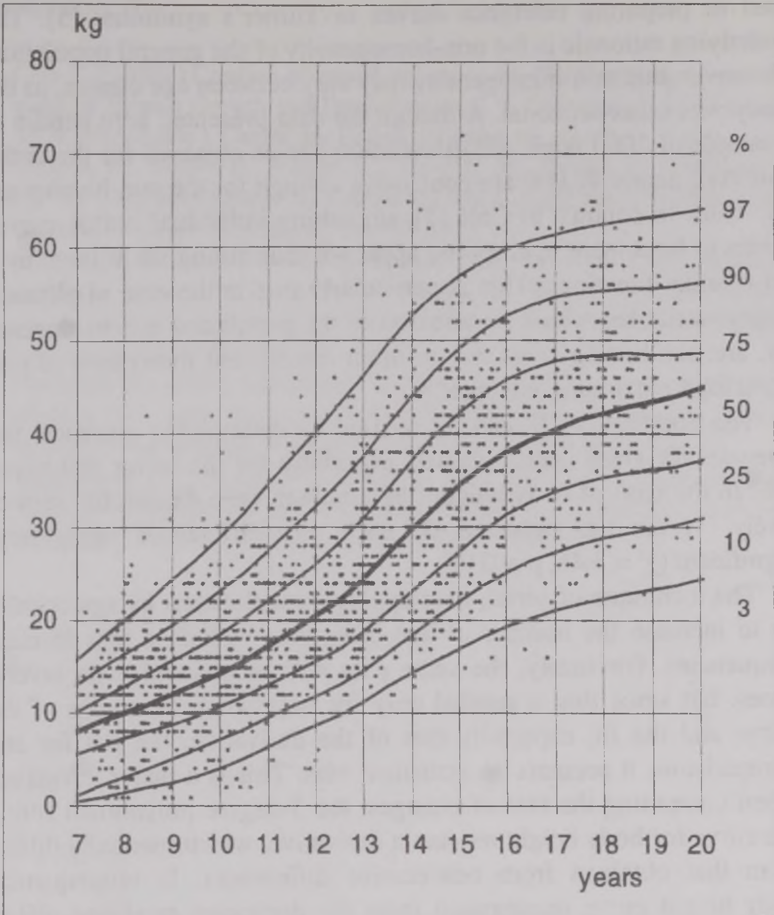

Figure 7. Centile grid for handgrip values of Polish girls with individual values shown. A random sample (n = 2000) from a national cohort of 36,000 subjects.

DISCUSSION

The approach presented here, consisting of empirical data smoothing without necessarily fitting them by analytical functions, seems to be reasonable enough to produce meaningful reference curves. It was used in preparing reference curves in Turner's syndrome [5]. The underlying rationale is the non-homogeneity of the general population. Moreover, that non-homogeneity may vary between age classes, as the study was cross-sectional. Although the data presented here pertain to a sample of 2000 boys, the distribution curves obtained for the entire cohort of nearly 40,000 are conclusive enough for the non-homogeneity. Thus, in contrast to Cole [1], smoothing individual centile curves seems to be a more appropriate approach than fitting all of them by a set of alike functions. This is particularly true in the case of physical fitness variables, which, in addition to the population non-homogeneity, are non-homogenous due to often insufficient motivation to perform for a maximum outcome.

The goodness of fit can be verified by determining empirical frequencies for given centile values, especially for the lower and upper 3%. In the case of body height, the numbers were 48 and 68, respectively, versus the expected 60 each, the differences being non-significant ($\chi^2 = 3.46$, $p > 0.05$).

The technique of serial, overlapping classifications by age enables us to increase the number of age categories without a loss in class frequencies. Obviously, the same data will be counted even several times, but since this is needed only for improving the course of the curve and the fit, especially that of the derivative, but not for any comparisons, it presents no statistical bias. This is a major advantage when computing the rate of changes: the 5-degree polynomial fitting the curve for body height renders a derivative, which markedly differs from that obtained from consecutive differences. In consequence, body height curve recomputed from the derivative produced differences exceeding 3 cm in relation to the original median (50th centile) curve. The condition, that the original (smoothed) M-curve and that reconstituted from the derivative be identical, is thus an obvious prerequisite.

In conclusion, the presented technique makes it possible to create reference curves without taking into account the type of distribution

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INDEX OF ANAEROBIC ENDURANCE IN REPEATED MAXIMAL EXERCISE BOUTS

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ABSTRACT

The aim of the study was to design an index of anaerobic endurance determined by a series of maximal exercise bouts or by a single exercise in which a given variable (e.g. power output) is continuously recorded, as, e.g., in the Wingate test. The index is a ratio of the mean value of that variable to the maximum recorded, thus representing the "efficiency" of the process studied. That index was found to be uncorrelated with the maximum value.

Key words: maximal exercise, repeated exercise bouts, anaerobic endurance

The study was supported by Project DS40 (grant from the State Committee for Scientific Research)

INTRODUCTION

Control of the training process, in a broad sense, is one of the key issues in contemporary sport. Obviously, the efficacy of training depends on the compatibility of its structure with the demands of sport competition with respect to the training media as well as to the mode of the performed exercise.

A wide range of exercise tests can be found in literature. Such tests permit an accurate assessment of loads applied, in relation to internal and external structures of tests. In order to assess physical endurance by physiological criteria, the following tests are in common use:

- Laboratory exercise tests for determining the anaerobic or aerobic fractions of the energetic potential, e.g. Margaria-Kalaman test, Wingate test, Åstrand-Rhyming test for determining ‡O_2max, the PWC_{170} test, graded exercise tests for determining the anaerobic threshold (PPA), etc.,
- Field tests, e.g. by Conconi or Cooper.

Those, as well as many other tests, applied for assessment of fitness or technical skills in various sports, are usually based on performing a single exercise. This is appropriate in many instances, but when the competition consists of many spurts or bouts of exercise, other solutions are to be sought.

A different approach has been presented by some other authors [2, 4], who applied a series of exercises separated by incomplete resting intermissions, like in interval training.

The aim of this study was to design an index enabling the assessment of tests consisting of repeated bouts of maximal exercise, or of a single exercise with a continuous recording of the variable in question, irrespective of the practical value of such test.

MATERIAL AND METHODS

As examples characterising the anaerobic potential, the following exercises were analysed:

- A set of 6 exercise bouts of supramaximal intensity, consisting of executing 16 pedal revolutions on a Monark 824E cycle ergometer (Sweden) coupled on-line to a desk computer and using a locally designed software [3]. Exercise bouts were spaced by intermissions lasting 15 s each [2].
- A set of 6 shuttle runs (2 × 25 m) spaced by intermissions lasting 15 s each.

The tests were performed by physical education students, in the morning, and were preceded by a warm-up lasting 15 min. In order to illustrate the index, measurements of maximum power output (P_m) and time to attain P_m, recorded in 10 randomly selected students, were used. The applied loads amounted to 0.075 kp/kg (0.736 N/kg) of body mass. Cycle ergometer tests were conducted according to the conventional Wingate test protocol [1].

In order to keep a decreasing trend in consecutive bouts of exercise, the measures of time (s) were expressed as velocities, i.e. reciprocal values were used (1/s).

DESIGNING THE ANAEROBIC ENDURANCE INDEX (AE)

If fatigue did not develop, all bouts of the exercise would be executed at the same, maximum level. Thus, the sum of those maximum values (in this instance — six) represents the subject's potential. Because of developing of fatigue, however, the actual sum of values will be smaller, and the ratio of that actual sum to the potential one is the anaerobic endurance index. This is, of course, equivalent to the ratio of the mean value of the (six) bouts of exercise to the maximum recorded value.

Those values, marked as "Mean" and "Max" respectively, are presented, $AE = \frac{Mean}{Max}$ together with all recorded measurements, in Tables 1–3. In order to visualise the changes in consecutive exercises, the data are also presented in Figs. 1–3.

For example, the highest power output in Subject 1 was recorded in Bout 1 and amounted to 10.87 W/kg, and the mean of his 6 values of power output amounted to 9.80 W/kg. Thus, the AE is equal to 9.80 / 10.87 = 0.901.

Table 1. Maximum power outputs (W/kg) attained by 10 students in 6 supramaximal, cycle ergometer exercise bouts (16 revolution test) spaced by 15 s intermissions

Subject No.	1	2	3	4	5	6	Mean	Max	AE
1	**10.87**	10.66	10.06	9.59	8.50	8.11	9.80	10.87	0.886
2	**9.38**	8.55	7.36	6.41	5.58	5.22	7.42	9.38	0.755
3	**9.76**	9.19	8.24	7.22	6.98	6.66	8.51	9.76	0.821
4	**10.15**	9.08	8.12	7.60	7.05	7.06	8.18	10.15	0.806
5	**9.05**	8.67	7.64	6.33	5.63	5.25	7.09	9.05	0.784
6	**10.31**	9.54	8.83	7.78	7.32	7.21	8.50	10.31	0.824
7	**9.66**	9.22	8.84	8.24	7.80	7.37	8.52	9.66	0.882
8	**9.08**	8.46	8.20	7.54	6.98	6.26	7.75	9.08	0.854
9	**9.07**	8.52	7.96	7.26	6.82	6.84	7.75	9.07	0.854
10	**8.93**	8.79	8.25	7.95	7.83	7.66	8.23	8.93	0.922

Table 2. Velocities (1/s) of attaining maximum power output (W/kg) recorded for 10 students in 6 supramaximal, cycle ergometer exercise bouts (16 revolution test) spaced by 15 s intermissions (1/s)

Subject No.	1	2	3	4	5	6	Mean	Max	AE
1	0.210	0.215	0.239	0.245	0.220	**0.264**	0.232	0.264	0.880
2	0.169	**0.274**	0.197	0.237	0.206	0.205	0.215	0.274	0.783
3	0.154	0.165	0.178	0.208	**0.266**	0.253	0.204	0.266	0.767
4	0.211	0.236	0.250	0.303	0.246	**0.264**	0.251	0.264	0.830
5	0.139	0.221	**0.277**	0.172	0.201	0.160	0.195	0.277	0.704
6	0.160	0.173	0.183	0.209	0.212	**0.228**	0.194	0.228	0.852
7	0.151	0.202	**0.221**	0.186	0.202	0.208	0.195	0.221	0.882
8	0.122	0.125	0.201	0.234	**0.244**	0.244	0.195	0.244	0.799
9	0.147	**0.186**	0.186	0.176	0.184	0.163	0.173	0.186	0.933
10	**0.177**	0.172	0.163	0.126	0.167	0.127	0.155	0.177	0.878

Table 3. Velocities (1/s) attained by 10 students in 6 2×25 m runs spaced by 15 s intermissions

Subject No.	1	2	3	4	5	6	Mean	Max	AE
1	**0.122**	0.117	0.111	0.109	0.103	0.105	0.111	0.122	0.911
2	**0.115**	0.109	0.104	0.100	0.098	0.097	0.104	0.115	0.901
3	**0.116**	0.108	0.107	0.102	0.102	0.101	0.106	0.116	0.915
4	**0.113**	0.109	0.104	0.100	0.100	0.099	0.104	0.113	0.922
5	**0.115**	0.113	0.106	0.103	0.098	0.094	0.105	0.115	0.912
6	**0.119**	0.114	0.107	0.101	0.100	0.099	0.107	0.119	0.898
7	**0.107**	0.103	0.099	0.095	0.093	0.091	0.098	0.107	0.916
8	**0.114**	0.107	0.110	0.102	0.103	0.096	0.105	0.114	0.923
9	**0.112**	0.109	0.104	0.101	0.101	0.097	0.104	0.112	0.926
10	0.108	**0.109**	0.104	0.103	0.106	0.105	0.106	0.109	0.971

Legend to tables:
Highest value (Max) recorded for given subject was bolded
AE = Mean / Max

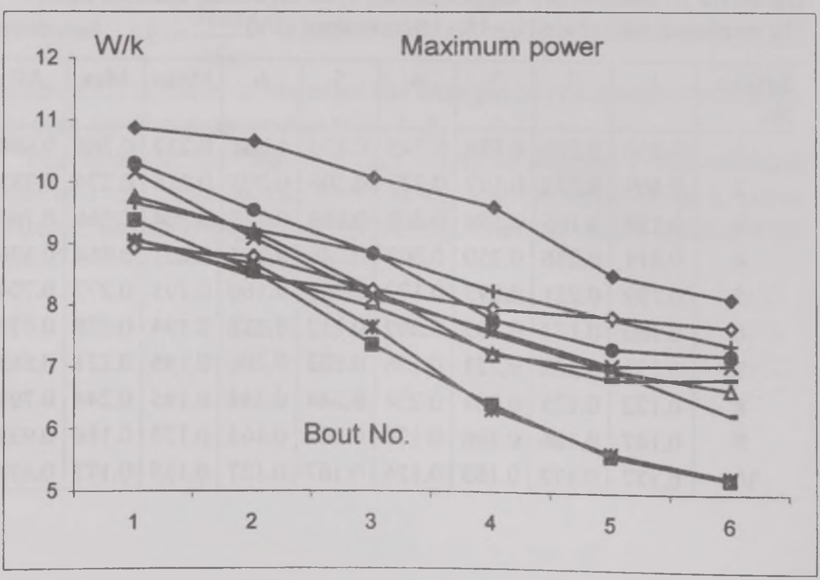

Figure 1. Maximum power output (W/kg) attained by 10 students in 6 cycle ergometer supramaximal exercise bouts ("16 revolutions test") spaced by 15 s intervals.

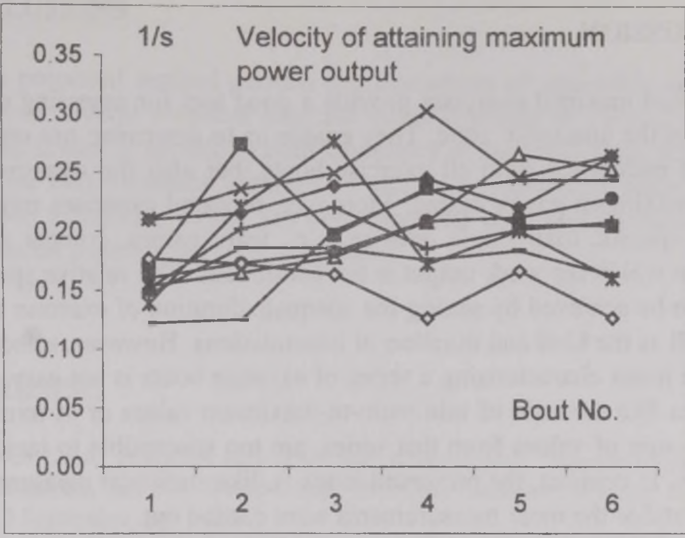

Figure 2. Velocity (1/s) of attaining maximum power output attained by 10 students in 6 cycle ergometer supramaximal exercise bouts ("16 revolutions test") spaced by 15 s intervals.

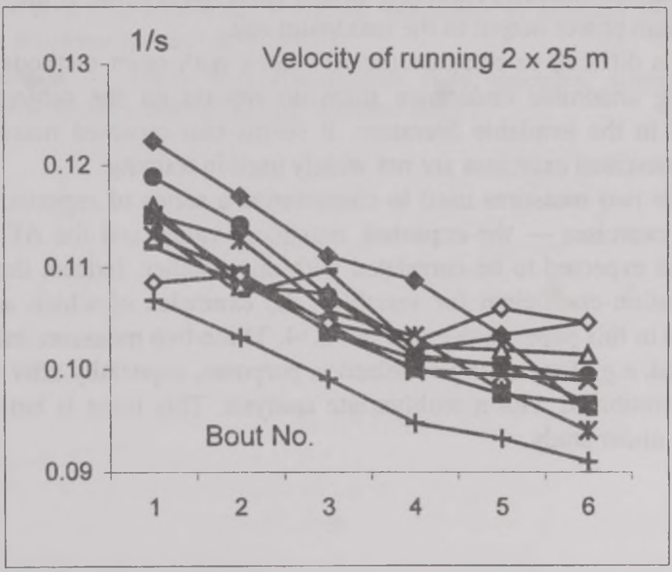

Figure 3. Velocity (1/s) of running attained by 10 students in six 2 × 25 m runs spaced by 15 s intervals.

