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1632

# Papers on anthropology

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PAPERS ON ANTHROPOLOGY
VIII

UNIVERSITY OF TARTU
CENTRE FOR PHYSICAL ANTHROPOLOGY

# PAPERS ON ANTHROPOLOGY

# VIII

TARTU 1999

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ISSN 1406–0140

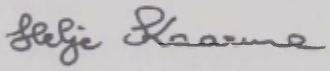
Tartu Ülikooli Kirjastuse trükikoda
Tiigi 78, Tartu 50410
Tellimus nr. 611

# PREFACE

Present-day anthropology with its numerous special branches has won an honourable place among other fields scientific and practical research. Nonetheless, all of us still have a lot of work ahead.

The University of Tartu and the Centre for Physical Anthropology carry on the tradition initiated by Prof. Juhan Aul — namely, we continue the systematic publication of papers on anthropology in Tartu.

We thank all the authors who have contributed to this collection and look forward to further cooperation with them in our following annual publications.



Prof. Helje Kaarma,
Head of the Centre for Physical Anthropology

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# DENTAL AND CRANIAL PATHOLOGIES IN TÄÄKSI $14^{TH}$–$18^{TH}$ CC. SKELETAL POPULATION

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ABSTRACT

It was possible to estimate pathological changes of 31 male, 27 female and 67 children's craniums. Pathologies may have different causes, they may be traumatic, age-related, environmentally induced (stress-markers) or caused by pathogenic micro-organisms. In this preliminary study macroscopic pathologies are just reported, the exact causes of the changes are not estimated.

## 1. MATERIAL AND METHODS

Description of Tääksi $14^{th}$ –$18^{th}$ cc. population in Middle-Estonia.

177 individuals were buried in Tääksi village cemetery during almost four centuries. 50% of children died before the age of 15 years; mortality of children was highest at the age of 3–4 years. Life expectancy at birth was 20.38 years; after the age of 45 years mortality of adults increased considerably. The size of the population that was buried in Tääksi cemetery during nearly 400 years was around 10 (one or two families). Measured by different methods, the average stature of men was 164.3–169.3 cm and of women 153.0–157.1 cm. The children of Tääksi were 15–20 cm shorter than present-day children in Estonia [1].

The material that was investigated for pathologies consists of 125 skeletons. The following macroscopic pathological changes are described:

1. Cranial lesions.
2. *Cribra orbitalia*.
3. Dental caries (caries of the crown and root neck area of the tooth).
4. Dental calculus (according to [3], three degrees).
5. Alveolar reduction (according [3], three degrees).

## 2. RESULTS

### *2.1. Cranial lesions*

Five craniums with injuries were found — four male and one female cranium. All injuries were healed (Table 1). Cranial lesions occurred in 17.9% of male skeletons and in 4.3% of female skeletons. Traumatic cranial lesions were more common in men; in Danish medieval population the incidences of cranial traumas were found on 5.9% of skeletons [2].

**Table 1.** Cranial lesions in Tääksi skeletal sample

| No | Age | Sex | Injured part of the cranium | Cause |
|---|---|---|---|---|
| XXVIII | 50.–55. years | female | Left side of the frontal bone, healed lesion. Circular depression. | ? |
| CLX | 50.–55. years | male | Left side of the frontal bone, healed lesion. | Strike by sharp instrument |
| LX | 60.–65. years | male | Left parietal and temporal bone, healed fissures. | Strike by blunt instrument |
| XXXI | 55.–65. years | male | Right side of the frontal bone, healed lesion. Circular depression. | ? |
| LXXXII | 30.–35. years | male | Left side of the frontal bone, partially healed. Diamond-shaped opening. (Traces of surgical treatment?) | Strike by sharp instrument |

### *2.2. Cribra orbitalia*

*Cribra orbitalia* is porosity of the bone tissue in the roof of the orbits. It refers to decreased values of red blood cells or low hemoglobin content in blood. Chronic diseases, blood loss, contaminated water, lack of iron in food and parasitic infections may cause *cribra orbitalia* [8, 10].

*Cribra orbitalia* was found in 36.3% of Tääksi skeletons. It was much more common in children and women (44.1% and 39.1%), than in men (7.1%).

In the Danish paleopopulation *cribra orbitalia* was present in nearly all the groups — in about 50% of children and in 10–20% of grown-ups. *Cribra orbitalia* was slightly more frequent in women than in men [2]. In South Carolina 19th century's population 36% of adults had *cribra orbitalia* [4].

### *2.3. Dental caries*

Dental caries is the most common and frequent disease of dental tissues. Dental caries is caused by the activity of bacteria, especially *Lactobacillus acidophilus* and *Streptococcus mutans*. If there is enough sugar in diet and appropriate association of bacteria in the dental plaque the favourable conditions for development of the dental caries are created [6].

In the Irish 17th–18th cc. Kilrush population, 21% had dental caries and in 16th c. Tintern population 58% suffered from dental caries [7].

In Tääksi 30.8% of the population suffered from dental caries (Table 2). The damages caused by caries in Tääksi population are high in comparison with Jõuga 11th–14th cc. population. In Jõuga population dental caries was found on 6.3% of skeletons [9].

It is worth mentioning that in Tääksi population dental caries of the root neck area mostly occurs together with the degeneration of alveolar bones. The accumulation of pathogenic bacteria in the region of the root neck of the tooth and degenerative changes of alveolar bones conduce to the development of the root neck caries. Caries of the root neck area is considerably more frequent in females (Table 2).

**Table 2.** Dental caries in Tääksi skeletal sample

| Group | Number of observed individuals | Caries of the tooth crown | Caries of the root neck area of the tooth | Both | Incidence of caries |
|---|---|---|---|---|---|
| Males | 21 | 4 | 5 | 4 | 61.9% |
| Females | 24 | | 15 | | 62.5% |
| Children | 59 | | 3 | 1 | 6.8% |
| Total | 104 | 4 | 23 | 5 | 30.8% |

### *2.4. Plaque and calculus*

Dental plaque consists of bacteria and proteins and it deposits faster if food contains sugar. Dental plaque may become calcified and change to dental calculus [8].

75% of Tintern 16th century's population in Ireland displayed calculus deposits [7].

Dental calculus occurred on 52.9% of Tääksi skeletons (Table 3). Considerable deposits of calculus were observed with degenerative changes of alveolar bones.

**Table 3.** Dental calculus in Tääksi skeletal sample

| Group | Number of observed individuals | Small amount | Medium amount | Large amount | Incidence of calculus |
|---|---|---|---|---|---|
| Males | 21 | 8 | 9 | 3 | 95.2% |
| Females | 24 | 7 | 9 | 1 | 70.8% |
| Children | 59 | 16 | 2 | | 30.5% |
| Total | 104 | 31 | 20 | 4 | 52.9% |

### *2.5. Alveolar reduction and periodontal disease*

Periodontal disease is an infection not only of the alveolar bone, but also of the soft tissues of the mouth [3]. Periodontal disease begins with the inflammation of the soft tissues of the mouth (gingivitis), which later spreads on to the bone tisssues, but not always. Chronic inflammation causes recession of the bone tissue, resulting in exposure of the roots of the teeth, loosening of the teeth and their loss. It has been suggested that periodontal disease is overdiagnosed on skeletons, because dental wear may also cause rising of the teeth [8]. The causes of exposure of the dental root are hard to determine, and therefore we call these changes degenerative changes of alveolar bones.