DISCUSSION

Repeated maximal exercises provide a good tool for assessing endurance in the anaerobic zone. They enable us to determine not only the global endurance from all exercise bouts, but also the dynamics of, e.g., maximum power output. Moreover, repeated exercises might be more specific than single ones in, e.g., team games, combat sports, etc., in which the work output is not continuous. The relative specificity can be achieved by setting the adequate duration of exercise bouts, as well as the kind and duration of intermissions. However, selecting a single index characterising a series of exercise bouts is not easy, since indices like the ratio of minimum-to-maximum values or of minimum to the sum of values from that series, are too susceptible to incidental values. In contrast, the presented index is, like statistical measures, the more stable the more measurements were carried out.

As follows from the definition of AE, it measures the ratio of actual performance to the expected one, the latter being represented by the maximum value recorded in the series of exertions. The same is true for an isolated exercise, like Wingate test, in which power output is being continuously recorded. In this case, AE is equal to the ratio of the mean power output to the maximum one.

It is difficult to compare the AE index with other methods of assessing anaerobic endurance since no reports on the subject were found in the available literature. It seems that repeated maximal or supramaximal exercises are not widely used in training.

The two measures used to characterise a series of repeated maximum exercises — the expected, maximum value, and the AE index, are not expected to be correlated with one another. Indeed, the mean correlation coefficient for variables, the examples of which are presented in this paper, was equal to –0.14. These two measures may thus be used, e.g., for ranking or selection purposes, especially after having been combined with a multivariate analysis. This issue is being currently under study.

CONCLUSIONS

1. The proposed method permits the assessment of anaerobic endurance from several identical exercise bouts repeated at steady, short intervals. It can be applied to both laboratory or non-laboratory tests.

2. The two measures obtained in this way: maximum value and anaerobic endurance index, are not correlated with one another and may thus be used for selection purposes.

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BLOOD PRESSURE READINGS, SOME DETERMINANTS OF BLOOD PRESSURE AND REGIONAL DIFFERENCES IN THE PREVALENCE OF HYPERTENSION IN SCHOOLCHILDREN IN ESTONIA

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ABSTRACT

Review of literature suggests that the precursors of elevated blood pressure (BP) appear in childhood. To the authors' knowledge, no large national studies on blood pressure level and regional differences in hypertension among children have been published in Estonia.

The objectives of the study were: 1) to assess mean systolic (SBP) and diastolic blood pressure (DBP) in 10–15-year-old children (4^{th}, 6^{th} and 9^{th} grade); 2) to find the determinants of systolic and diastolic blood pressure; 3) to compare the prevalence of hypertension in different regions of Estonia.

33,047 schoolchildren aged 10–15 years underwent screening during the 1998/99 school year. Blood pressure was measured in 23,047 children (69.7% of the screened children). Boys comprised 48.2% and girls 51.8% of the children.

The data collected at routine school health check-up included age, sex, blood pressure, height and weight. Body mass index was calculated. Systolic and diastolic blood pressure were recorded as the first and the fifth Korotkoff phases, respectively.

Statistical analysis was performed using SPSS for Windows 8.0.

Mean systolic and diastolic blood pressure increased with the age and all data remained within 95% CI, except DBP in 9^{th} grade girls. These data did not differ from those presented in literature. The main determinants of blood pressure in schoolchildren were body weight and height; body mass index was less important. The study revealed large regional differences in the rate of systolic hypertenison (0–18.2118.2%), diastolic hypertenison (0–13.6%) and in increase of

18.2%), diastolic hypertenison (0–13.6%) and in increase of both blood pressures (0–7.5%). In some regions the data exceeded those published in literature. Analysing blood pressure data, we reached the conclusion that it was necessary to use automated test devices for screening, and mercury sphygmomanometers should be used for clinical measurements of blood pressure, especially in children and adolescents with high blood pressure.

Key words: schoolchildren, blood pressure, rise factors in schoolchildren

INTRODUCTION

Review of the literature on adolescents suggests that the precursors of elevated blood pressure (BP) appear in childhood. Screening and hypertension treatment guidelines, however, have been based mainly on findings for middle-aged population [1]. Hypertension is an underrecognised clinical entity in children, and studies are needed to define the mechanisms and magnitude of cardiovascular risk [2] The fact that most teenagers with persistent elevated blood pressure have essential hypertension is still a great concern, because for most of these adolescents hypertension will be liflong and, if left untreated, can be associated with significant morbidity and mortality in the adult years [3]. Measurements of ambulatory blood pressure as an adjunct to casual/clinic blood pressure measurements are currently widely used for the diagnosis of hypertension [4]. To the authors' knowledge, no large national studies of blood pressure level and regional differences in hypertension among children have been published in Estonia. In 1988-1996 the monitoring of main noncommunicable disease risk factors, among others hypertension, was carried out in 15-year-old adolescents within the WHO CINDI Children's Program [5]. In these years the increasing rate of all risk factors was established. The prevalence of high systolic blood pressure (SBP) increased from 3% to 6% and of diastolic blood pressure (DBP) — from 7% to 10% [6]. The incorporation of blood pressure measurement into the routine pediatric examination of 10–15-year-old schoolchildren (4^{th}, 6^{th} and 9^{th} grades) and central analysis of these data began all over Estonia from 1997 to 1999, according to *Guideline for identification of noncommunicable risk factors in schoolchildren* [7].

MATERIAL AND METHODS

The objectives of the study were: 1) to assess mean SBP and DBP in 10–15-year-old children (4^{th}, 6^{th} and 9^{th} grades); 2) to find the determinants of SPB and DBP; 3) to compare the prevalence of hypertension in different regions of Estonia.

The subjects of the study were 33,047 schoolchildren aged 10–15 years, who underwent screening during the 1998/99 school year (from September 1998 to May 1999) .The number of children in each grade was as follows: 4^{th} grade — 11,095; 6^{th} grade — 11,048 persons and 9^{th} grade — 10,904 persons. Blood pressure was measured in 23,047 children (69.7% of the screened children). Boys comprised 48.2% and girls 51.8% of the children.

The data collected during the routine health check-up included age, sex, blood pressure, height and weight. Anthropometric measurements included height, which was measured to ± 0.1 cm, and weight, to ± 0.1 kg. Body mass index (BMI) was calculated (weight in kilograms divided by square of height in meters). A single blood pressure measurement was obtained on the subjects' right arm in relaxed, sitting position by the school doctor using a standard mercury sphygmomanometer, an aneroid sphygmomanometer or automated devices with proper cuff size [7]. SBP and DBP were recorded as the first and the fifth Korotkoff phases, respectively.

All statistical analysis was performed using SPSS for Windows 8.0. The mean data of blood pressure, standard deviation and 95% CI for mean were calculated. Hypertension rates were calculated by categories of SBP or DBP, following the classification of the WHO CINDI Children Program Protocol [5]: optimal (SBP in 10–12 years < 125 mm Hg, 13–15 years <135 mm Hg and DBP in 10–12 years < 75 mm Hg, 13–15 years < 80 mm Hg); hypertension (SBP in 10–12 years = 125 mm Hg, 13–15 years = 135 mm Hg and DBP in 10–12 years = 75 mm Hg and in 13–15 years = 80 mm Hg). Correlation analysis was performed to establish significant relationships ($p<0.05$) between systolic and diastolic blood pressure and age, body weight and height .

RESULTS

For the whole population, the mean age of children in the 4th grade was 10 ± 1 years, in the 6th grade 12 ± 1, and in the 9th grade 15 ± 1 years.

The findings for the mean SPB and DBP are shown in Table 1.

Table 1. Mean systolic and diastolic blood pressure by age and sex and 95% CI

Variable / grade/sex	mean	95% CI
Systolic blood pressure		
4th grade: boys	103.0	102.65–103.44
girls	102.5	102.14–102.93
6th grade: boys	108.2	107.79–108.63
girls	108.6	108.20–109.01
9th grade: boys	117.3	116.87–117.81
girls	113.6	113.17–114.01
Diastolic blood pressure		
4th grade: boys	60.5	60.16–60.80
girls	60.8	60.41–61.27
6th grade: boys	63.6	63.30–63.92
girls	63.9	63.61–64.20
9th grade: boys	68.3	67.71–68.94
girls	67.5	67.90–68.00

Mean blood pressure readings increased with age in both sexes. All mean blood pressure data remained within 95% confidence interval, except the data of 9th grade girls. No significant gender differences were found in mean SBP and DBP.

To find some determinants of blood pressure, the interrelationships between SBP and DBP, age, body height, weight and body mass index were analysed, and the results are shown in Table 2.

Table 2. Correlation coefficients between age, body weight, height, body mass index and blood pressure

Variables	Age	Weight	Height	BMI	SBP	DBP
Age	1.00 p= .	0.72 p=.000	0.79 p=.000	0.41 p=.000	0.38 p=.000	0.23 p=.000
Weight	0.72 p=.000	1.000 p=.	0.85 p=.000	0.83 p=.000	0.48 p=.000	0.28 p=.000
Height	0.79 p=.000	0.85 p=.000	1.000 p=.	0.42 p=.000	0.44 p=.000	0.26 p=.000
BMI	0.41 p=.000	0.83 p=.000	0.42 p=.000	1.000 p=.	0.36 p=.000	0.21 p=.000
SBP	0.38 p=.000	0.48 p=.000	0.44 p=.000	0.36 p=.000	1.000 p=.	0.46 p=.000
DBP	0.24 p=.000	0.28 p=.000	0.26 p=.000	0.21 p=.000	0.46 p=.000	1.000 p=.

BMI — body mass index; SBP — systolic blood pressure; DBP — diastolic blood pressure.

All the variables have significant positive correlation. SBP correlated significantly with body weight and height, and less with age and body mass index. DBP correlated significantly with body weight and height. Thus, the main determinants of SBP and DBP were body weight and height. The influence of age and body mass index on blood pressure was less pronounced.

The rate of prevalence of hypertension in different regions by age and sex is shown in Table 3.

Table 3. The rate of prevalence of systolic hypertension in different regions by age and sex

Region	4th grade	6th grade	9th grade	Boys	Girls
Whole Estonia	2.5%	6.7%	5.9%	5.6%	4.4%
Tallinn	2.5%	7.5%	4.7%	5.5%	4.3%
Tartu	2.9%	4.1%	4.1%	3.1%	4.3%
Harju	0.6%	4.9%	8.0%	6.5%	2.5%
Hiiu	5.0%	10.6%	14.1%	9.6%	12.4%
Ida-Viru	2.5%	2.3%	1.9%	2.2%	2.2%

Region	4th grade	6th grade	9th grade	Boys	Girls
Jõgeva	0%	0%	0%	0%	0%
Järva	0.8%	4.2%	4.3%	2.5%	3.5%
Lääne	0%	7.5%	7.3%	7.3%	4.3%
Lääne-Viru	2.5%	2.1%	5.7%	3.5%	3.1%
Pärnu	1.1%	6.5%	7.7%	5.3%	4.9%
Põlva	1.7%	4.1%	6.3%	5.2%	2.6%
Rapla	0%	5.7%	7.8%	6.4%	2.6%
Valga	0%	9.7%	3.4%	3.5%	4.0%
Viljandi	2.6%	9.8%	6.1%	7.2%	5.0%
Võru	8.8%	12.9%	13.6%	18.2%	4.9%

Table 3 shows that most students had optimal blood pressure, but 0-18.2% of them had systolic hypertension. The prevalence of systolic hypertension in different regions of Estonia differed by up to 8%. In most regions boys had elevated blood pressure more often than girls.

Table 4. The rate of prevalence of diastolic hypertension in different regions by age and sex

Region	4th grade	6th grade	9th grade	Boys	Girls
Whole Estonia	4.8%	9.2%	5.9%	6.6%	6.8%
Tallinn	6.7%	7.5%	4.7%	5.5%	4.3%
Tartu	1.8%	5.5%	2.9%	3.4%	3.5%
Harju	0.6%	1.1%	0%	0.8%	0.4%
Hiiu	5.0%	17.0%	10.6%	9.6%	12.4%
Ida-Viru	6.1%	6.6%	4.1%	5.4%	5.5%
Jõgeva	0%	0%	0%	0%	0%
Järva	0.8%	8.4%	3.3%	3.1%	5.3%
Lääne	1.7%	8.6%	2.4%	6.3%	3.6%
Lääne-Viru	3.8%	7.6%	3.2%	4.4%	5.4%
Pärnu	3.9%	8.3%	5.6%	5.2%	6.9%
Põlva	2.9%	8.6%	4.2%	4.2%	6.4%
Rapla	2.7%	10.2%	3.5%	4.1%	7.0%
Saare	2.8%	11.1%	5.1%	5.1%	7.3%
Valga	2.7%	13.6%	1.7%	4.0%	5.8%
Viljandi	4.3%	7.9%	4.6%	5.6%	5.6%
Võru	8.8%	11.8%	13.6%	12.6%	10.4%

Diastolic hypertension occurred in 0-13.6% of children. Regional differences in the rate of diastolic hypertension were smaller than in systolic hypertension, and in only four counties diastolic hypertension was more frequent in boys than in girls.

The prevalence of both systolic and diastolic hypertension in different regions by age and sex shown in Table 5.

Table 5. Prevalence of systolic and diastolic hypertension in regions by age and sex

Region	4th grade	6th grade	9th grade	Boys	Girls
Whole Estonia	1.0%	2.7%	1.7%	1.8%	1.8%
Tallinn	1.1%	3.6%	1.9%	2.4%	2.1%
Tartu	1.1%	1.4%	1.2%	1.0%	1.4%
Harju	0.6%	1.1%	0%	0.8%	0.4%
Hiiu	2.5%	2.1%	5.9%	1.2%	6.7%
Ida-Viru	1.4%	1.1%	0.9%	1.2%	1.0%
Jõgeva	0%	0%	0%	0%	0%
Järva	0%	0.8%	1.1%	0%	1.2%
Lääne	0%	2.2%	1.2%	1.0%	1.4%
Lääne-Viru	1.8%	0.6%	0.7%	0.8%	1.3%
Pärnu	0.4%	2.9%	2.3%	1.7%	2.1%
Põlva	0%	2.0%	1.3%	1.3%	0.9%
Rapla	0%	2.5%	0%	0.9%	0.9%
Saare	0.9%	2.8%	3.0%	1.0%	3.2%
Valga	0%	1.9%	0%	0%	0.9%
Viljandi	0.7%	3.1%	1.3%	1.5%	1.9%
Võru	5.9%	4.1%	5.6%	7.5%	2.2%

The increased of both systolic and diastolic blood pressure was found in 0–7.5% of schoolchildren.

DISCUSSION

Measurements of ambulatory blood pressure are currently widely used for the diagnosis of hypertension [4]. The relevance of childhood BP measurement for pediatric health care and the development of adult essential hypertension has undergone a substantial conceptual change during the past two decades [8]. In *Odense Schoolchild Study* it was found that the findings of baseline blood pressure were a significant factor in the prediction of rising SBP or DBP, or both [9].