In Tääksi population 38.1% of the skeletons suffered from degenerative changes of the alveolar bone (Table 4). Alveolar reduction was slightly higher in Tääksi males than in females.

The Danish Middle Age population shows also higher alveolar reduction for women [2]. Chronic periodonditis was present in 71% of the Tintern 16th c. population and in 12% of the Kilrush 17th to 18th cc. population [7].

**Table 4.** Degenerative changes of alveolar bone in Tääksi skeletal sample

| Group | Number | Slight | Medium | Considerable | Incidence in population |
|---|---|---|---|---|---|
| Males | 22 | 5 | 4 | 10 | 86.4% |
| Females | 24 | 3 | 6 | 11 | 83.3% |
| Children | 59 | 1 | | | 1.7% |
| Total | 105 | 9 | 10 | 21 | 38.1% |

### *2.6. Chronic dental abscess*

Dental abscess may form in association with caries and periodontal disease. Inflammation of the tissues around the tooth roots is caused by bacteria. Bacteria gathered into the dental cavity or between the gum and the root neck of the tooth (in the case of periodontal infection) are intruding around the dental roots causing inflammation there [5].

Chronic dental abscess was found on 37.5% of the female, 45.5% of the male and 1.7% of the children's skeletons — in total in 20% of the Tääksi population.

In the Irish 16th c. Tintern population 38% had dental abscess [7].

## SUMMARY

Estonian population, especially in the southern parts of Estonia, suffered from a number of wars and famines, and also plague and other epidemics during the $14^{th}$–$18^{th}$ cc. This was a time of change that had a negative influence on the demographic situation and the health of the population.

High occurrence of *cribra orbitalia* (especially on children's skeletons) and different dental pathologies refer to the unfavourable environmental conditions — poverty, unsanitary living conditions and poor oral hygiene. Dental caries is frequent in Tääksi $14^{th}$–$18^{th}$ cc. population in comparison with Jõuga $11^{th}$–$18^{th}$ cc population. Dental calculus, degenerative changes of the alveolar bones, chronic dental abscess and caries of the tooth neck area were very characteristic of Tääksi population. Some craniums showed evidence of violence — traumatic lesions of the skull.

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# THE INFLUENCE OF OVERWEIGHT ON THE OUTCOMES OF EARLY CARDIAC REHABILITATION IN PATIENTS AFTER SURGICAL REVASCULARISATION OF MYOCARDIUM AND ACUTE MYOCARDIAL INFARCTION

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ABSTRACT

**Objective:** To estimate the change in the indices of functional capacity, cardiorespiratory reserve and metabolic indices during a formal II-phase comprehensive cardiac rehabilitation programme in overweight (BMI larger than 27) compared with normal-weight (BMI less or equal to 27) patients with coronary artery disease (CAD).
**Design:** Prospective randomised study.
**Participants:** 47 male patients who had undergone surgical revascularisation of the myocardium either by coronary artery bypass surgery (CABS) or percutaneous transluminal coronary angioplasty (PTCA) or/and acute transmural myocardial infarction (AMI).
**Measurements:** cardiopulmonary exercise test was performed and blood lipids were measured before and after a 12-week complex rehabilitation programme. The indices of cardiorespiratory reserve and exercise capacity with simultaneous ECG registration were assessed at rest, at anaerobic threshold and at maximal load.
Results: The essential indices of exercise capacity and cardiorespiratory reserve revealed remarkable improvement in both subsets: peak oxygen consumption increased 17.1±24.9% in the overweight subset and 24.4±27.6 in the normal-weight subset, maximal exercise capacity, 35.9±37.0% and 18.1±23.7%, exercise capacity at anaerobic threshold, 35.5±44.5% and 5.6±24.8%, respectively.
**Conclusions:** Complex cardiac rehabilitation in the early period after AMI and/or surgical revascularisation of the myocardium improves significantly the essential indices of exercise capacity and cardiorespiratory reserve in overweight patients but does not influence plasma lipid level. Aerobic exercise training on the veloergometer using indi-

vidualised intensity is optimal and safe also for overweight patients with severe CAD. To reduce weight and to improve plasma lipid profile, measurements of daily total caloric consumption, dietary fat, and nutritients should be assessed at baseline and followed up for change in defined periods over time.

**Key words:** coronary artery disease, overweight, complex cardiac rehabilitation

## INTRODUCTION

Overweight has been established as an independent risk factor for development of coronary artery disease (CAD) [1]. Because of the well-known differences in common laboratory risk indices for CAD [2, 3] between normal-weight and overweight patients one could assume different changes in metabolic parameters, indices of exercise capacity and cardiorespiratory reserve in cardiac rehabilitation in the two subgroups. However, the effects of exercise therapy and cardiac rehabilitation in overweight patients with CAD have not been sufficiently studied. The aim of the study was to estimate changes in the indices of functional capacity, cardiorespiratory reserve and metabolic indices during a formal II-phase comprehensive cardiac rehabilitation programme in overweight compared with normal-weight patients.

## MATERIALS AND METHODS

The study was designed as a prospective randomised study with enrolment of 47 patients who had undergone surgical revascularisation of the myocardium either by coronary artery bypass surgery (CABS) or percutaneous transluminal coronary angioplasty (PTCA) or/and acute transmural myocardial infarction (AMI). We compared the benefits of a medically supervised cardiac rehabilitation and exercise training programme in overweight male patients (BMI larger than 27, with mean age 60.2±8.4 years) and benefits in normal-weight patients (body mass index less or equal to 27, mean age 63.9±7.5 years) [4, 5]. The clinical data of the patients are presented in Table 1.

The patients underwent bicycle cardiopulmonary testing before and after a rehabilitation programme, while the functional indices of cardio-

respiratory system were measured (gas-analyser *Oxycon Record, Erich Jaeger* Company, 1993); ECG registration in 12 standard leads and arterial blood pressure were simultaneously registered at each 1 minute. Exercise test was performed using stepwise increasing workload by 10 watts per minute ( Ergometer *Siemens Elema*, 1990) with an initial load of 40 watts. Ventilatory anaerobic threshold (AnTh) was determined considering the main criteria described by Wassermann *et al.* (6). The patients' subjective level of exertion was quantified at each 1 minute using the Borg 1–10 scale [7]. Blood lipids (total cholesterol, HDL-cholesterol and triglycerides) were measured before and after 12-week rehabilitation after an overnight fasting period.

**Table 1.** Clinical characteristics of the two subsets

| | overweight n=24 | normal n=23 |
|---|---|---|
| Only AMI in previous history | | 1 |
| CABS and AMI in previous history | 11 | 13 |
| Only CABS in previous history | 7 | 4 |
| Only PTCA in previous history | 2 | 3 |
| PTCA and AMI in previous history | 4 | 2 |

Three to six weeks after surgery or AMI, the patients started with exercise therapy three times a week with a duration of 50 minutes and overall length of 12 weeks. The session consisted of three principal parts according to a classical scheme: warm-up period of 5–10 minutes, aerobic exercise of 20–30 minutes and cool-down of 5–10 minutes. Aerobic training was performed on the bicycle at the intensity level of submaximal energy expenditure according to the methodology described in detail elsewhere [8]. The rehabilitation programme included regular education sessions twice a month on CAD risk factor reduction.

## STATISTICAL ANALYSIS

Statistical analysis was performed by using the computer software package STATISTIGA. Data were expressed as mean values ±SD. The Kolmogorov-Smirnov test was employed when comparing non-parametric variables between and within groups. The p-values $\leq 0.05$ were considered statistically significant.

## RESULTS

Complete metabolic and cardiorespiratory pre-rehabilitation data for the overweight and normal-weight cohort were available at baseline (see Table 2).

**Table 2.** Metabolic characteristics of the overweight and the normal-weight study groups

| | Overweight | Normal | p |
|---|---|---|---|
| BMI | 29.8±2.7 | 24.4±1.8 | p<0.05 |
| CHOL | 5.9±1.7 | 6.1±1.0 | p=n.s. |
| TRIGL | 2.0±1.2 | 1.7±1.0 | p=n.s. |
| HDL | 1.2±0.2 | 1.3±0.3 | p=n.s. |

BMI — body mass index (kg/m$^2$), CHOL — total serum cholesterol (mmol/l), TRIGL — serum triglycerides (mmol/l), HDL — high density serum lipoprotein cholesterol (mmol/l)

The mean values of total plasma cholesterol for both groups exceeded the normal values to a quite similar extent, while the values of the other indices of lipid profile remained within normal limits.

Table 3 presents the resting values of cardiorespiratory function. Pre-test systolic blood pressure in both subsets was somewhat higher than normal while diastolic blood pressure remained at the upper limit in the group of overweight patients and within normal values in the group of normal-weight subjects. No statistically significant difference occurred in the values of arterial blood pressure between the two cohorts.

**Table 3.** Resting values of cardiorespiratory function

| | Overweight | Normal | p |
|---|---|---|---|
| $HR_{rest}$ | 78.9±11.5 | 77.7±14.5 | n.s. |
| $BPsyst_{rest}$ | 148.3±25.7 | 145.3 | n.s. |
| $BPdiast_{rest}$ | 87.3±14.5 | 83.2±13.2 | n.s. |
| $Ve_{rest}$ | 15.2±2.5 | 14.4±3.8 | n.s. |

$HR_{rest}$ — heart rate at rest (beats/min), $Bpsyst_{rest}$ — systolic blood pressure at rest (mm/Hg), $Bpdiast_{rest}$ — diastolic blood pressure at rest (mm/Hg), $Ve_{rest}$ — ventilation at rest (l/min)

For indices of cardiorespiratory function at AnTh, see Table 4. Evident differences were noted in $Ve_{AnTh}$, $\dot{V}O_{2\ AnTh}$ and $O_2\ pulse_{AnTh}$ where the indices were significantly higher in the case of overweight subjects while exercise capacity and oxygen consumption per kilogram of body mass revealed insignificantly higher levels in the same subset. The oxygen cost of work response relative to the work rate revealed significantly higher values in the overweight subgroup. Anaerobic metabolism occurred slightly later in overweight patients.

**Table 4.** Indices of cardiorespiratory function at AnTh

| | Overweight | Normal | p |
|---|---|---|---|
| $HR_{AnTh}$ | 105.7±13.0 | 114.2±16.7 | n.s. |
| $W_{AnTh}$ | 90.0±24.7 | 84.7±28.2 | n.s. |
| $Ve_{AnTh}$ | 49.3±10.5 | 39.5±6.4 | <0.05 |
| $\dot{V}O_{2\ AnTh}$ | 14.2±3.1 | 13.6±3.5 | n.s. |
| $\dot{V}O_{2\ AnTh}$ | 1294.3±304.8 | 1005.6±266.5 | <0.05 |
| $O_2\ pulse_{AnTh}$ | 12.3±2.8 | 8.9±2.1 | <0.05 |
| $\dot{V}O_{2AnTh}/\ W_{AnTh}$ | 14.9±3.3 | 12.3±2.1 | <0.05 |
| $TIME_{AnTh}$ | 5.5±2.4 | 5.1±2.9 | n.s. |

$HR_{AnTh}$ — heart rate at AnTh (beats/min), $W_{AnTh}$ — work at AnTh (W), $Ve_{AnTh}$ — ventilation at AnTh (l/min), $\dot{V}O_{2AnTh}$ — oxygen consumption at AnTh (ml/min/kg), $\dot{V}O_{2\ AnTh}$ — total oxygen consumption at AnTh (ml/min), $O_2\ pulse_{AnTh}$ — oxygen pulse at anaerobic threshold (ml), $\dot{V}O_{2AnTh}/W_{AnTh}$ — the oxygen cost of work response relative to work rate at AnTh (ml/min/W), $TIME_{AnTh}$ — time of gaining AnTh (min)

Table 5 gives the peak values of cardiorespiratory function. Several indices of cardiorespiratory reserve and exercise capacity revealed higher values in the cohort of overweight subjects, reaching statistical difference in $Ve_{max}$, $Peak\dot{V}O_2$, Peak $\dot{V}O_2/W_{max}$ and $O_2\ pulse_{max}$. Maximal heart rate and systolic blood pressure remained at a nearly similar level in both groups.

After cardiac rehabilitation, no changes occurred in body mass index and plasma lipids in either subset. Statistically significant improvement in the essential indices of cardiorespiratory reserve and exercise capacity was noted in both cohorts.

Table 6 shows improvement in the indices of cardiorespiratory function and exercise capacity in the complex cardiac rehabilitation program. The essential indices of exercise capacity and cardiorespira-

tory reserve demonstrated remarkable improvement in both subsets. However, the favourable change occurring within the complex rehabilitation programme was more uniform in the cohort of normal-weight patients.