This study assessed the mean SBP and DBP levels in children and adolescents, the relationships of blood pressure measured in schoolchildren to age and anthropometric data and the prevalence of hypertension in different regions.

The mean systolic and diastolic blood pressure readings remained within 95% CI, except 15-year-old girls' diastolic blood pressure (mean DBP 67.5 mm Hg, 95% CI 67.9 – 68.0 mm Hg). Replacing the mercury sphygmomanometer by an aneroid sphygmomanometer or automatic devices may be a source of inaccurate BP readings. Another possibility was that school physicians did not follow properly the protocol of measurements. In 10–15-year old adolescents no significant gender-related difference in SBP was found. Gender differences in SBP and DBP pressure were less than 1 mm Hg at all ages, which is clinically insignificant. These data differ from data in literature were boys had greater blood pressure readings than girls at all ages [10, 11].

Age, sex and body size are the most important determinants of blood pressure in childhood and adolescence. We also studied the association between age and anthropometric data. The current data were similar to others where significant correlation was found between blood pressure and body weight, height and body mass index. [8, 12, 13]. In this study not so close relationship was found between blood pressure and body mass index as it was in K. Sudi and co-authors' study on obese children and adolescents [14].

The incorporation of blood pressure measurement into the routine pediatric examination not only facilitated the detection of significant asymptomatic hypertension secondary to a previously undetected disorder, but also confirmed that mild elevations in blood pressure during childhood were more common than previously recognised, particularly in adolescents. It is understood that hypertension may be a sign of an underlying disease, or elevated blood pressure may represent the early onset of essential hypertension. Therefore, blood pressure measurements should be taken at an interval on all children. At the very least, blood pressure measurements should be recorded on school and hospital admission [15]. In Estonia, the blood pressure of primary-school children should be measured at every school health check-up — in the 1st, 4^{th}, 6^{th}, and 9^{th} grades. These standards were not fulfilled and BP was measured only in 69.7% of children and adolescents .

In some series the prevalence of hypertension in childhood has been found to be between 1% [8] and 2% to 5% [16]. The current study revealed that isolated systolic hypertension (highest rate in boys of Võru county — 18.2%) and diastolic hypertension (highest rate in 6^{th} grade girls of Hiiu county — 17.0%) was more frequent than the elevation of both blood pressures (highest rate in girls of Hiiu county — 6.7%). Thus, Estonian schoolchildren had increased blood pressure more often than children in the USA.

A limitation of the present study is that the results were based on single measurements with different test devices. Nonetheless, as shown in many prospective population studies, a single blood pressure reading is strongly predictive of future cardiovascular diseases. It has been confirmed that a significant percentage of children with high blood pressure in the first survey will be hypertensive in the future [17]. In clinical routine doctors judge single blood pressure readings as equal or different, independent of any statistical consideration. Scientific societies with highest reputation also share the same point of view. In their recommendations they accept that the ongoing practice of judging the blood pressure of the patients meets the needs of an epidemiologist [18]. The summary report of the 1992 American national standard for measurement of resting and ambulatory blood pressures permits the use of automatic or electronic devices based on Korotkoff sounds [19]. In epidemiological surveys, in which the differences in blood pressure between groups of people are more important than absolute levels, it may be more appropriate to use these devices, but they cannot be recommended for use on children in clinical situations where accuracy of the absolute measurement is required [20]. Therefore, it could be presumed that school physicians can use test devices as screening instruments and should have mercury sphygmomanometers with proper cuffs for clinical measurements of blood pressure, especially for children with higher blood pressure.

Despite the limitations of the current study, the measurements of schoolchildren's blood pressure and their rate of hypertension proved the importance of paying attention to schoolchildren's hypertension and the quality of school health care.

Population-wide primary prevention, early detection and control of higher blood pressure are indicated since childhood [1, 21, 22].

CONCLUSION

These data lend strong support to two strategic concepts. First, with such screening of blood pressure a substantial increase can be achieved in the proportion of children and adolescent population, who have favourable levels of blood pressure. Second, population-wide efforts should be made for early detection of children and teenagers with unfavourable blood pressure levels, so that diagnostic and therapeutic efforts can be instituted early, first and foremost by improving lifestyle.

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FRIEDRICH BIDDER

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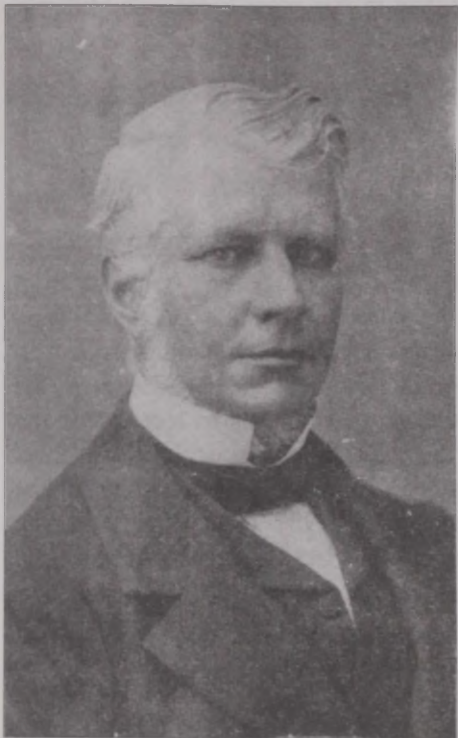
At the opening ceremony of the University of Tartu of the Republic of Estonia on 1 December 1919 the University Curator Peeter Põld asked the audience not to forget the famous scholars who had worked at the University in earlier times. He also recalled several 19th-century scientists by name. One of them was the well-known physiologist Friedrich Bidder [11].

CHILDHOOD AND EDUCATION

Georg Friedrich Karl Heinrich Bidder was born on 28 October (9 November New Style) 1819 at the manor of Treppenhof in Livonia (Vipe village on the right bank of the Daugava River, Jekabpils district, Latvia) as the son of a bailiff. He first studied at a private school in Riga and thereafter graduated from the gymnasium of Mitau (Jelgava). He worked as a private tutor for the family of von Schöpping and in 1828 took up studies of medicine at the University of Tartu. Bidder was lucky to be a student of both Jakob Friedrich Wilhelm Parrot and Martin Heinrich Rathke. Already as a student, he attracted attention by his excellent spoken Latin [6]. He graduated from the Faculty of Medicine on 24 (12) April 1834 with a doctoral dissertation on obstetrics and was awarded the degree of Doctor of Medicine. On application by the University, the Emperor allowed him to remain at the service of the Faculty of Medicine, and he was sent to continue his education abroad. Using a state scholarship, he studied at Berlin University and, for a shorter time, at other universities. In Berlin, he was particularly impressed by the lectures on comparative anatomy and physiology by the renowned naturalist J. Müller. Müller's school that included J. Henle, T. Schwann, A. Filomafitski, R. Remack, A. Kölliker, E. Dubois-Reymond, H. Helmholtz and R. Virchow introduced new methods of research, founded new laboratories and institutes, and applied cell theory and evolution theory to carry out experiments in human and animal physiology [5]. In one of his speeches, E. Dubois-Reymond described the working conditions in Berlin as follows: "There were no studious and helpful assistants; there were no public libraries; there was no warehouse of equipment that would have opened its treasuries. You had to purchase books, chemicals, other materials and instruments for experiments at your own expense; quite often you had to make them with your own hands. You had to solder elements, to glue rubber tubes as they could not be bought anywhere yet. You had to saw, plane, file, turn and polish. The need for getting advice and help in mechanics led us to workshops where talented artisans taught us various skills. We learned to know each screw of the instrument, studying it like the anatomy of an animal. If our kind teacher gave a valuable piece of apparatus to our disposal, how diligently we examined it, and, what is most important, how good care we took of it." This shows how accomplished scientists were trained in Germany. According to Bidder, the famous Berlin institute had only one microscope, and even that had been borrowed from Carl Eduard



Liphard, the versatilely educated owner of Raadi manor near Tartu. Bidder was also among its users in Berlin. As early as on the fifteenth day of his stay in Berlin, Bidder was not a spectator any more but a fellow researcher. "Herr Doktor, kommen Sie doch hinauf in mein Kabinett. Sie werden dort besser arbeiten können als hier in diesem Gewirre," (Do come upstairs to my study, Mister Doctor. You'll be more comfortable working there than in this mess here) was Müller's unexpected invitation [1].

RESEARCH AND TEACHING

F. Bidder's work as a lecturer and researcher and his social activities are connected with the University of Tartu. After his return from abroad, he was employed as a prosector, as this post had been reserved for him. In 1836 he became Professor Extraordinary and in 1842 Professor in Ordinary of Anatomy, this means Head of the Department of Anatomy. As Professor of Anatomy he lectured on the fundamental course of anatomy and supervised practical classes. Even later, as Professor of Physiology, he lectured on anatomy when the Chair of Anatomy was vacant from 1853–1957. From time to time he also lectured on histology. He started it in 1837 under the title *General anatomy together with histology as an introduction to physiology, based on E. Weber's handbook of anatomy*. In 1838–1839 he taught the subject *Animal tissue studies* (also after E. Weber); from 1839 he complemented it with microscope demonstrations. In 1840–1842 he called this subject *Foundations of histology*.

As in Berlin, the anatomists and physiologists of Tartu also worked in a joint laboratory of anatomy until 1848 when F. Bidder obtained separate rooms for physiologists on the first floor of the *Anatomicum*. Already as Professor of Anatomy, F. Bidder developed fruitful cooperation with Professor of Physiology A. W. Volkmann. The latter acquainted the students systematically with methods of physiological research by means of animal experiments and microscope demonstrations. Volkmann had brought along his own microscope from Leipzig. Like Volkmann, F. Bidder also emphasised the experimental aspect of physiological research and complemented his lectures with experi-

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UNTERSUCHUNGEN

ÜBER DIE

TEXTUR DES RÜCKENMARKS

UND DIE

ENTWICKELUNG SEINER FORMELEMENTE

VON

DR. F. BIDDER UND DR. C. KUPFFER

IN DORPAT.

MIT FÜNF TAFELN.

LEIPZIG,

DRUCK UND VERLAG VON BREITKOPF UND HAERTEL.

1857.

ments and microscope demonstrations. From 1843, after Prof. A. W. Volkmann left Tartu, Bidder was Head of the joint Department of Physiology and Pathology and from 1860–1869 of the independent Department of Physiology.

F. Bidder started his lectures on physiology in the first term of 1844. He lectured 5–6 hours a week, usually an hour a day both in the spring and the autumn terms. The lectures covered general as well as special physiology. In the autumn term F. Bidder lectured on special physiology and general pathology (3 hours per week) and in the spring term on pathological anatomy (3 hours per week). In 1846 he announced the lectures *Pathological anatomy, particularly in relation to histology (based on the works of J. Müller, Vogel, etc.).* From the early 1860s, when pathology separated from physiology, and pathology was taught by Jakob Ernst Arthur Böttcher, Bidder lectured on physiology both in autumn and spring terms six hours per week. In addition to the regular course, in some terms Bidder lectured optionally on recent achievements in physiology one hour a week, sometimes also on physiology of generations one hour a week. F. Bidder's lectures were classically lucid and consistent. He was fluent in Latin. C. v. Kupffer, who was a medical student at Tartu University from 1849–1854 (later Professor of Anatomy and Histology) wrote in his autobiography: "Bidder's lectures on physiology fascinated me even more than those of Reichert's, as they were illustrated by numerous, nearly always successful experiments" [5]. In the late 1860s F. Bidder, together with his student A. Schmidt, conducted practical classes for students, which were optional at that time.

As textbooks he recommended in his lectures the works of J. Müller, R. Wagner, G. Valentin and Lehmann.

The Tartu physiology laboratory, supervised by F. Bidder, studied mainly the topical problems of the physiology of the nervous and cardiovascular systems, digestion and metabolism. F. Bidder's first research papers dealt with the histophysiology of the retina and the functional significance of the cones (1839, 1841). This was one of the first studies in this field. Only as late as 1984 A. Cris and A. König established the difference between the functions of the rods and the cones, and the role of visual purple.

In 1842 F. Bidder published jointly with A. W. Volkmann, and thereafter independently, his results of sympathetic nervous system research, which morphologically and experimentally confirmed its functional autonomy and introduced the concept of the neuron. In 1847 F. Bidder proved the integrity of the ganglion cell and the nerve fibre in the sympathetic nervous system. These studies attracted attention; F. Bidder's name became widely known among physiologists. He was put forward to the authorities of the Russian Empire for a prize.

In 1857 F. Bidder and V. v. Kupffer generalised the results of embryogenetic studies of structural elements of the spinal cord.

In their numerous morphophysiological studies on the unity of structure and function, F. Bidder, his students and colleagues established the embryogenesis, structure and function of the vegetative nervous system, cytoarchitectonics of the spinal cord, laid foundation to the concept of neuroglia (first described by R. Virchow), differentiated between the ganglion cells, introduced the concept of the neuron. In these studies F. Bidder and his colleagues proved themselves as masters of precise morphophysiological experiment. The paper *Microscopic research of nerve rudiments in the cerebrum*, published in 1856 by F. Bidder's students F. Ovsyannikov and N. Yakubovich was based on a series of 25,000 preparations. This was a fundamental contribution to neuromorphology for which the Paris Academy of Science awarded the authors the Montioni Prize.

The histophysiological trend in neurology, which was developed in their studies by F. Bidder and his students M. Lavdovski, A. Babukhin, V. Bekhterev and several others made it possible to establish the general regularities of the nervous system and laid foundations to the development of neuropathology and psychiatry, which in the second half of the 19th century separated as independent clinical disciplines.

In these years F. Bidder also published the results of his research on lymph circulation, diuresis, innervation of blood vessels and several other areas of physiology. His comparative anatomical and physiological studies were also of great significance. In 1846 they resulted in the discovery and description of "Bidder's organ" in amphibians' secretory system and in 1852 in the discovery of a complex of ganglion cells in frog's heart on the border between the atrium and the ventricle, which became known as Bidder's knot. F. Bidder's closest collaborator C. v. Kupffer later conducted a number of significant comparative physiological studies of the connective tissue, presented original methods of cytochemical analysis and was the first to describe stellar cells in the liver as elements of the reticuloendothelial system. Those cells were named after Kuppfer.

Particularly important among F. Bidder's papers are those on the role of digestive juices in metabolism. He began these studies in 1848 in collaboration with the well-known Tartu biochemist C. Schmidt, and they presented the results in the joint monograph *Digestive juices and Metabolism* (1852). They studied the principal problems of physiology and biochemistry of digestion and metabolism, establishing facts that have retained their scientific significance till the present. The main task was to determine the organism's protein need as the central issue in nutrition physiology. They were the first to solve the problem of nitrogen exchange in metabolism. Along with protein metabolism, the authors also considered gas metabolism (emission of CO_2), thus obtaining an overview of the general energy balance of the organism. They were the first to emphasise the extremely important question of rational nutrition, of the quantitative composition of food. The paper stressed the need for fixed proportions between nutrients and the irreplaceable role of proteins in food. The equivalent energetic relation 100:147 was found between proteins and fats. The paper demonstrated for the first time that gastric juice contains free hydrochloric acid, explained the significance of bile in digestion of fats and discovered the psychomotor secretion of gastric juice. The paper laid the foundation for studying gas exchange in humans under various conditions (C. Voit, M. Pettenkofer *et al.*).