**Table 5.** Peak values of cardiorespiratory function

| | Overweight | Normal | p |
|---|---|---|---|
| $HR_{max}$ | 118.4±11.9 | 121.0±22.0 | n.s. |
| $BPsyst_{max}$ | 199.2±28.5 | 196.4±32.6 | n.s. |
| $BPdiast_{max}$ | 104.8±18.4 | 93.8±14.9 | n.s. |
| $W_{max}$ | 103.8±26.5 | 93.9±31.6 | n.s. |
| $Ve_{max}$ | 59.0±15.1 | 47.3±14.5 | <0.05 |
| Peak $\dot{V}O_2$ | 16.1±3.7 | 14.7±4.0 | n.s. |
| Peak $\dot{V}O_{2\,max}$ | 1475.3±330.1 | 1085.1±310.3 | <0.05 |
| Peak $\dot{V}O_{2\,max}/W_{max}$ | 14.5±2.8 | 12.0±2.3 | <0.05 |
| $O_2\,pulse_{max}$ | 12.5±2.6 | 9.0±2.6 | <0.05 |

$Hr_{max}$ — maximal heart rate (beats/min), $Bpsyst_{max}$ — maximal systolic blood pressure (mmHg), $Bpdiast_{max}$ — maximal diastolic blood pressure at (mmHg), $W_{max}$ — maximal work capacity (W), $Ve_{max}$ — maximal ventilation (l/min), Peak $\dot{V}O_2$ — individual maximal oxygen consumption (ml/min/ kg), Peak $\dot{V}O_{2max}$ — maximal total oxygen consumption (ml/min), Peak $\dot{V}O_{2\,max}/W_{max}$ — the oxygen cost of work response relative to work rate at maximal load (ml/min/W), $O_2\,pulse_{max}$ — maximal oxygen pulse (ml)

**Table 6.** Improvement in the indices of cardiorespiratory function and exercise capacity in the complex cardiac rehabilitation program

| | Overweight | | | Normal | | | |
|---|---|---|---|---|---|---|---|
| | Δ | Δ (%) | p* | Δ | Δ (%) | p* | p** |
| $W_{AnTh}$ | 28.3±32.3 | 35.5±44.4 | <0.05 | 3.1±21.8 | 5.6±24.8 | =0.1 | n.s. |
| $VO_{2\,AnTh}$ | 1.7±3.9 | 12.7±27.8 | =0.6 | 2.9±4.4 | 22.6±32.7 | <0.05 | n.s. |
| $\dot{V}O_{2\,AnTh}$ | 160.4±401.6 | 13.6±28.6 | =0.3 | 211.0±304.7 | 22.7±32.2 | <0.05 | n.s. |
| $\dot{V}O_{2AnTh}/W_{AnTh}$ | −2.2±4.9 | −8.8±35.5 | <0.05 | 4.1±14.3 | 42.8±150.1 | <0.05 | <0.05 |
| $O2\,pulse_{AnTh}$ | 1.6±2.6 | 13.8±22.7 | =0.1 | 2.1±3.2 | 27.2±39.7 | <0.05 | n.s |
| $W_{max}$ | 32.1±31.9 | 35.9±37.0 | <0.05 | 16.1±22.3 | 18.1±23.7 | <0.05 | n.s. |
| $Ve_{max}$ | 5.0±11.8 | 11.5±23.0 | =0.07 | 5.8±11.3 | 15.0±24.3 | <0.05 | n.s. |
| Peak $\dot{V}O_2$ | 2.4±3.4 | 17.1±24.9 | <0.05 | 3.1±3.7 | 24.4±27.6 | <0.05 | n.s. |
| Peak $\dot{V}O_2$ | 236.7±312.8 | 18.0±24.4 | <0.05 | 233.0±279.0 | 24.5±27.4 | <0.05 | n.s |
| Peak $\dot{V}O_2/W_{max}$ | −1.8±3.4 | −9.0±22.5 | <0.05 | 0.7±2.5 | 6.9±20.3 | <0.05 | <0.05 |
| $O_2\,pulse_{max}$ | 1.5±2.5 | 12.6±22.0 | <0.05 | 1.2±2.4 | 17.7±30.0 | <0.05 | n.s. |

p* describes the statistical significance of improvement before and after rehabilitation within the group

p** describes the statistical significance of the difference in rehabilitation efficiency between the groups

## DISCUSSION

Data regarding the effects of early cardiac rehabilitation in overweight patients with severe ischemic heart disease are quite limited. The present report demonstrated significant improvement in the indices of exercise capacity and cardiorespiratory reserve, but not on the level of blood lipids and body mass index, in a cohort of overweight coronary patients. The studies of Lavie and Milani showed improvement in most coronary risk factors in overweight patients, including reduction of BMI and favourable modifications in lipid profile, although improvement in exercise capacity was more appreciable in normal-weight patients [5, 9]. In the present study favourable changes in exercise capacity were more expressed in the subset of overweight patients. At the same time, a trend of increase in the indices of oxygen consumption after a 12-week rehabilitation programme was more pronounced in normal-weight subjects. The described differences between the two groups did not reach statistical significance. Overweight patients demonstrated more evident and statistically significant improvement in exercise economy compared with normal-weight subjects. However, the initial values of $\dot{V}O_{2AnTh}/W_{AnTh}$ and $Peak\dot{V}O_2/W_{max}$ were significantly higher in the overweight cohort and hence the favourable decline relatively more remarkable. In both subsets cardiac rehabilitation resulted in significantly improved exercise capacity and fitness which, according to the data of Blair and co-authors, predicts improvement in all-cause mortality [10]. Moreover, the greatest relative benefit of higher fitness levels was observed among more obese subjects [10–12]. Although some of the improvement in exercise capacity may be attributed to spontaneous recovery after a cardiac event, [13] the large and highly significant change in exercise tolerance among overweight patients was noteworthy.

For death from myocardial infarction, triglyceride levels and waist/hip ratios served as significant risk factors, while neither BMI nor total cholesterol levels showed significant predictive values [14]. Several studies have shown that it is not weight (mass) which causes the obesity problems but rather the amount of adipose tissue an individual has, as well as its distribution [12, 15]. These facts underline the need to assess not only simple height-weight measurements but also other reliable anthropometric indices of weight and body composition like the waist/hip ratio and percentage of body fat, which should be estimated at baseline and after rehabilitation [5, 12]. Weight loss is associated with significant decrease in arterial pressure, left

ventricular hypertrophy and insulin resistance [16–18]. In addition, Wood and colleagues [19] have demonstrated that weight reduction with either exercise or dietary caloric restriction has beneficial effects on plasma HDL- and triglyceride levels. Our data support the suggestion that for favourable alteration of lipid profile, the dietary aspects of CHD should be handled separately, and daily caloric intake and expenditure have to be balanced in order to reduce body mass in overweight patients. However, the data from the Cooper Institute for Aerobic Research indicate that overweight patients may gain health benefits from improvement in fitness levels without considerable change in weight [10, 11].

Despite the relatively short interval between a cardiac event or surgical procedure and onset of rehabilitation, no adverse effects arising from regular physical effort occurred either in overweight or normal-weight patients. Thus, moderate aerobic training appears to have an optimal effect on the indices of cardiorespiratory reserve and exercise capacity in overweight coronary patients during early cardiac rehabilitation.

## CONCLUSIONS

Complex cardiac rehabilitation in the early period after AMI and/or surgical revascularisation of the myocardium improves significantly the essential indices of exercise capacity and cardiorespiratory reserve in overweight patients but does not influence plasma lipid level. Overweight does not appear to have adverse effects on the results of a formal rehabilitation programme. Moreover, aerobic exercise training on the veloergometer using individualised intensity is optimal and safe also for overweight patients with severe CAD. To reduce weight and to improve plasma lipid profile, measurements of daily total caloric consumption, dietary fat, and nutritients should be assessed at baseline and followed up for change in defined periods over time.

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# SOMATIC ASYMMETRY OF SWIMMERS *VERSUS* UNTRAINED SUBJECTS

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ABSTRACT

Somatic asymmetry was studied in 8 male and 9 female swimmers, as well as in 6 male and 14 female control subjects by determining the relative asymmetry index (RAI) for various anthropometric measurements. Asymmetry was much more pronounced in the control groups than in swimmers. In the females, all indices except for ankle width were significant in the control subjects, while in swimmers only the index for thigh girth was significant. In the males, significant indices were found for thigh and arm girths, foot width and elbow width in the control subjects, while in swimmers — only for calf girth. In none of the groups significant asymmetry for upper or lower extremities was found. Highest significant asymmetry was found in control subjects for wrist width (1.15% in men and 2.89% in women). In swimmers, the highest significant values did not exceed 0.6%. Skinfold thickness (not discussed above) showed asymmetry both in controls and swimmers, in addition it varied very highly. In conclusion, swimming seems to be extremely effective in reducing somatic asymmetry in young males and females.

## INTRODUCTION

Asymmetry of the human body has long been a subject of interest not only for anthropologists [5] but also for specialists in sports coaching, rehabilitation, etc. [1, 4]. Anatomical asymmetry, which develops with age due to the functional sidedness of the body, may be seriously enhanced by practising some sports, e.g. tennis or shooting [7]. Conversely, some sports, classified as symmetrical ones, may be expected to reduce anatomical asymmetry. Swimming may be regarded as a

good example [8] since buoyancy facilitates movements which are of particular importance when correcting, for example, faulty posture.

Marked somatic and functional asymmetry has been reported in children aged up to 10 years, whether practising swimming or not [2, 3], but no reports were found in the available literature concerning youths or adults. The aim of this study was thus to determine possible differences between swimmers and untrained subjects regarding selected anthropometric measurements.

## MATERIAL AND METHODS

The study was conducted on 8 male and 9 female swimmers aged 16–21 years. They were members of various sports clubs and were holders of the first official rating in sports. Their training experience ranged from 4 to 13.5 years, and they practised various swimming styles. The control group consisted of 6 male and 14 female students of a secondary school, aged 16–17 years. The mean values of their age, body height and mass are presented in Table 1.

**Table 1.** Mean values (±SD and ranges) of age, body height and mass of swimmers and control subjects

| | Men (n=6) | | Women (n=14) | |
|---|---|---|---|---|
| | Mean ±SD | Range | Mean ±SD | Range |
| **Control subjects** | | | | |
| Age (years) | 16.2±0.4 | (16–17) | 16.4±0.5 | (16–17) |
| Body height (cm) | 175.5±3.4 | (169–179.4) | 163.2±3.7 | (157–167) |
| Body mass (kg) | 66.8±4.1 | (60–72) | 54.6±2.9 | (51–59.5) |
| **Swimmers** | | | | |
| Age (years) | 18.3±2.0 | (16–21) | 17.3±1.9 | (16–20) |
| Body height (cm) | 180.2±7.0 | (171–192) | 170.9±4.6 | (161–176) |
| Body mass (kg) | 72.4±4.9 | (68–80.5) | 59.7±2.4 | (56–63.5) |
| Training experience (years) | 8.6±3.3 | (4–13.5) | 7.8±2.9 | (5.5–13) |

The following anthropometric measurements were performed: lengths of upper and lower extremities and of the foot; girths of the arm, forearm, thigh and calf; widths of the wrist, elbow, foot, ankle and knee;

thickness of two skinfolds (on the arm and calf). All measurements were taken with an accuracy of 0.1 mm.

The relative asymmetry index (RAI) was determined by the formula: $RAI = 100 \times (r-l)/l$ [4], where '*r*' and '*l*' stand for 'right' and 'left', respectively. The significance of RAI values was determined by Student's t-function: $t=RAI/S_{RAI}$, where $S_{RAI}$ is the standard error of the index.

The differences between the groups were assessed by using Student's t-test for independent data, the level of $P \leq 0.05$ being considered significant.

## RESULTS

The mean values of anthropometric measurements and the relative asymmetry indices are presented in Tables 2 and 3.

**Table 2.** Absolute anthropometric values of dominant extremities and relative asymmetry indices (means±SD) in male swimmers and control subjects

| Group | Controls (n=6) | | Swimmers (n=8) | |
|---|---|---|---|---|
| Variable | (cm) | RAI (%) | (cm) | RAI (%) |
| Lower limb length | 92.4±2.4 | 0.01±0.04 | 97.9±9.3 | 0.01±0.03 |
| Upper limb length | 76.2±1.8 | 0.13±0.12 | 80.7±3.3 | 0.00 |
| Thigh girth | 53.6±2.5 | 0.76±0.23* | 53.3±2.1 | 0.25±0.33# |
| Calf girth | 36.0±1.0 | 0.51±0.59 | 37.0±2.3 | 0.26±0.24* |
| Forearm girth | 23.9±1.2 | 0.97±0.95 | 27.7±3.6 | 0.41±0.53 |
| Arm girth | 25.2±2.1 | 1.14±0.69* | 29.8±1.0 | 0.51±0.63 |
| Foot length | 26.6±0.42 | 0.76±0.64* | 26.8±1.1 | 0.05±0.13# |
| Foot width | 9.95±0.35 | 2.68±3.93 | 9.71±0.53 | 0.55±0.86 |
| Ankle width | 7.37±0.26 | 0.94±1.72 | 7.20±0.20 | 0.18±0.50 |
| Knee width | 9.22±0.45 | 1.23±1.39 | 9.53±0.38 | 0.26±0.74 |
| Wrist width | 5.33±0.19 | 2.98±3.75 | 5.18±0.23 | 0.72±2.04 |
| Elbow width | 7.42±0.38 | 1.15±1.06* | 7.53±0.47 | 1.33±2.00 |
| Arm skinfold | 1.29±0.81 | –1.68±15.3 | 0.86±0.24 | 4.21±3.80* |
| Calf skinfold | 0.73±0.37 | –2.77±40.2 | 0.55±0.32 | 0.00 |

RAI — Relative asymmetry index; * Significant asymmetry ($p<0,05$); # Significantly different from the respective value in the control group ($p<0,05$)