In an extremely interesting experiment F. Bidder and C. Schmidt introduced in dogs' stomachs hollow sounds through which gastric juice could flow out. During meals the amount of gastric juice increased. Then, however, an original change was made in the experiments: instead of feeding the dogs, food was only placed in their range of vision. The amount of gastric juice increased even then. This led to the discovery of the psychomotor reaction. Bidder's student Philip Ovsyannikov later became a professor in St. Petersburg and was, in its turn, the teacher of Ivan Pavlov, who understood the importance of the experiments carried out in Tartu. Repeating and refining the old experiments of Tartu, he repeatedly emphasised in his works, including the lectures *On the Operation Principles of Digestive Glands* (1897), that the foundations of his theory of conditioned response came from F. Bidder and C. Schmidt.

Bidder supervised 77 doctoral dissertations. His students became renowned scientists and lecturers. The best-known of them are A. P. Walther (Kiev), P. Ovsyannikov (Kazan, St. Petersburg), N. Yakubovich (St. Petersburg), C. v. Kuppfer (Tartu, Kiel, Königsberg, Munich), H. A. A. Schmidt (Tartu), J. E. A. Böttcher (Tartu), C. Gaehtgens (Rostock), etc.

Sometimes F. Bidder also assisted Rudolf Buchheim in carrying out experiments on animals. Inspired by F. Bidder's and C. Schmidt's methods, Buchheim began to apply them in his studies on the impact of medicines on the organism.

F. Bidder had been brought up in the spirit of rationalist ideas. His world outlook was somewhat inconsistent, but he was one of the most remarkable physiologists in mid-19th century Europe. His and his collaborators' achievements were highly appreciated in the world of science; his research results were quoted in books of reference and textbooks. From 1857 H. Bidder was a corresponding member of St. Petersburg Academy of Sciences; in 1879 the Academy of Sciences awarded him the Baer gold medal. In 1884 Bidder was elected honorary academician of St. Petersburg Academy of Sciences, in the same year he became an honorary member of the University of Tartu. From 1884 he also was medical counsellor for the Ministry of Internal Affairs. Bidder was also an honorary member of the universities of Kazan and Kiev and an honorary member of the British Royal Medical Society.

WORK AS RECTOR

After Bidder had displayed his managerial qualities as Dean of the Faculty of Medicine in 1846–1850 and 1854, his superiors and colleagues elected him Rector of the University of Tartu. He held this post from 1858-1865. He was among those who devised the statute of Russian universities that was approved by the Emperor in 1865. Although the councils of most universities in the Russian Empire acknowledged women's right to participate in lectures and take exams in order to qualify for academic degrees, Tartu University like Moscow University did not consider admission of women to universities advisable. This reflected the opinion of F. Bidder, Rector of Tartu

University, as well as that of E. Bradcke, Curator of Tartu education district, chairman of the board for compiling the new university statute, and, as a result, women were banned from the university. Bidder supported in every way the organisations of professors and students, and academically collegial relations. Thanks to Bidder, student fraternities, after long-time waiting, acquired official status.

RETIREMENT

After thirty-five years of service, F. Bidder retired in 1869 as Merited Professor. Only for a short time he remained chairman of University parish council, which had been established at his initiative. He continued working privately as a medical practitioner and from 1884 was Counsellor at the Ministry of Internal Affairs.

F. BIDDER AS PRESIDENT OF THE NATURALISTS' SOCIETY

F. Bidder became a member of the Naturalists' Society (NS) early in 1869, when K. E. v. Baer had recently been elected its president. In 1877 Bidder became Baer's successor as President of NS.

By 1869 the economic situation of NS had reached a critical low; the former President resigned and Secretary quit the membership. On 30 January 1869, under Baer's supervision, the Society's resources were mobilised, and new members, including Professors F. Bidder and A. Schmidt, were recruited [8].

F. Bidder was elected President of NS on 13 January 1877 [15], and he held this post until 1890. As the minutes of NS meetings and reports show, Bidder participated actively in the work of the Society. He initiated research problems and participated in practical application of results. He also dealt with organisational matters, particularly with the transition of the Society to the University.

The first meeting Bidder chaired as NS President took place on 17 February 1877, on K. E. v. Baer's birthday. The president's address was devoted to the memory of K. E. v. Baer [16]. It was unanimously decided to hold Baer's memorial meeting on 17 February annually, no matter on which day of the week this date would fall.

To attract broader circles into the activities of the Society, Bidder began to publishing the agenda of the meetings in the newspaper. On 20 October of the same year this innovation was met with approval.

It took more than a year for Bidder to reorganise NS and affiliate it to the University. At the meeting of 17 March 1877 Bidder spoke about the relationship between NS and the Livonian Non-profit Economic Society (NS was one of its branches). The Livonian Non-profit Economic Society (LNES) had ceased to support NS, and it was questionable whether NS could survive. It was inevitable to reorganise NS, and Bidder, who knew the requirements of the University, proposed to separate NS from LNES and ask the University administration to affiliate NS to the University. The application for separation of NS from LNES was signed by seven acting members. On 27 April of the same year NS was granted dissociation from LNES, and the paragraphs affiliating NS to LNES were removed from NS statute. Then NS applied to the University Rector, asking to affiliate NS to the University. Rector's affirmative answer was received on 7 November of the same year. Next, it was necessary to obtain Emperor's approval to the affiliation of NS to the University. In the letter of 18 August 1878, the University administration informed NS that the Emperor had approved the affiliation of NS to the University on 2 June and its statutes on 13 June 1878. On 24 August 1878 NS received a respective message from the University, and from that day onwards NS was officially affiliated to the University and could use University premises (NS library had been transferred to the University library even earlier).

President Bidder supported and supervised studies of all aspects of nature. Having grown up in the country, he was aware of the worries of farmers and foresters. He emphasised the urgent need for studying the pests who devastated fields and forests (*Kornwurm* and *Baumspinner*). In the following years Bidder called for a campaign against these pests [16].

An interesting facet in Bidder's work is his observations in the parish of Oppekaln (Latvian Apekaln) in Central Livonia. In the hilly landscape of this area, deep lakes (20 feet) alternate with swamps and bog lakes with muddy shores and a depth of no more than 11 feet. Water exchange in these lakes is insufficient, but they are abundant in fish. In winter the fish gather around holes in ice, but many fish die. The holes hewn in ice spread the smell of bog. The following species of fish were found in the lakes: *Cobitis fossilis* (*Misgurnus fossilis*) — weatherfish, *Cyprinus blicca* (*Blicca bjoerkna*), *Perca fluviatilis* — perch, *Esox lucius* — pike. Bidder issued an appeal to inform NS about the lakes where the above mentioned phenomena have occurred and substantiated the need for hewing holes in ice. NS also commissioned lake water analyses. On 15 January 1878 NS listened to the report of E. Johanson M.Sc. on the results of lake water analysis [20].

Bidder received a lot of recognition during his presidency of NS. In 1879 he was the first to get the Baer Memorial Medal from the St. Petersburg Academy of Sciences, and he was elected Honorary Member of the Academy in acknowledgement for his merits as the greatest physiologist of his time and a university lecturer. In 1884, on the 50th jubilee of defending his doctoral dissertation, he was elected honorary member of Tartu University. At the annual meeting on 26 January 1884 Bidder was unanimously elected NS President for the following three years [21].

In 1889 NS acquired its own premises in Tiigi Street. F. Bidder was hopeful that under its own roof the Society could make more progress than before. The autumn term of 1889 was the last one for F. Bidder as NS President. On 18 January 1890 he did not turn up at the annual meeting but sent a letter asking not to re-elect him. He was elected an honorary member, and the delegation of NS gave him a message about it and thanked him for the work done.

For a long time, he participated actively in the work of a charitable society. F. Bidder lived to the old age of 84 years, retaining a sound mind and full physical strength. Only in the last years of his life he withered, although his vision and hearing remained unimpaired until his death. F. Bidder died quietly in Tartu on the morning of 10 August (22 August New Style) 1894 and has been buried at Raadi cemetery in Tartu.

In 1989 a monument by sculptor V. Dzintare was erected at F. Bidder's birthplace. It bears his bas-relief and the text in Latvian: "Here the renowned physiologist, Academician of St. Petersburg Academy of Sciences, Rector of Tartu University Friedrich Bidder. 1810–1894 began his journey through life."

F. BIDDER'S BEST-KNOWN WORKS

1. Die Selbstständigkeit des sympatischen Nervensystems durch anatomische Untersuchungen nachgewiesen. Leipzig, 1842 (together with A. W. Volkmann).
2. Vergleichend-anatomische und histologische Untersuchungen über die Harn- und Geschlechtswerkzeuge der nackten Amphibien. Dorpat, 1846.
3. Neue Beobachtungen über das Verhalten der Ganglienkörper zu den Nervenfasern. Leipzig, 1874 (with an appendix by A. W. Volkmanni).
4. Über funktionell verschiedene und räumlich getrennte Centra im Froschherzen. Archiv Anat. Physiol. Wiss. Med., 1852.
5. Untersuchungen über die Textur des Rückenmarks und die Entwickelung seiner Formelemente (co-author C. Kuppfer). Leipzig.

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COMPARISON OF ANTHROPOMETRIC VARIABLES OF 12-15-YEAR-OLD PRE- AND POST-OIGARCHEAL BOYS FROM TARTU

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ABSTRACT

The study was aimed at comparing absolute and relative anthropometric characteristics in pre- and post-oigarcheal boys. The subjects were 361 schoolboys of 12-15 years of age. The analysis included 96.39% of boys (n=348), who answered the question about their oigarcheal status.

Student's t-test was used to find the differences of means of the pre-oigarcheal and post-oigarcheal subgroups in each age group. Post-oigarcheal boys tended to be superior in absolute measurements: for example in biacromial width, chest width, waist width, head width, sitting height, length of upper limb, and in chest, waist and limb girths, but these differences were statistically significant only in some age groups. From relative measurements, relative chest width and depth, and relative chest girth were superior in post-oigarcheal boys, although these differences were significant only in some age groups. In the whole sample there were also statistically significant differences in favour of post-oigarcheal boys in relative biacromial width, relative bicristal width and relative head measurements. Non-linear discriminant analysis allowed to separate the pre-oigarcheal and post-oigarcheal boys by 13 anthropometric parameters, not taking into account the age. The safety of separation reaches the 82% probability.

Key words: anthropometry, boys, oigarcheal status

INTRODUCTION

Normal pubertal development is characterized by major physical changes. The relationship between anthropometric characteristics and sexual maturation has been the theme of many studies [1, 7, 8, 9], mostly of girls. The age at first ejaculation can be used as an index of genital and sexual maturation in male puberty [3, 4]. The data about it are difficult to obtain, as only the adolescents' self-assessment can be used.

The aim of this study is to compare not only absolute but also relative somatic dimensions, including head variables, and some indices in pre- and post-oigarcheal boys aged from 12 to 15 years and to find the main tendencies of differences between these subgroups of Tartu children.

MATERIALS AND METHODS

The study was carried out from 1997 to 1999 in Tartu schools as a part of a study on the physical status of Tartu children. The present sample consists of 361 schoolboys of 12–15 years of age.

Each boy was asked whether he had begun to have ejaculations (pollutions) yet, and if he had, then the exact age (date) when the first ejaculation happened (*status quo* and retrospective methods). Confidentiality and anonymity of subject information were stressed, as was the right to refuse consent.

Anthropometric measurements were carried out by the author according to the rules described by K. Norton et al. [6] and supported by ISAK — height to the nearest 0.1 cm, weight to the nearest 0.1 kg with beam platform scales and skinfolds measurements with a Holtain calliper.

Head measurements were taken according to methods developed by R. Martin [5].

At each age cross-sectionally obtained data were divided into groups of pre- and post-oigarcheal boys, and descriptive statistics were calculated for all variables of age and oigarcheal groups. Student's t-test was used to determine the differences of means of the subgroups in each age group. Discriminant analysis was used to classify the pre-oigarcheal and post-oigarcheal groups.

The statistical package SAS was used for data processing.

In addition of basic statistics (mean, standard deviation) the following indexes were calculated: BMI, acromiocristal index (ratio of bicristal diameter to biacromial diameter in %), thoracal index (ratio of depth and width of the chest in %), cephalic index (ratio of the maximum width of the skull to its maximum length in %), and also relative measurements (% of variable from body height).

RESULTS

Table 1 lists the percentages of boys with oigarche and without oigarche at each age. 96.39% of boys (n=348) from 361 answered this question.

Table 1. Distribution of 12–15-year-old Tartu boys according to incidence of oigarche

Age	Without oigarche		With oigarche		Total
(years)	n	%	n	%	n
12	61	96.83	2	3.17	63
13	82	87.23	12	12.77	94
14	73	73.74	26	26.26	99
15	45	48.91	47	51.09	92
Total	261	75	87	25	348

The data were surprising — the percentages of occurrence of oigarche were relatively low (Table 1) till age 15. The mean oigarcheal age was 13.35±0.11 years /(SD=0.99), the earliest age when oigarche occurred was 10.00 years.

Comparison of somatic measures and indices between pre- and post-oigarcheal boys is presented in Tables 2–8.

Post-oigarcheal boys tended to be superior in absolute measurements: for example, in biacromial width, chest width, waist width, head width, sitting height, upper limb length, and in chest, waist and limb girths, but these differences were statistically significant only in some age groups, mostly in 15-year-olds. From relative measurements, relative chest width and depth and relative chest girth were superior in post-oigarcheal boys, although these differences were significant only in some age groups.

Post-oigarcheal boys at age 14–15 had significantly larger ($p<0.05$) biacromial width, waist width, at age 15 chest width, chest girth, waist girth, medial thigh girth and upper arm girth (Table 4 and 5) in comparison with boys of the same age who had not had oigarche. Between the oigarcheal groups the only statistically significant difference in skinfolds was that of supraspinale in 12-year-olds. At age 13 or 14 there were also significant differences ($p<0.05$) between oigarcheal groups in head-plus neck length, sitting height, bicristal width and head width ($p<0.001$).

In relative measurements we could not find any statistically significant differences within age groups (Table 8), except at age 12 in relative chest depth ($p<0.0001$), at age 12 and 15 in relative chest girth, and at age 15 in relative chest width ($p<0.01$). At age 13 the cephalic index and thoracal index were also statistically significantly ($p=0.0125$) larger in post-oigarcheal boys. T-test of oigarcheal groups of the whole sample revealed statistically highly significant differences ($p<0.0001$) in favour of post-oigarcheal boys in most of variables (Table 2–8) and also in relative variables ($p<0.01$). Exceptions were all skinfolds, indexes, relative sitting height, relative chest depth and relative limb lengths.

First, linear discriminant analysis was performed, by different methods, for the whole sample, not taking into account the age. In this case the safety of separation was less than 80%, which was not considered sufficient. As the sample was large enough, we also tried non-linear discriminant analysis, using the variables selected by stepwise method.

Table 2. Means and standard deviations (SD) of weight and height in 12–15-year-old boys by oigarcheal status

Variable	Age (years)	Pre-oigarcheal Mean	Pre-oigarcheal SD	Post-oigarcheal Mean	Post-oigarcheal SD
weight (kg)	12	43.32	9.57	40.30	6.08
	13	44.80	10.75	48.03	6.96
	14	49.24	10.54	53.41	8.57
	15	57.82	9.63	61.58	9.15
height (cm)	12	153.16	7.49	155.00	8.20
	13	157.68	7.42	159.31	5.97
	14	164.45	9.81	167.82	8.15
	15	171.73	7.35	173.70	4.79

* Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within the age group ($p<0.05$).
** Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within the age group ($p<0.01$).
Variables that are statistically significantly different ($p<0.0001$) between oigarcheal groups of boys aged 12–15 are given in bold.