**Table 3.** Absolute anthropometric values of dominant extremities and relative asymmetry indices (means±SD) in female swimmers and control subjects

| Group | Controls (n=14) | | Swimmers (n=9) | |
|---|---|---|---|---|
| Variable | (cm) | RAI (%) | (cm) | RAI (%) |
| Lower limb length | 84.4±2.8 | 0.14±0.19 | 98.7±6.7 | 0.01±0.04 |
| Upper limb length | 67.3±17.8 | 0.17±0.35 | 75.2±2.5 | 0.00 |
| Thigh girth | 53.7±2.4 | 1.25±1.07* | 54.7±2.4 | 0.53±0.34* |
| Calf girth | 35.0±1.3 | 1.56±1.24* | 33.7±1.3 | 0.23±0.50# |
| Forearm girth | 22.9±1.4 | 2.49±1.45* | 23.4±1.6 | 0.90±1.45 |
| Arm girth | 26.2±2.1 | 2.72±2.77* | 2.77±1.6 | 0.82±1.18 |
| Foot length | 24.0±1.1 | 0.62±0.72* | 23.3±0.79 | 0.26±0.44 |
| Foot width | 9.01±0.52 | 2.01±1.77* | 8.64±0.46 | 1.20±2.06 |
| Ankle width | 7.04±1.1 | 4.35±7.73 | 6.43±0.47 | 0.15±0.50 |
| Knee width | 8.54±0.80 | 2.43±2.17* | 8.79±0.53 | 1.56±2.20 |
| Wrist width | 4.80±0.33 | 1.93±3.14* | 4.74±0.32 | 0.47±1.42 |
| Elbow width | 6.64±0.35 | 2.89±2.70* | 6.90±0.22 | 1.51±2.65 |
| Arm skinfold | 1.95±0.63 | 13.6±20.7* | 1.26±0.42 | 4.31±8.87 |
| Calf skinfold | 1.35±0.34 | 6.90±13.2 | 0.72±0.27 | 0.34±5.54 |

RAI — Relative asymmetry index; * Significant asymmetry ($p<0,05$); # Significantly different from the respective value in the control group ($p<0,05$)

In general, asymmetry was much more pronounced in the control groups than in swimmers (Figure 1). In the control groups, significant indices were found for thigh and arm girths, foot width and elbow width in men, and for all variables except the lengths of extremities and ankle width in women. In swimmers, significant but very small indices were found only for calf girth in men and thigh girth in women. When comparing swimmers with control subjects, significant differences in RAI values were found for thigh girth and foot length in men and for calf girth in women.

Highest asymmetry in men was found for wrist width (3%, n.s.) in control subjects and for arm skinfold (4.21, $p<0.05$) and elbow width (1.33%, n.s.) in swimmers. In women, highest values were found for ankle width (4.35%, n.s.), calf skinfold (6.9%, n.s.) and arm skinfold (13.6%, $p<0.05$) in control subjects, and for knee width (1.56%, n.s.) and arm skinfold (4.31%, n.s.) in swimmers.

In the control groups, the variabilities of asymmetry were much higher than in swimmers, especially regarding skinfold thicknesses.

Those variabilities were very low in swimmers, except width (±2.65%) and skinfolds (arm skinfold — ±8.87%) in women.

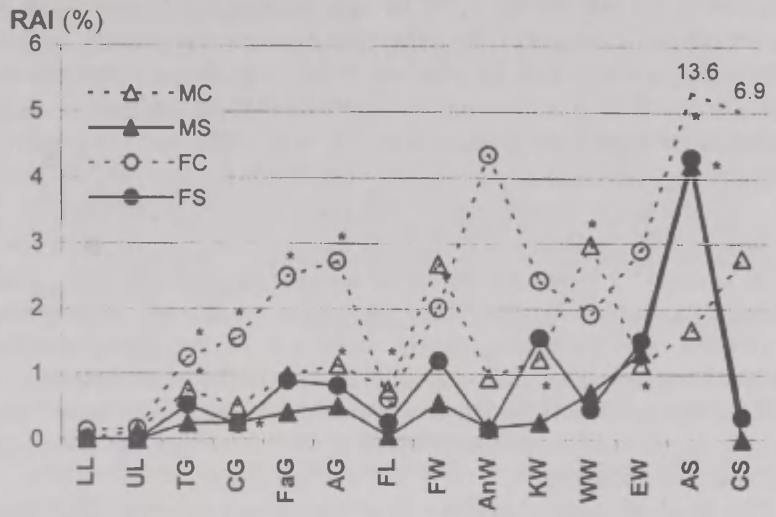


**Figure 1.** Somatic asymmetry profiles in 4 groups of subjects: male (n=8) and female (n=9) swimmers (MS and FS respectively), and in male (n=6) and female (n=14) control subjects (MC and FC).
Legend:
First letter: L – lower; U – upper; T – thigh; C – calf; Fa – forearm; A – arm; F – foot; An – ankle; K – knee; W – wrist; E – elbow
Second letter: L – length; G – girth; W – width; S – skinfold
* Significant asymmetry index ($p<0.05$)

## DISCUSSION

As demonstrated by Starosta [6], swimming symmetrises movements. This, in its turn, may lead to greater anatomical symmetry. A high degree of somatic and dynamic asymmetry was reported by Koszczyc for children aged 7–10 years [2, 3]. It was attributed to functional asymmetry resulting from their life style. His results are not, however, comparable with those presented here as they were obtained in young children.

The relatively high asymmetry observed in this study in the control subjects, attaining 3% for wrist width in men and as much as 4.3% for ankle width in women, decreases substantially in swimmers, in whom asymmetry did not exceed 1.3% in men (elbow width) and 1.6% in women (knee width). On the other hand, some asymmetry indices were highly variable, which resulted in non-significant mean values. Ankle width in female controls (4.3±7.7%) and skinfolds may serve as examples. It should be pointed out that in a study on many sports, conducted by Krawczyk *et al.* [4], asymmetry in the control group did not exceed 2%. On the other hand, the highest asymmetry, reported in the latter study for tennis players, was as high as about 8%. Since somatic asymmetry is not known to be a factor in sport selection, such discrepancies must be attributed to intensive use of asymmetric movements, and swimming seems to be one of the most powerful symmetrising activities. This is due to the specificity of swimming [1], i.e. performing exercise in an environment which is "unnatural" and forces one to overcome the resistance of water making the body lighter at the same time.

The level of physical activity in contemporary societies decreases steadily. Therefore we should popularise motor activities which are indispensable for improving our health [6]. That deficiency in physical activity is particularly acute in youths in whom somatic asymmetry has been found remarkable. Swimming may thus be recommended as an activity requiring relatively little effort and applicable to all groups.

## CONCLUSIONS

1. As compared to control subjects, somatic symmetry is markedly more pronounced in swimmers of both sexes. Since selection for swimming is unlikely to involve somatic symmetry, regular swimming may be regarded as a strong symmetrising stimulus.