Table 3. Means and standard deviations (SD) of lengths in 12–15-year-old boys by oigarcheal status

Variable (cm)	Age (years)	Pre-oigarcheal Mean	Pre-oigarcheal SD	Post-oigarcheal Mean	Post-oigarcheal SD
head-plus neck length	12	28.67	1.35	28.70	1.27
	13	29.06	1.27	29.95*	1.38
	14	30.07	1.77	30.64	1.51
	15	31.04	1.41	31.22	1.33
trunk length	12	45.44	2.59	45.44	2.97
	13	46.36	2.97	46.28	1.88
	14	48.68	3.08	49.73	3.24
	15	51.38	2.81	51.74	2.52
sitting height	12	79.04	3.42	78.55	5.16
	13	80.38	3.83	81.21	2.82
	14	83.95	4.96	86.15*	4.02
	15	88.11	4.14	88.97	3.30
length of the lower limb	12	83.06	5.10	84.83	4.56
	13	86.41	4.56	86.82	4.14
	14	90.04	6.53	91.26	4.78
	15	94.34	4.96	95.29	3.47

Variable (cm)	Age (years)	Pre-oigarcheal Mean	Pre-oigarcheal SD	Post-oigarcheal Mean	Post-oigarcheal SD
length of the upper limb	12	67.58	3.97	68.35	2.76
	13	69.72	3.93	70.84	3.00
	14	73.09	5.28	74.37	4.12
	15	75.82	4.13	77.45*	2.69
foot length	12	24.58	1.50	24.45	0.07
	13	25.06	1.45	24.92	1.14
	14	25.96	1.57	26.14	1.42
	15	26.94	1.35	27.02	1.08

* Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within the age group (p<0.05).
** Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within the age group (p<0.01).
Variables that are statistically significantly different (p<0.0001) between oigarcheal groups of the boys aged 12–15 are given in bold

Table 4. Means and standard deviations (SD) of widths and depths in 12–15-year-old boys by oigarcheal status

Variable	Age (years)	Pre-oigarcheal Mean	Pre-oigarcheal SD	Post-oigarcheal Mean	Post-oigarcheal SD
biacromial width	12	32.22	1.75	32.90	2.97
	13	33.19	2.24	34.11	1.69
	14	34.73	2.72	36.00*	2.38
	15	36.65	1.98	37.54*	2.06
chest width	12	23.13	1.57	22.80	0.71
	13	23.67	1.89	23.76	1.43
	14	24.60	2.04	25.31	2.01
	15	25.69	2.02	27.02**	1.93
waist width	12	21.78	1.82	20.90	1.13
	13	22.27	2.21	22.76	1.39
	14	22.51	1.84	23.59*	1.73
	15	23.91	1.67	24.81*	1.88
bicristal width	12	23.75	1.73	23.20	1.13
	13	24.21	1.84	24.87	1.27
	14	25.05	1.95	26.07*	1.49
	15	26.74	1.76	27.24	1.42

Variable	Age (years)	Pre-oigarcheal		Post-oigarcheal	
		Mean	SD	Mean	SD
chest depth	12	16.56	1.47	15.50	0.85
	13	16.69	1.82	17.68	1.80
	14	17.39	1.75	17.90	1.56
	15	18.34	1.77	18.74	1.36
abdominal depth	12	16.36	2.16	15.95	1.34
	13	16.47	2.23	17.02	1.63
	14	16.56	1.49	16.95	1.62
	15	17.48	1.70	17.96	1.44
elbow (humerus) width	12	6.13	0.43	6.10	0.28
	13	6.22	0.40	6.49	0.63
	14	6.52	0.44	6.69	0.34
	15	6.84	0.49	6.91	0.34
knee (femur) width	12	8.93	0.50	8.60	0.42
	13	8.95	0.54	9.24	0.35
	14	9.16	0.55	9.40	0.46
	15	9.46	0.50	9.54	0.42
ankle (bimalleolar) width	12	6.91	0.39	6.65	0.07
	13	6.88	0.39	6.98	0.37
	14	7.09	0.43	7.22	0.40
	15	7.32	0.40	7.40	0.39
head length ¤	12	18.10	0.66	17.70	1.70
	13	18.23	0.77	18.16	0.79
	14	18.32	0.81	18.47	0.61
	15	18.50	0.67	18.73	0.53
head width	12	14.49	0.61	14.30	0.57
	13	14.44	0.49	14.99**	0.37
	14	14.49	0.57	14.65	0.41
	15	14.69	0.57	14.90	0.54

* Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within age the group ($p<0.05$).

** Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within age the group ($p<0.01$).

¤ Statistically significantly different ($p<0.01$) between oigarcheal groups of boys aged 12–15.

Variables that are statistically significantly different ($p<0.0001$) between oigarcheal groups of boys aged 12–15 are given in bold.

Table 5. Means and standard deviations (SD) of girths in 12–15-year-old boys by oigarcheal status

Girths (cm)	Age (years)	Pre- oigarcheal Mean	Pre- oigarcheal SD	Post- oigarcheal Mean	Post- oigarcheal SD
head	12	54.63	1.66	54.10	3.54
	13	54.98	1.61	55.55	1.43
	14	55.22	1.82	55.68	1.47
	15	56.08	1.53	56.57	1.39
chest (mesosternale)	12	74.56	6.42	72.30	3.68
	13	75.23	7.72	76.86	4.98
	14	78.25	6.89	81.11	5.96
	15	83.46	6.65	87.07**	6.03
waist (minimum)	12	65.49	6.49	62.45	0.21
	13	65.91	7.28	66.40	5.25
	14	66.85	5.44	68.47	5.22
	15	70.68	5.52	73.29*	5.45
gluteal (hips)	12	80.34	8.28	75.85	3.61
	13	80.39	7.73	82.77	5.11
	14	82.56	7.07	85.38	5.69
	15	88.04	6.69	90.39	5.87
thigh (medial)	12	42.61	4.95	41.05	2.48
	13	42.63	4.65	43.28	4.26
	14	43.13	4.34	44.19	4.14
	15	45.62	4.11	47.69*	4.23
upper arm (relaxed)	12	23.44	2.97	21.40	1.98
	13	22.99	2.99	23.68	2.29
	14	23.58	2.81	24.71	2.57
	15	25.54	2.74	26.93*	2.98

* Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within age the group ($p<0.05$).
** Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within age the group ($p<0.01$).
Variables that are statistically significantly different ($p<0.0001$) between oigarcheal groups of boys aged 12–15 are given in bold.

Table 6. Means and standard deviations (SD) of skinfolds in 12–15-year-old boys by oigarcheal status

Skinfold (mm)	Age	Pre-oigarcheal		Post-oigarcheal	
		Mean	SD	Mean	SD
triceps	12	10.72	4.67	7.15	1.63
	13	9.04	4.03	9.04	3.84
	14	7.91	2.87	7.70	3.81
	15	7.88	3.09	8.92	3.59
subscapular	12	7.46	3.92	5.25	0.35
	13	7.01	4.61	7.28	2.86
	14	6.52	2.57	6.74	2.64
	15	6.91	2.64	7.77	3.21
biceps	12	6.44	2.97	3.80	0.00
	13	5.33	2.86	6.40	2.83
	14	4.30	1.38	4.94	2.55
	15	4.47	1.76	5.03	2.47
iliac crest	12	10.40	6.33	6.45	1.49
	13	9.91	7.58	10.33	5.66
	14	8.22	4.42	9.03	4.78
	15	8.97	4.83	10.58	6.82
supraspinale	12	6.71	5.37	3.85**	0.07
	13	5.89	5.01	5.54	3.01
	14	5.27	3.81	6.43	5.19
	15	5.82	3.82	6.59	4.37
abdominal	12	11.63	8.01	6.25	1.77
	13	9.66	8.50	9.75	5.89
	14	8.33	5.63	9.29	6.39
	15	9.99	7.55	11.62	8.14
front thigh	12	19.86	9.72	15.75	4.46
	13	17.84	9.75	17.49	6.16
	14	13.69	6.54	14.82	8.35
	15	14.20	7.55	16.15	8.77
medial calf	12	12.16	6.61	9.10	3.82
	13	10.54	5.43	11.93	5.06
	14	8.92	4.25	9.14	4.99
	15	9.31	4.03	10.97	5.43

* Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within age the group ($p<0.05$).

** Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within age the group ($p<0.01$).

Variables that are statistically significantly different ($p<0.0001$) between oigarcheal groups of boys aged 12–15 are given in bold.

Table 7. BMI in 12–15-year-old Tartu boys by oigarcheal status

Index	Age (years)	Pre-oigarcheal		Post-oigarcheal	
		Mean	SD	Mean	SD
BMI	12	18.30	2.79	16.71	0.76
	13	17.86	3.01	18.89	2.23
	14	17.99	2.28	18.90	2.35
	15	19.45	2.36	20.37	2.63

* Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within the age group (p<0.05).
** Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within the age group (p<0.01).
Variable is statistically significantly different (p<0.0001) between oigarcheal groups of boys aged 12–15.

Table 8. Some indexes (in %) in 12–15-year old boys

Variable	Age (years)	Pre-oigarcheal		Post-oigarcheal	
		Mean	SD	Mean	SD
rel. sitting height	12	51.64	1.31	50.66	0.65
	13	50.99	1.30	50.99	1.10
	14	51.07	1.12	51.35	0.90
	15	51.31	1.16	51.22	1.28
rel. biacromial width¤	12	21.04	0.70	21.21	0.79
	13	21.05	0.99	21.41	0.81
	14	21.11	0.91	21.45	0.85
	15	21.36	1.03	21.61	1.03
rel. bicristal width¤	12	15.50	0.69	14.97	0.06
	13	15.35	0.75	15.61	0.60
	14	15.23	0.75	15.54	0.60
	15	15.57	0.63	15.69	0.75
rel. chest width¤	12	15.11	0.77	14.72	0.32
	13	15.01	0.89	14.92	0.82
	14	14.97	1.00	15.07	0.80
	15	14.95	0.92	15.55**	1.01
rel. chest depth	12	10.81	0.78	10.00**	0.02
	13	10.58	0.93	11.10	1.12
	14	10.57	0.77	10.67	0.88
	15	10.68	0.89	10.79	0.73
rel. chest girth¤	12	48.67	3.19	46.65**	0.10
	13	47.69	3.88	48.29	3.25
	14	47.57	2.87	48.34	2.75
	15	48.60	3.05	50.13*	3.19

Variable	Age (years)	Pre-oigarcheal		Post-oigarcheal	
		Mean	SD	Mean	SD
rel. length of lower limb	12	54.21	1.16	54.73	0.05
	13	54.79	0.99	54.49	0.97
	14	54.72	1.22	54.38	0.84
	15	54.80	1.13	54.86	1.16
rel. length of upper limb	12	44.12	1.20	44.11	0.56
	13	44.21	1.07	44.47	0.99
	14	44.43	1.30	44.31	0.98
	15	44.15	1.30	44.59	0.93
acromiocristal index	12	73.73	3.88	70.65	2.94
	13	73.03	4.26	72.97	3.38
	14	72.21	3.96	72.55	3.56
	15	73.01	4.73	72.69	3.95
thoracal index	12	71.64	4.76	67.96	1.61
	13	70.58	5.93	74.57*	7.84
	14	70.83	6.03	70.94	6.26
	15	71.57	6.52	69.63	4.69
rel. head length	12	11.84	0.58	11.41	0.49
	13	11.58	0.59	11.42	0.65
	14	11.16	0.59	11.02	0.41
	15	10.79	0.49	10.79	0.34
rel. head width	12	9.48	0.49	9.23	0.12
	13	9.17	0.43	9.42	0.34
	14	8.84	0.54	8.75	0.49
	15	8.57	0.45	8.58	0.32
rel. head girth	12	35.73	1.53	34.89	0.44
	13	34.92	1.38	34.91	1.41
	14	33.65	1.50	33.23	1.30
	15	32.71	1.42	32.58	0.82
cephalic index	12	80.15	4.00	81.01	4.57
	13	79.32	4.27	82.75*	4.92
	14	79.27	4.42	79.40	3.49
	15	79.52	4.57	79.60	3.66

* Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within the age group ($p<0.05$).

** Statistically significant difference between pre-oigarcheal and post-oigarcheal boys within the age group ($p<0.01$).

¤ Statistically significantly different ($p<0.01$) between oigarcheal groups of boys aged 12–15.

Variables that are statistically significantly different ($p<0.0001$) between oigarcheal groups of boys aged 12–15 are given in bold.

The most important results of non-linear discriminant analysis are presented in Table 9. All multivariate statistics confirmed truthfully that the model was relevant (probability level p<0.0001). The values of F statistics were highly significant and proved the hypothesis about differences between the means of the two groups.

Table 9. Results of nonlinear discriminant analysis of the sample

Squared Distance to OIGARCHE

From OIGARCHE	0	1
0	0	2.12152
1	1.31155	0

Generalized Squared Distance to OIGARCHE

From OIGARCHE	0	1
0	13.38689	14.24961
1	14.69844	12.12810

Multivariate Statistics and Exact F Statistics

S=1 M=5.5 N=162

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.790402	6.6499	13	326	0.0001
Pillai's Trace	0.209598	6.6499	13	326	0.0001
Hotelling-Lawley Trace	0.26518	6.6499	13	326	0.0001
Roy's Greatest Root	0.26518	6.6499	13	326	0.0001

Percent Classified into OIGARCE:

From OIGARCE	0	1	Total
0	82.68	17.32	100.00
1	15.12	84.88	100.00

Error Count Estimates for OIGARCHE:

	0	1	Total
Rate	0.1732	0.1512	0.1622
Priors	0.5000	0.5000	

The safety of separation reached the 82 % probability (total error count estimates 16.22%). The following 13 body parameters were necessary for separation of oigarcheal groups: body height, sitting height, foot length, BMI, ankle width, biacromial width, chest depth, head girth, chest girth, waist girth, medial thigh girth, triceps skinfold and suprailiac skinfold.

DISCUSSION

The mean oigarcheal age of the sample was 13.35±0.11 years /(SD=0.99), which is quite similar to Hungarian data (13.55±0.13 yr.) from 1991 [2], especially if we take into consideration that the oigarcheal age of the population is somewhat higher as only an half of boys had oigarche till age 15. Unfortunately, we have no earlier data about oigarche in Estonian boys for comparison.

Surprisingly, the number of boys who reported that they had had oigarche was quite low.

There could be three possible reasons for this. The first reason may be that the boys were ashamed to answer yes; the second reason may be that they could not understand the question, and the third that oigarche really occurred until age 15 in quite a low percentage of boys. From each boy, these delicate questions were in writing asked in privacy. The purpose of the study was thoroughly explained, and the question was coherently and intelligibly presented. All the boys were also encouraged to ask if they could not understand the question.

There was an occasion when a tall 15-year-old boy with the dominance of ectomorphy and with genital size of 25 ml answered that he had no pollutions yet. Even if the anthropologist delicately asked to check his answers, he was sure that everything was correct. This may be connected with quite big ectomorphy and not so high mesomorphy of Estonian boys at this age period. In any case, the problem needs a longitudinal study. It seems that the results of comparison of groups with different oigarcheal status and discriminant analysis were somewhat incompatible. On the one hand, boys of the same age with different oigarcheal status were not statistically significantly different by anthropometric characteristics, except at age 14–15 in biacromial width and waist width, and at age 15 in sitting in height, length of upper limb, chest width and some girths (chest, waist, medial thigh, upper arm), relative chest width, relative chest girth. On the other hand, discriminant analysis showed that the separation of two oigarcheal groups only by anthropometry was successfully possible. It is evident that same-age boys with oigarche have a tendency to have larger chest, waist and girth of limbs, although these differences are significant at age 15. Attempts at discriminant analysis showed that the probability will grow with increasing the number of variables entered. Nevertheless, even a relatively small number of variables made it possible to differentiate between the two oigarcheal groups. In the whole sample the boys with and without oigarche were statistically significantly different by all anthropometric characteristics that were significantly different only in some age groups. This underlines the big variability in age groups and the need for bigger samples in studies of pubertal children, particularly boys. Therefore, the analysis of the whole sample gave better opportunities for discovering the general tendencies. In comparison with girls of the same age [10], the maturational differences in boys could not be established so easily and obviously because of the greater variability of dimensions in boys.

In conclusion, anthropometric differences between the oigarcheal groups are evident if we do not consider separate variables but a whole complex of characteristics.

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ASSESSMENT OF SKELETAL AGE IN PUBERTAL GIRLS BY THREE SCORING SYSTEMS

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ABSTRACT

The purpose of the study was to compare the skeletal ages obtained by three scoring systems (TW-2, RUS, CARPAL) in 11–14-year-old girls. X-ray pictures of wrist and hand were obtained from 80 girls. The skeletal age was assessed by measuring 20 bones and using three scoring systems proposed [11]. The lowest skeletal age was obtained with CARPAL and the highest with RUS. TW-2 gave intermediate age and was close to chronological age. Measurements of skeletal age correlated between themselves, with breast development stage and height but not with the chronological age. In conclusion, TW-2 provided the most relevant information on skeletal age in pubertal girls. Results confirmed the relationship between skeletal and sexual maturation.

Key words: girls, sexual maturation, skeletal age assessment, skeletal maturation

INTRODUCTION

The profound studies of Tanner and collaborators [10, 11] provided an opportunity to replace the atlas method for assessment of skeletal age [4, 12] by measurement of 20 wrist and hands bones. This way the assessment became more precise and reliable [1, 8, 11]. Tanner *et al.* [11] proposed three separate scoring systems founded on measurement of all 20 bones (TW-2), radius, ulna and finger bones (RUS), and carpals only (CARPAL). The last two scoring systems made it possible to reduce the number of measured bones to 13 or to 7, respectively. However, serious doubts have been expressed that for assessment of skeletal maturation seven carpals or the radius and ulna are less important than finger bones. Moreover, the carpals give different (for several purposes worse) information than the long bones do [11]. In order to minimise influences related to these cautions, biological weights for each separate bone have been introduced. The scores proposed by Tanner *et al.* [11] are obtained by summation of "weighted" bone measurements. Against this background, standards for evaluation of boys' and girls' skeletal age have been elaborated [11].

The aim of the present study is to compare the skeletal ages based on the scoring systems TW-2, RUS, and CARPAL between themselves and with chronological age in pubertal girls (breast development stages 2 to 5). The background for this research task consists in the fact that in girls aged from 11 to 16 years substantial differences exist between the pattern of skeletal maturing scores obtained by means of TW-2, RUS and CARPAL [11].

MATERIAL AND METHODS

Informed consent for X-ray picture of wrist and hand was obtained from 80 girls, their parents and school principals. All the girls were considered healthy by school physicians. No girls studied exhibited symptoms of acute or chronic disease. The chronological age of girls ranged from 11 to 14 years. 27.8% of the girls were 11 years old, 30.4% 12 years, 24.1% 13 years, and 17.7% 14 years old (mean age ±SD 12.3±1.1 years). Their height ranged from 140 to 173 cm (mean height ±SD 156.5±7.2 cm). According to the scale proposed by Tanner [9] for assessment of breast development, 25.0% of the girls were in stage 2, 42.1% in stage 3, 25.0% in stage 4, and 7.9% in stage 5.

X-ray pictures of the left hand and wrist were made at Tartu polyclinics. The size of 20 bones was measured independently by two technicians. They were informed neither about the aim of the study nor about other characteristics of the subjects.

The study design was approved by the Ethics Committee of the Medical Faculty of Tartu University.

Statistics. The obtained material was characterised by means of descriptive frequency analysis and by the comparison of individual data obtained with various scoring systems using the paired t-test. For testing correlations, Pearson product-moment correlation coefficient was computed. In order to find the significance of sexual maturation, the breast development stage number (a nonparametric measure) was plotted against other measures computing the Spearman correlation coefficient. Significance was evaluated by designating the 0.05 probability level as significant.

RESULTS

The distribution of individual data of skeletal age assessed by three scoring systems (Table 1) as well as the average values (Table 2) showed that the lowest values were obtained by CARPAL and the highest values by RUS. The average value obtained by TW-2 was close to the average chronological age, although the area of distribution of individual skeletal ages by TW-2 was more extended than the area of distribution of chronological ages (Table 1). The comparison of individual data by paired t-test (Table 2) confirmed significant differences between the results of assessment of skeletal age by TW-2, RUS and CAPRAL. Nevertheless, significant correlations were found between all the three measurements of skeletal age (Table 3). Chronological age did not correlate with any measurement of skeletal age, but breast development stage and height did (Table 3).

Table 1. Distribution of studied girls by chronological age and skeletal age, assessed by various methods

Age in years	Chronological age	Skeletal age		
		TW-2	RUS	CARPAL
8	0%	0%	0%	1.3%
9	0%	0%	0%	16.2%
10	0%	20.0%	2.5%	46.3%
11	27.8%	28.8%	2.5%	23.7%
12	30.4%	32.5%	33.8%	8.8%
13	24.1%	8.7%	33.7%	0%

Age in years	Chronological age	Skeletal age		
14	17.7%	3.8%	18.8%	0%
15	0%	3.7%	6.2%	0%
16	0%	2.5%	2.5%	3.7%

Table 2. Comparison of individual skeletal ages, assessed by three methods, and calendar age (paired t-test)

	Mean±SD (years)	TW-2 p	RUS p	CARPAL p
Skeletal age				
TW-2	11.9±2.2			
RUS	13.3±1.1	<0.001		
CARPAL	10.9±1.3	<0.001	<0.001	
Chronological age	12.1±1.6	N.S.	<0.001	<0.001

N.S. — non-significant

Table 3. Correlations between recorded values

	Chrono-logical age	Height	TW-2	RUS	CARPAL
Pearson coefficient					
Chronological age	xx				
Height	0.102	xx			
Skeletal age:					
TW-2	0.014	0.272[xx]	xx		
RUS	0.192	0.507[xxx]	0.434[xxx]	xx	
CARPAL	0.119	0.394[xxx]	0.323[xxx]	0.388[xxx]	xx
Spearman coefficient					
Breast development stage	0.240[x]	0.597[xxx]	0.395[xxx]	0.683[xxx]	0.394[xxx]

x p<0.05
xx p<0.02
xx p<0.001

Skeletal age lagged behind calendar age most frequently when assessed by CAPRAL. The percentage of respective girls increased with calendar age (Table 4) and advanced breast development (Table 5). Skeletal age showed acceleration as compared with the chronological age most frequently when assessed by RUS. The percentage of respective girls decreased with chronological age (Table 4) and advanced breast development (Table 5). When skeletal age was assessed by TW-2, the frequency of cases of satisfactory accordance with chronological age (difference ± 1 year) was between 63–68% at ages from 11 to 13 years (Table 4). However, this frequency was the highest in breast development stage 5 and the lowest in stage 2.

Table 4. Distribution of differences between chronological and skeletal ages (assessed by three scoring systems) in 11–14-year old girls

Chronological age (years)	TW-2			RUS			CARPAL		
	Skeletal age lagging behind more than 1 year	±1 year	Skeletal age in advance more than 1 year	Skeletal age lagging behind more than 1 year	±1 year	Skeletal age in advance more than 1 year	Skeletal age lagging behind more than 1 year	±1 year	Skeletal age in advance more than 1 year
11	0%	68%	32%	0%	9%	91%	36%	64%	0%
12	29%	67%	4%	4%	42%	54%	75%	25%	0%
13	28%	63%	9%	6%	36%	58%	89%	0%	11%
14	54%	38%	8%	7%	62%	31%	100%	0%	0%
Pooled data	24.0%	60.8%	15.2%	3.8%	35.4%	60.8%	70.9%	25.3%	3.8%

Table 5. Distribution of differences between chronological and skeletal ages (assessed by three scoring systems) in girls of various stages of breast development

Chronological age (years)	TW-2			RUS			CARPAL		
	Skeletal age lagging behind more than 1 year	±1 year	Skeletal age in advance more than 1 year	Skeletal age lagging behind more than 1 year	±1 year	Skeletal age in advance more than 1 year	Skeleal age lagging behind more than 1 year	±1 year	Skeletal age in advance more than 1 year
2	28%	36%	36%	9%	28%	63%	47%	53%	0%
3	32%	68%	0%	3%	42%	55%	74%	26%	0%
4	16%	68%	16%	0%	32%	68%	78%	11%	11%
5	0%	83%	17%	0%	17%	83%	100%	0%	0%

DISCUSSION

The obtained results demonstrated that the scoring system RUS gave systematically higher and CAPRAL lower skeletal age than TW-2, although all three measurements of skeletal age were in significant correlation. Obviously, "biological weights" for adjusting the measurements of various bones [11] did not account completely for the actual differences in skeletal maturation rate of individual bones in our contingent of girls.

The skeletal age was close to the chronological age when it was assessed by TW-2. Despite that, these two measurements did not correlate between themselves. However, breast development stage and height correlated significantly with all three measurements of skeletal age. Thus, our results are in accordance with previous data indicating the relationship between skeletal maturation and several manifestations of sexual maturation [2, 7]. The pubertal growth spurt is one of the typical manifestations of the sexual maturation process. Our finding of correlation between girls' height and skeletal age is in accordance with several results indicating the relationship between skeletal maturation and pubertal growth spurt [3, 5, 6, 7].

In conclusion, our result indicated that the most relevant information on skeletal age is provided by the scoring system TW-2. Our results also confirmed the relationship between skeletal and sexual maturation.

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THE EXTENT OF SEXUAL DIFFERENCES IN SOMATIC TRAITS AND MASS OF INTERNAL ORGANS IN HUMAN FOETAL LIFE

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ABSTRACT

To assess foetal sexual differences in somatic traits and mass of internal organs two methods of analysis were used: significance tests for measures of location (Student's t test and Welch test) and the Mollison relative deviation. The study data comprised a group of 3889 male and female foetuses at the age of 20 to 42 weeks of intrauterine life. The applied methods showed that in the foetal period the studied features begin to differentiate between the sexes. It was found that from the age of 22 weeks male foetuses gained higher values of somatic traits and mass of internal organs than females, although the extent of the differences was not the same during the entire period under study.

Key words: foetal sexual differences, human foetal life, mass of internal organs in foetal ontogenesis

INTRODUCTION

The divergence between men and women in the pattern of ontogenetic development and in morphologic build is the manifestation of sexual dimorphism. It is shaped during growth and becomes most pronounced at the end of the progressive phase of ontogenesis. It is quite well recognised in the entire postnatal development with respect to body dimensions, body proportions and also body tissue components. However, foetal sexual differences in somatic traits and mass of internal organs are still poorly understood, although their documentation has not only a cognitive value but is of practical importance too. To date, scientific opinions concerning this issue are divided, often equivocal or even inconsistent [9, 8, 12, 2]. In most recent literature works on this subject are lacking. Even if prenatal sexual dimorphism has been studied, only physiological and biochemical characteristics have been taken into account, while morphological traits have not been considered.

The adult form of sexually dimorphic characteristics is the outcome of a long and complex process of development, which begins early in the embryonic period and ends at adolescence. After a short period of identical growth, about the 35th day of intrauterine life, the anatomical and physiological differentiation of the male and the female genotype appears. This course of action is determined by a number of factors of genetic, hormonal as well as environmental nature. The genetic sex determined at conception gives the direction to the development of the gonadal sex, which in its turn affects the shaping of the phenotypic sex [10]. The sex-differences are not confined only to the so-called chromosomal sex and hormonally differentiated gonads and reproductive organs, but are also extended to a considerable number of other features showing the sex-dissimilarities, which are dependent on genes located on the autosomal chromosomes [5, 13].

The present paper is part of the study of sex-differences during human foetal development. The consecutive steps of our investigation reveal that sexual dimorphism appears in the dynamics and the level of development of morphologic traits, in developmental interrelationships between them and in the strength of reaction to non-genetic risk factors. The main purpose of this initial report is to assess the extent of sexual differences in somatic dimensions and mass of internal organs of human foetuses.

MATERIAL AND METHODS

The study material consisted of 3889 foetuses (2203 males and 1686 females) aged between 20 to 42 weeks of intrauterine life. It was obtained at the Institute of Gynaecology and Obstetrics of the Medical Academy in Poznań, in the years 1970–1990. The data include stillborns and newborns who died during the first 24 hours following birth. The reasons for foetuses' deaths were not known — that is foetuses with genetic defects, congenital malformations or a disease, which possibly might cause the miscarriage, were not selected for the study.

The analysis of sexual dimorphism in somatic traits (total body length, head-rump length, body weight, circumferences of the head, shoulder, chest and abdomen) and mass of the internal organs (of the brain, heart, lung, liver, spleen, kidney, adrenal gland, thymus) was carried out in weekly age groups. To estimate the extent of sex-differences the following procedures were used:

1. significance tests for measures of location — Student's t test and Welch test;
2. the method of Mollison relative deviation.

Since the significance Student's t test assumes homogeneity of variances in the groups under comparison, when the two variances for the male and female samples were statistically distinct, its alternative was performed, namely Welch test.

The Mollison relative deviation was calculated according to the formula:

$$\frac{\bar{x}♀ - \bar{x}♂}{s♂} \times 100 \text{ [Stęślicka 1958]}$$

The formula gives the difference between the means of a given trait for the male and female foetuses in percentage units of standard deviation for the males.

To show the developmental tendencies in sexual dimorphism of somatic traits and mass of the internal organs, the above measure of differences was graphed, using the biometrical profiles constructed as follows:

$$\frac{\bar{x}♀ - \bar{x}♂}{s♂} \pm \frac{s♀}{s♂}$$

The obtained profiles enabled us to evaluate the sex-differences in the foetal period separately for each characteristic (Fig. 1). If in the female foetuses a given trait is found to be greater than in the males, then its profile line is shifted to the right (+) to the arithmetic mean for the male sample, if the opposite is the case, the displacement to the left (–) represents lower values of a feature in the females. The biometrical profiles provide information not only on the normalised mean differences but also about the dispersion of the data around the mean. When S♀= S♂, then the profile lines are shifted by 1 to the male deviation, if S♀ > S♂, then the displacement is greater than 1, and S♀ < S♂ implies that it equals less than 1. Thus, the distances between the extreme profile lines and the centre line inform which of the sexes exhibit greater variability about the mean.