2. Children should be encouraged to practise swimming, since it would not only enhance their motor activity but could improve their functional and motor symmetry as well.

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# RELATIONSHIPS BETWEEN ANTHROPOMETRIC VARIABLES AND PERFORMANCE CHARACTERISTICS OF ELITE SINGLE SCULLERS

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ABSTRACT

The purposes of this investigation were to study: 1) the anthropometric profile of Estonian top level single scullers; and 2) how specific anthropometric characteristics are related to the performance parameters of rowers obtained on single sculls and rowing ergometer. Ten experienced male rowers (18.9±1.7 yrs; 186.2±6.3 cm; 79.3±7.3 kg; BMI: 22.8±1.1 kg·m$^{-2}$; %body fat: 9.3±1.4%) participated in this study. Sum of six skinfold thicknesses (i.e., triceps, subscapular, abdominal, suprapinal, front-thigh, medial calf) was measured (Holtain skinfold calliper, UK). In addition, muscle mass, skeletal mass and cross-sectional area (CSA) of thigh were calculated. The rowers were subjected to two measurement sessions on a rowing ergometer (Concept II, USA). An incremental exercise test to determine $\dot{V}O_{2max}$ and a 2000 metre time trial were performed. In addition, competition results of a 2000 metre race on single sculls were obtained. Muscle mass was the major predictor of rowing performance on single sculls, while rowing performance time on rowing ergometer was significantly related to height, body mass, BMI, lean body mass, CSA thigh, muscle mass and skeletal mass values. In conclusion, the results of this study indicate that the anthropometric profile of Estonian top level single scullers is consistent with the anthropometric characteristics of other sculling rowers. According to the results of our investigation, muscle mass was the best anthropometric predictor of 2000 metre rowing performance on single sculls.

**Key words:** anthropometric profile, performance, single scullers

## INTRODUCTION

Examination of anthropometric characteristics of a specific sport can help sport scientists and coaches to understand top level performance. Many studies of elite athletes have been published with specific profiles of performance-related factors (1). The quantification of the physique of elite athletes is a relevant reference point in relating body structure and sports performance. The anthropometric profile of rowers has been reported to be closely related to the level of performance [1, 4, 11, 13, 14, 16].

A typical rowing competition takes place on a 2000 metre course and lasts 6–7 minutes. During the competition race, anaerobic alactic and lactic as well as aerobic metabolic capacities are stressed to their maximum [13,16]. A rower has to perform a stroke with a peak force of 800 to more than 1000 Newton more than 200 times [16]. Rowing demands a high level of strength and endurance [4]. Rowing involves a large body mass, and body size and body mass are undoubtedly performance-related factors [4, 11, 13, 14, 16]. However, differences in anthropometric characteristics have been observed between rowers in the two categories — sculling and sweep rowing [1, 14].

The purposes of this investigation were to study: 1) the anthropometric profile of Estonian top level single scullers; and 2) how specific anthropometric characteristics are related to the performance parameters of rowers obtained on single sculls and the rowing ergometer.

## MATERIAL AND METHODS

### *Subjects*

Ten male Estonian national-level single scullers volunteered to participate in the study. The subjects were training regularly and had being do so for the last 4.70±1.83 years. The measurements took place at the beginning of the autumn season. This study was approved by the Medical Ethics Committee of the University of Tartu. Each subject gave informed written consent to participate in the investigation.

### *Anthropometry*

Body height (Martin metal anthropometer) and weight (medical balance scale) of the subjects were measured and body mass index (BMI,

$kg \cdot m^{-2}$) calculated. Sum of six skinfold thicknesses (i.e., triceps, subscapular, abdominal, supraspinal, front-thigh, medial calf) was measured (Holtain skinfold calliper, UK) [2]. Body density was determined according to the skinfold prediction equation of Durnin and Womersley [3] and percentage body fat was then calculated from body density according to the equation of Siri [15]. In addition, muscle mass was calculated according to Martin *et al.* [8]. While skeletal mass was calculated according to Martin (9), cross-sectional area (CSA) of thigh was estimated according to Hawes [6].

*Testing procedures*

All exercise tests were performed on a wind resistance braked rowing ergometer (Concept II, Morrisville, USA). The rowers were fully familiarised with the use of this apparatus. Power output and stroke frequency were delivered continuously by the computer display of the rowing ergometer. Heart rate (HR) was measured continuously and stored at five seconds' intervals during all exercise tests (Sporttester Polar Vantage NV, Kempele, Finland). At the first measurement session, a progressive incremental exercise test to maximal intensity was performed [10, 17]. This was carried out in order to determine the maximum oxygen uptake ($\dot{V}O_{2max}$) (in $l \cdot min^{-1}$ and $ml \cdot min^{-1} kg^{-1}$). Expired gas was sampled continuously during the test for the measurement of $\dot{V}O_2$ (TrueMax 2400 Metabolic Measurement System, Parvo Medics, USA). At the second measurement session, the subjects were asked to cover a 2000 metre distance on the rowing ergometer in the least time possible (2000 metre "all-out" test). In addition, competition results of 2000 metre distance on single sculls were obtained.

*Statistical methods*

Descriptive statistics (mean±standard deviation [SD]) for each of the dependent variables were determined. Differences between the results of 2000 metre time trials on the rowing ergometer and single sculls were estimated by independent t-test with an error of estimate set to 0.05. Pearson Product Moment Correlation coefficient was used to determine the relationships between the results of 2000 metre time trials on the rowing ergometer and single sculls, and anthropometric variables. Again, an alpha level of 0.05 was used.

## RESULTS

The mean (±SD) age, height, weight, BMI and physical performance characteristics of the rowers are presented in Table 1. Table 2 presents the mean (±SD) skinfolds, sum of six skinfolds, percentage of body fat, LBM, thigh CSA, muscle mass and skeletal mass indices of the rowers. The interrelationships between the results of 2000 metre distances on single sculls and rowing ergometer, and different anthropometric characteristics are presented in Table 3. Significant relationship was observed between the results of the 2000 metre time trial on single sculls and muscle mass index, while rowing performance time on the rowing ergometer was significantly related to the following anthropometric parameters: height, body mass, BMI, LBM, CSA thigh, muscle mass and skeletal mass.

**Table 1.** Physical and performance characteristics of rowers (X±SD)

| Variable | X± SD | Minimum | Maximum |
|---|---|---|---|
| Age (yrs) | 18.90±1.66 | 17.00 | 21.00 |
| Height (cm) | 186.20±6.25 | 179.00 | 198.00 |
| Weight (kg) | 79.27±7.30 | 69.40 | 94.80 |
| BMI ($kg \cdot m^{-2}$) | 22.83±1.10 | 21.35 | 24.69 |
| $\dot{V}O_{2max}$ ($l \cdot min^{-1}$) | 4.854±0.631 | 3.910 | 6.130 |
| $\dot{V}O_{2max}kg^{-1}$ ($ml \cdot min^{-1} \cdot kg^{-1}$) | 61.61±5.59 | 54.90 | 71.30 |
| E2000 (sec) | 398.44±17.73 | 362.80 | 415.50 |
| S2000 (sec) | 448.20±13.07* | 428.48 | 463.87 |

BMI — body mass index; $\dot{V}O_{2max}$ — maximal oxygen uptake; E2000 — 2000 metre time trial on a rowing ergometer; S2000 — 2000 metre time trial on single sculls.