The average dimorphism of a given character in foetal ontogenesis D_{α} was represented graphically (Fig. 3) using the formula:

$$D_{s'} = \frac{\sum D_i}{N} \pm \frac{S♀}{S♂}; \quad S♀ = \sqrt{\frac{\sum (n_i - 1)S_i^2}{\sum (n_i - 1)}}; \quad S♂ = \sqrt{\frac{\sum (n_i - 1)S_i^2}{\sum (n_i - 1)}}$$

i	—	age groups i = 20,...42 week
N	—	the number of age groups
S♀, S♂	—	the common standard deviation for a given variable independent of age
S_i	—	the standard deviation for a given week
n_i	—	the numbers in a given week

Fig. 2 summarises the sex-difference (D_0) for all traits at each week of foetal ontogenesis, based on the formula:

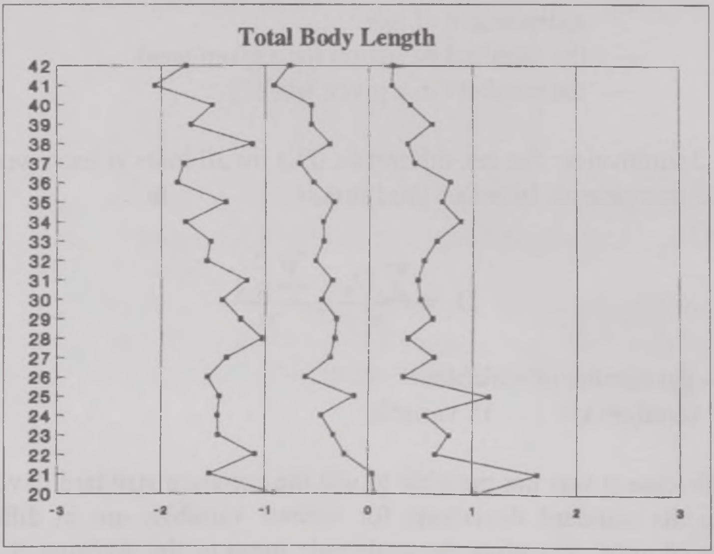
$$D_0 = \frac{\sum D_k}{N} \pm \frac{\sum \frac{S♀}{S♂}}{N}$$

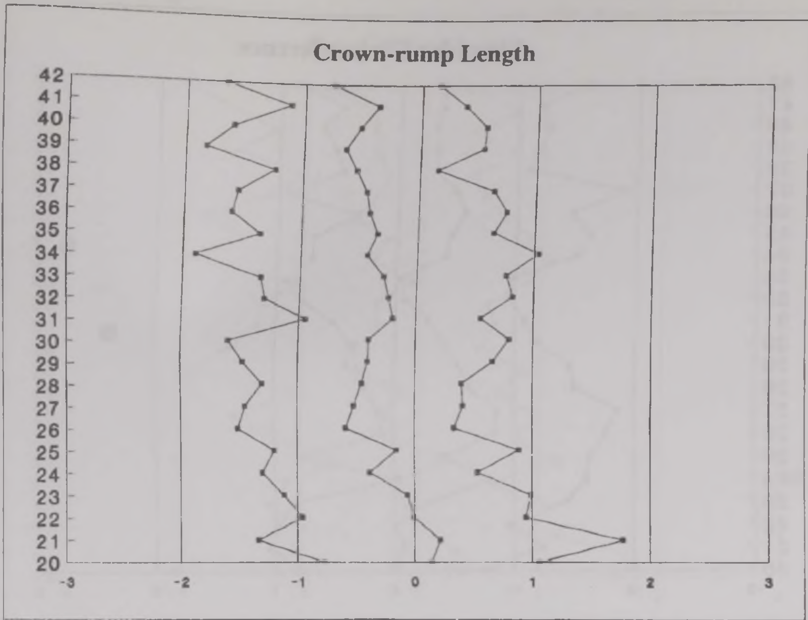
N — the number of variables
k — variables k = 1,...,15 variable

In this case it was not possible to use the common standard deviation since the standard deviations for various variables are in different kinds of units. Therefore the arithmetic mean of the divisions S♀/S♂ was applied (the division has no units of measurement).

RESULTS

The applied methods for evaluating the degree of sexual dimorphism turned out to be equally effective. According to them a feature is sexually dimorphic if the mean difference between the sexes exceeds 100% of the male standard deviation, or if the Student's t statistic is close to 10. The differences were found not to satisfy the above conditions, neither for the t values nor for the relative standard deviation (Fig. 1), except for the mass of the brain at the ages of 27 and 42 weeks and body mass at the age of 27 weeks. Therefore, despite statistically significant differences in most variables from the 27th week, the somatic traits and mass of internal organs show no evidence of sexual dimorphism during the intrauterine period between the 20th and 42nd weeks. There is a possibility that great dispersion of variables, characteristic of the foetal period, covers sexual dissimilarities even if the differences between the arithmetic means of these variables are quite large.

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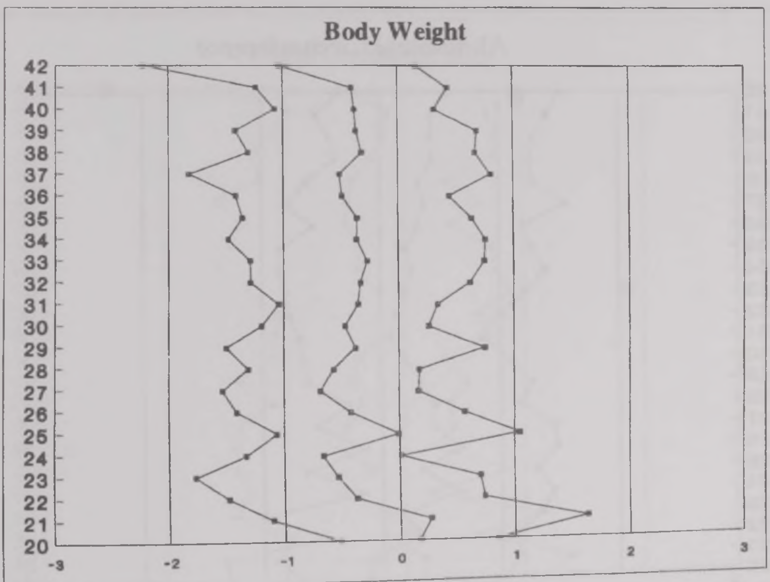
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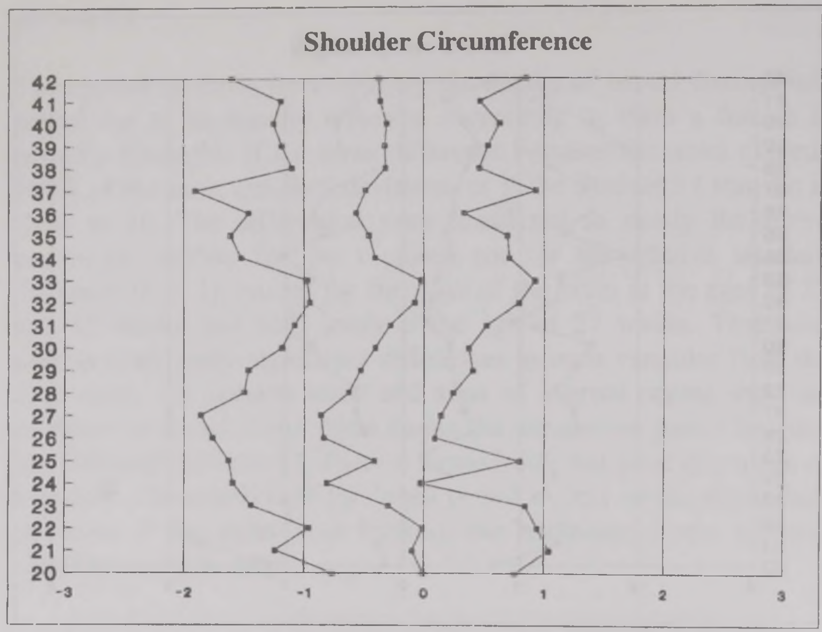
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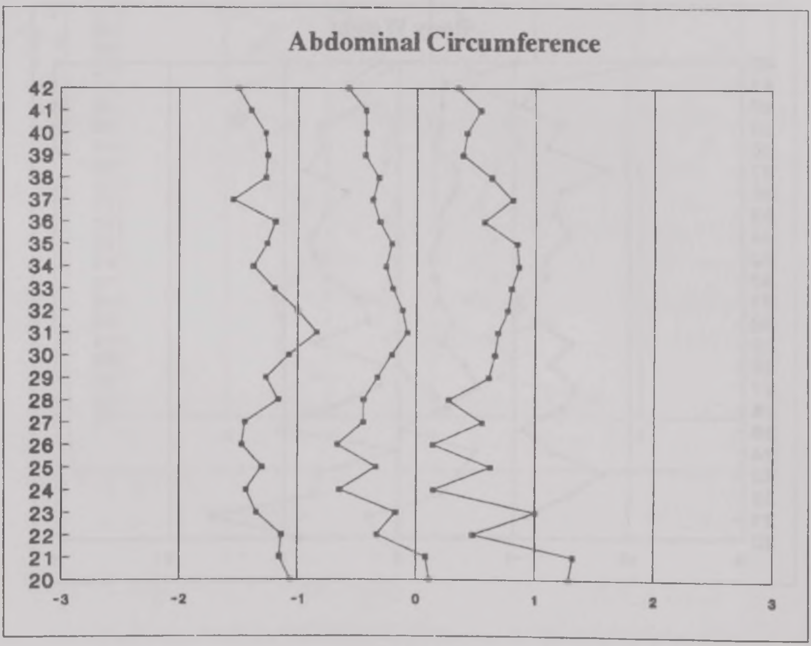
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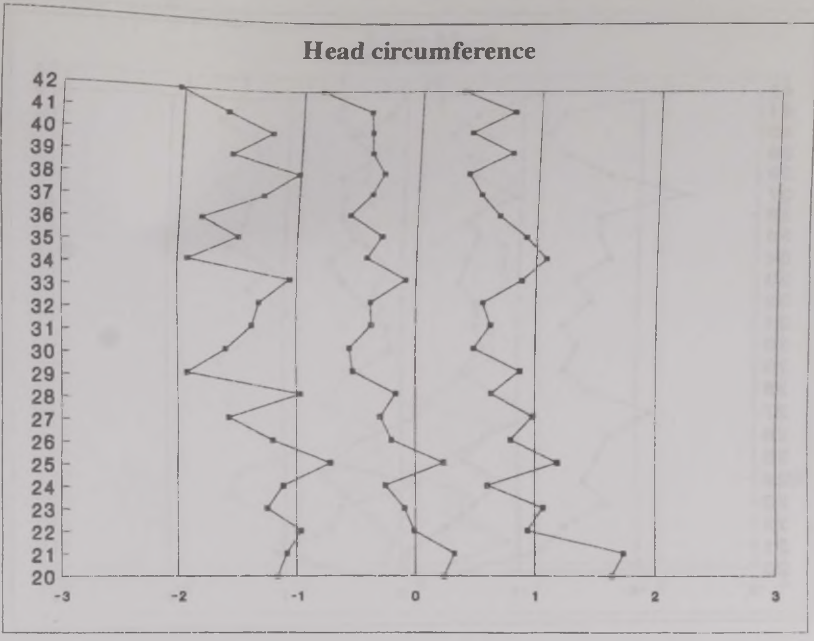
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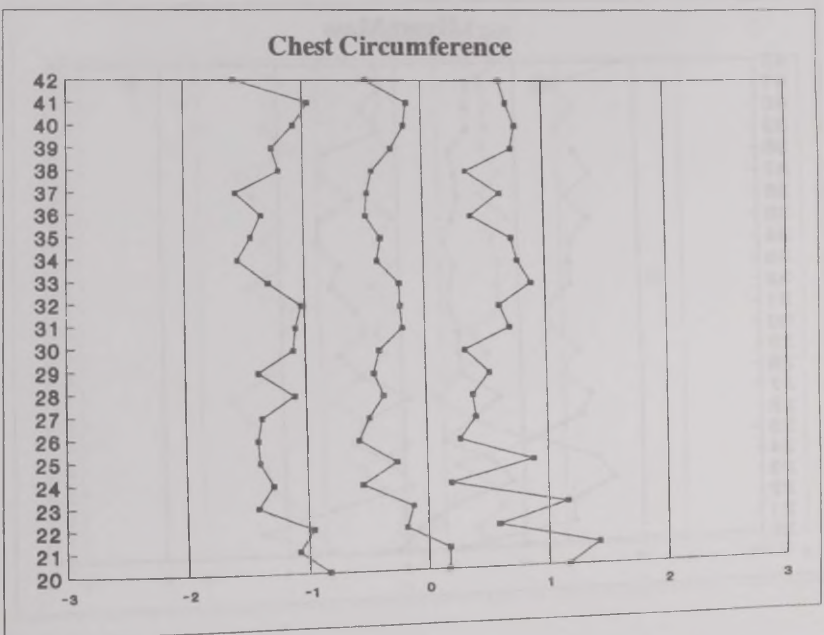
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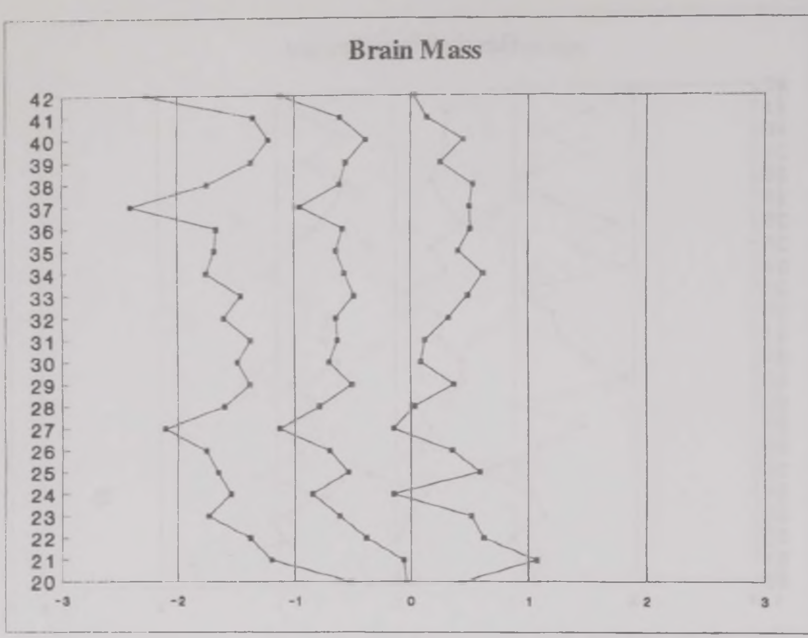
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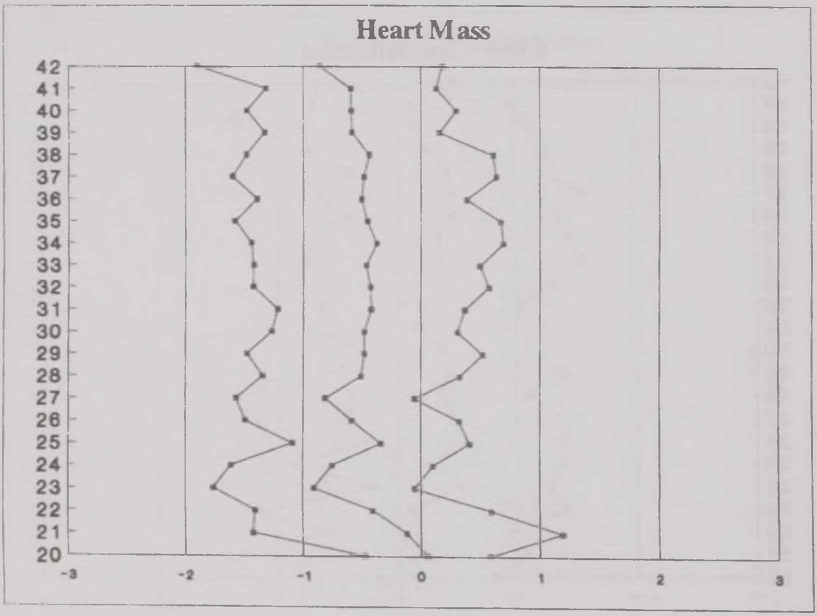
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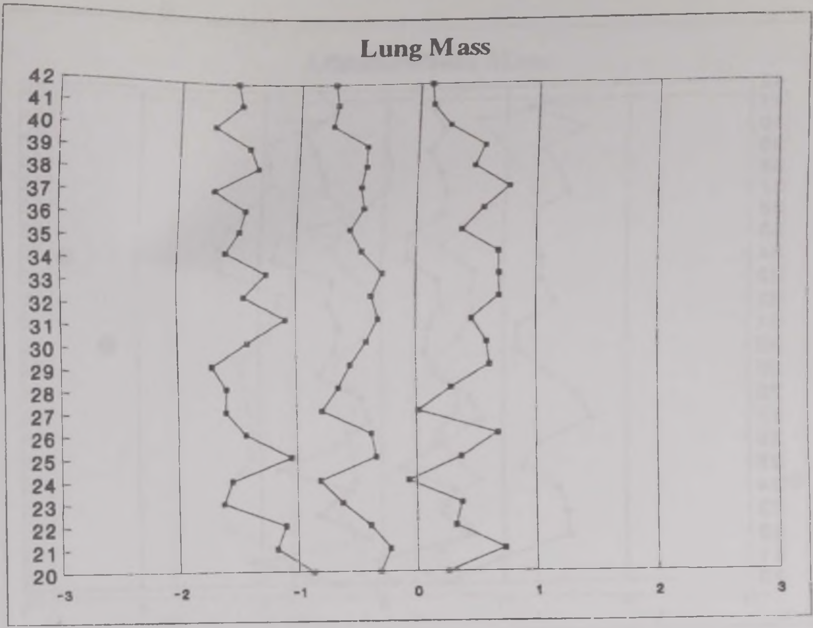
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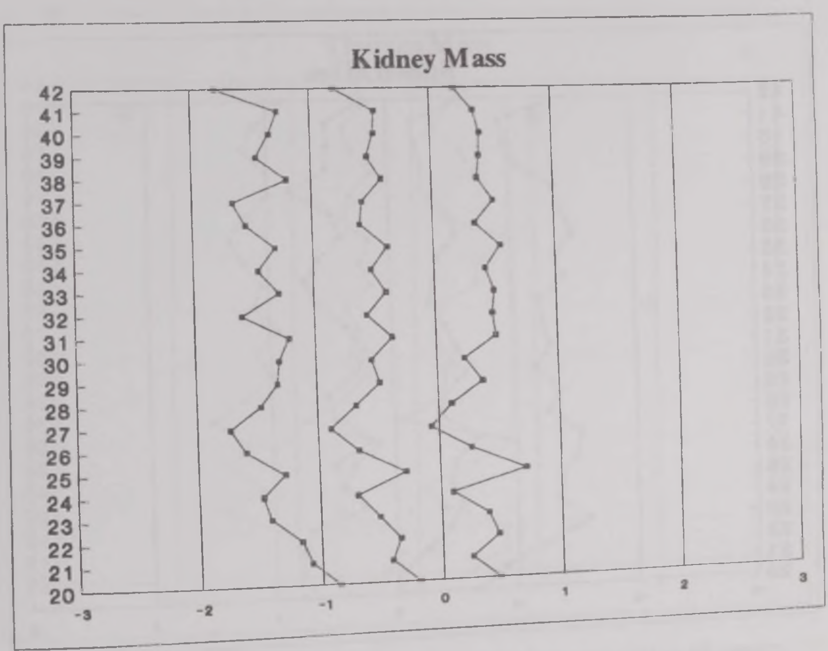
Kidney Mass
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41
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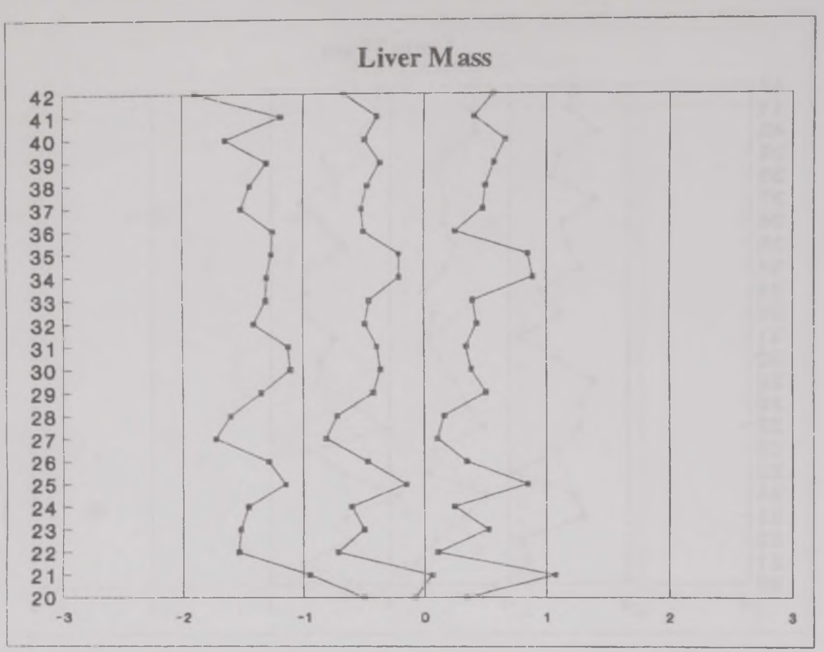
Liver Mass
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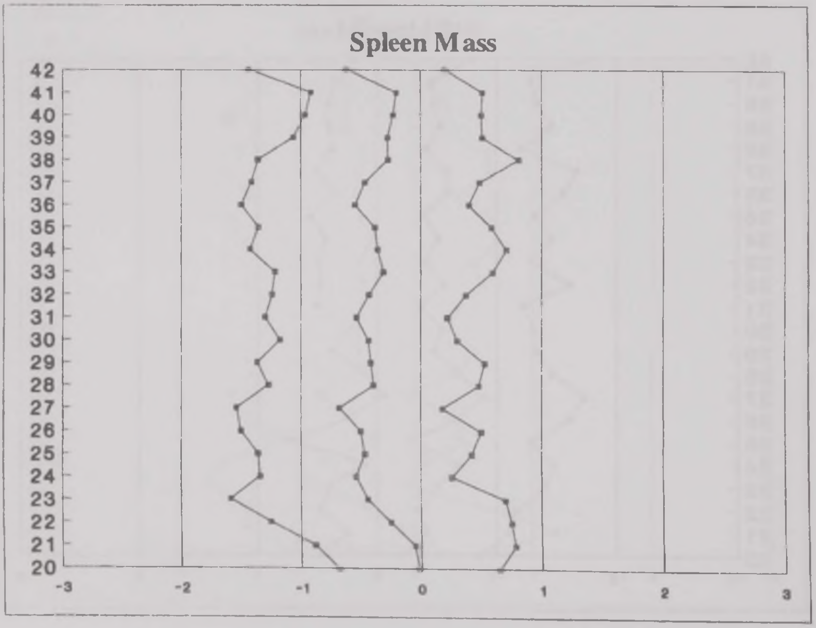
Spleen Mass
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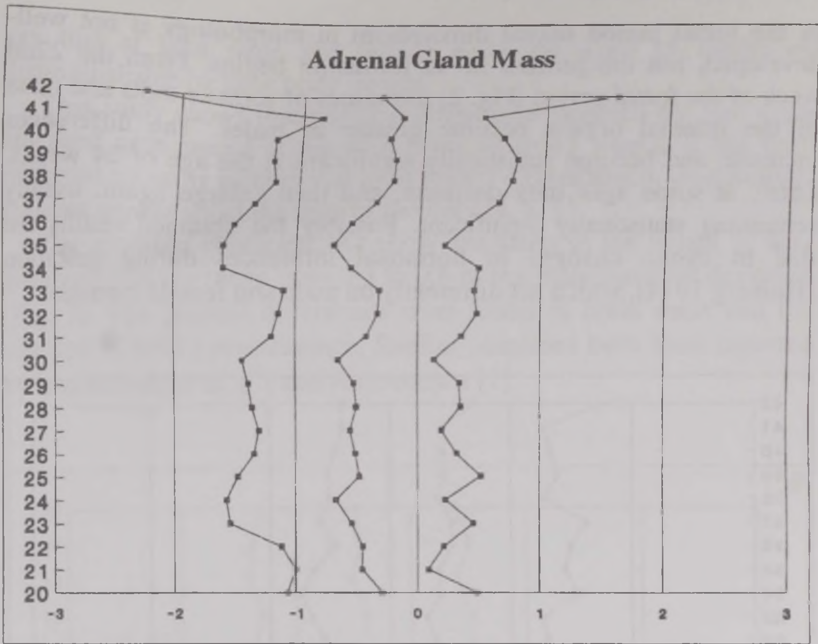

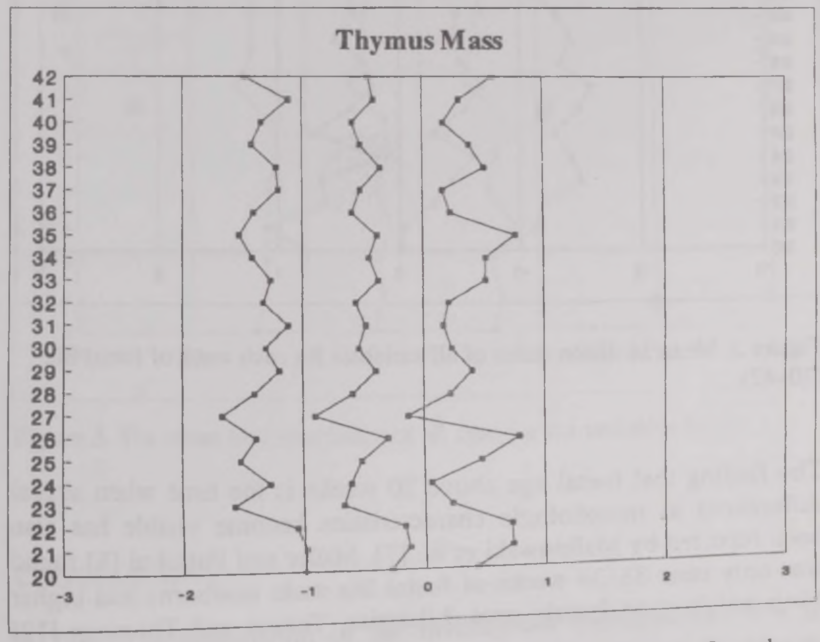

Figure1. Profiles of normalised variables (1–15) from ages 20 to 42 weeks.

In the foetal period sexual dimorphism in morphology is not well-developed, but the process of its formation begins. From the 22nd week of the foetal period (Fig. 2) the values of somatic traits and mass of the internal organs become greater in males. The differences increase, and become statistically significant at the age of 24 weeks. Later, at some ages they decrease, and then enlarge again, usually remaining statistically significant. Possibly the obtained results are due to cyclic changes in hormonal influences during gestation [Halberg 1974], which act differently on male and female foetuses.

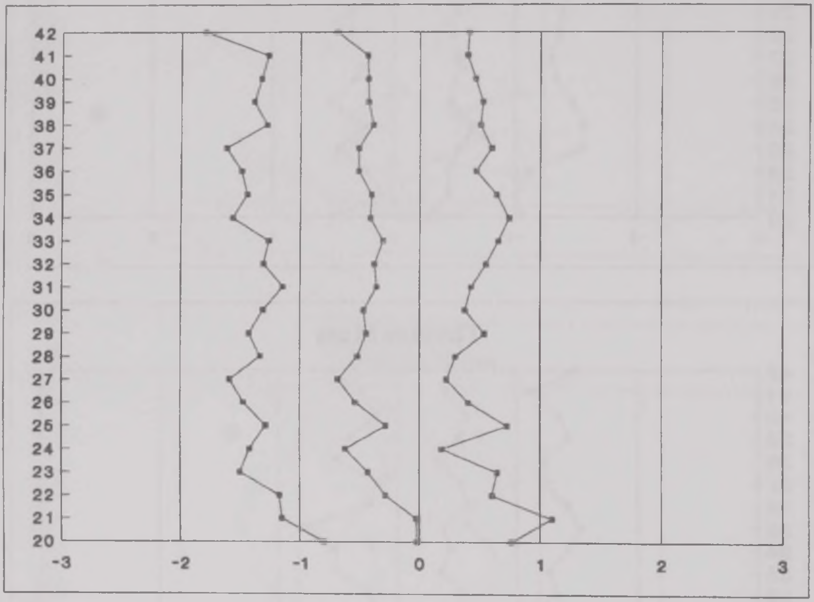

Figure 2. Mean Mollison index of all variables for each week of foetal life (20–42).

The finding that foetal age above 20 weeks is the time when sexual differences in morphologic characteristics become visible has also been reported by Malinowski *et al.* [7]. Miller and Futrakul [8] found that only after 33–34 weeks of foetal life male newborns had higher birth weight than female ones. Likewise, Tanner and Thomson [12] say that at least male and female newborns aged 35 weeks are distinguishable by their body weight.

This study shows that physical differences between the two sexes are most pronounced at the ages from 38 to 42 weeks. It has been observed by many authors that most sexual differences in morphologic features appear about the time of delivery [4, 3, 2].

The analysed characteristics show similarity in the extent of sex-differences. They range from 0.3 to 0.6 of the male standard deviation (Fig. 3). The greatest differences were found in brain mass and the smallest in head circumference. Similar outcomes have been reported by Malinowski *et al.* [7] and Andronescu [1].

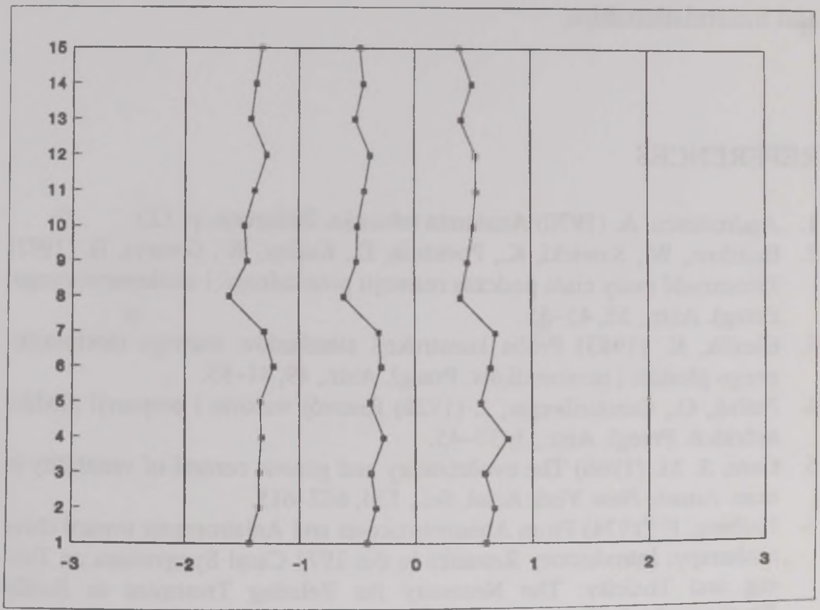

Figure 3. The mean Mollison index of all ages for the variables 1–15.

CONCLUSIONS

1. Sexual differentiation of the investigated characteristics has its onset in the foetal stage. From the age of 22 weeks of intrauterine life the male foetuses gained higher measurements of somatic

dimensions and mass of the internal organs than the females, although the extent of the differences was not the same during the entire period of foetal ontogenesis under study.
2. It was found that in the foetal period the mass of internal organs showed greater sexual dimorphism than somatic traits. The largest differences were observed in brain mass and the smallest in head circumference.
3. None of the studied features can be considered significantly sexually dimorphic.

With the obtained results the existence of sexual dimorphism in the foetal stage is only indicated. In our opinion a more thorough picture of sexual dimorphism could be discovered by comparing the male and female foetal characteristics in the context of their growth dynamics and interrelationships.

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