* Significantly different from E2000; $p<0.05$.

**Table 2.** Anthropometric characteristics of rowers (X±SD)

| Variable | X±SD | Minimum | Maximum |
|---|---|---|---|
| **Skinfolds (mm)** | | | |
| Triceps | 5.50±2.01 | 4.00 | 10.00 |
| Subscapular | 7.70±1.06 | 6.00 | 9.00 |
| Biceps | 3.40±0.70 | 3.00 | 5.00 |
| Suprailiac | 6.80±2.44 | 4.00 | 11.00 |
| Supraspinal | 6.50±1.72 | 4.00 | 9.00 |
| Abdominal | 8.00±1.70 | 5.00 | 10.00 |
| Mid-thigh | 10.60±2.95 | 6.00 | 15.00 |
| Medial calf | 6.40±2.17 | 4.00 | 10.00 |
| Sum 6 SF (mm) | 44.70±9.53 | 30.00 | 62.00 |
| %body fat | 9.34±1.44 | 7.50 | 11.90 |
| LBM (kg) | 71.78±5.85 | 63.80 | 83.50 |
| Thigh CSA ($cm^2$) | 258.01±27.89 | 210.60 | 307.11 |
| Muscle mass (kg) | 49.50±6.06 | 41.03 | 62.17 |
| Skeletal mass (kg) | 10.98±1.48 | 9.28 | 13.84 |

Sum 6 SF — sum of triceps, subscapular, biceps, suprailiac, supraspinal and mid-thigh skinfolds; LBM — lean body mass; CSA — cross-sectional area.

**Table 3.** Correlations between the 2000 metre time trials on single sculls and on the rowing ergometer, and different anthropometric characteristics of rowers

| Variable | Single sculls | Rowing ergometer |
|---|---|---|
| Height (cm) | –0.36 | –0.77* |
| Body mass (kg) | –0.50 | –0.91* |
| BMI ($kg \cdot m^{-2}$)# | –0.41 | –0.63* |
| Sum 6SF (mm) | 0.20 | 0.02 |
| %Body fat (%) | 0.06 | 0.01 |
| LBM (kg) | –0.51 | –0.91* |
| CSA thigh (cm2) | –0.50 | –0.66* |
| Muscle mass (kg) | –0.64* | –0.85* |
| Skeletal mass (kg) | –0.42 | –0.88* |

# abbreviations are the same as in Tables 1 and 2.

* Statistically significant; $p<0.05$.

## DISCUSSION

The present findings were consistent with previous investigations where age, height, body mass, $\dot{V}O_{2max}$ and performance standard on a 2000 metre time trial on a rowing ergometer are taken into account (see Table 1) [1, 10, 11, 12, 16, 17]. Being consistent with Bourgois *et al.* [1] and Shephard [14], the results shown in Table 2 indicate that rowers are relatively lean and present a high proportion of muscle mass. In support of our findings (see Tables 1 and 2), Hahn [15] has suggested that successful rowers are tall, heavy and possess a low skinfold reading.

Perhaps because it is difficult to combine muscularity with leanness, a number of rowers sampled have also carried a substantial amount of body fat (e.g., 11.0–16.8% in men and 13.6–29.3% in women) [14]. However, the percentage of body fat in our subjects was remarkably lower (9.34±1.44%). These differences could be explained by the fact that sweep rowers have been reported to be taller and heavier, and are also characterised by greater muscle development than scullers [1, 14].

Muscle mass was the major predictor of rowing performance on single sculls and the rowing ergometer (see Table 3). This is consistent with the anthropometric data of adult male rowers that have been published and emphasise the importance of body mass and body size for rowing performance [1]. As demonstrated in many studies, a typical rower is a tall, heavy and lean athlete with a high amount of slow-twitch muscle fibres in working muscles [4, 7, 16]. These morphological qualities are achieved by long hours of aerobic training combined with weight training and genetic inheritance [11, 16]. The long hours of specific rowing training result in a rower with a large aerobic capacity [11, 16] as demonstrated by the high values of $\dot{V}O_{2max}$ indices of our subjects (see Table 1).

2000 metre time trial on a rowing ergometer has widely been used to assess rowing performance [10, 11, 12, 16, 17]. In the present study, performance time was significantly lower in rowing on the ergometer as compared to rowing on single sculls (see Table 1). This is explained by the fact that 2000 metre rowing on the ergometer is more intensive than on single sculls. Thus, the 2000 metre time trial need not exactly reflect the metabolic effort of on-water rowing on single sculls, although a significant correlation ($r=0.72$; $p<0.05$) was observed between the results of 2000 metre time trials on the rowing ergometer and on single sculls. In addition, individual rowing ergometer perform-

ance times do not take into account all differences in skills and efficiency when rowing on single sculls. This suggests some caution when using performance times on the rowing ergometer to predict on-water rowing [11]. The results of this study also demonstrated some differences in selected anthropometric variables when predicting the results of 2000 metre time trials on the rowing ergometer and on single sculls (see Table 3).

In summary, the results of this study indicate that the anthropometric profile of Estonian top level single scullers is consistent with the anthropometric characteristics of other sculling rowers. The results of the present investigation suggest that on-water rowing performance on single sculls could be assessed using specific anthropometric variables. However, individual rowing ergometer performance times do not exactly account for the differences in skill and efficiency when rowing on single sculls. According to the results of our investigation, muscle mass was the best predictor of 2000 metre rowing performance on single sculls.

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# ANTHROPOMETRIC CORRELATES OF STRENGTH CHARACTERISTICS IN MIDDLE-AGED OBESE FEMALES

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ABSTRACT

The purpose of this study was to determine the possible relationships between anthropometrical and isoinertial, isometric and isokinetic strength indices in middle-aged obese women. Eighteen obese (body mass index [BMI]>27.0 kg/m$^2$) and 15 control (BMI<27.0 kg/m$^2$) females participated in this investigation. Three series of anthropometrical measurements were taken according to O-scale physique assessment system. The ratio of waist to hip circumferences (WHR) was calculated. Body composition was measured using bioelectrical impedance method (Bodystat 500, UK). Strength was measured in isoinertial (one repetition maximum leg extension [1RM LE]), isometric (0.52 rad. from full extension) and isokinetic (at the contractile speed of 4.16 rad·sec$^{-1}$) contexts. Obese women possessed significantly higher ($p<0.05$) values for skinfold, girth and breadth measurements. 1RM LE strength was also significantly higher in obese group. While isometric and isokinetic strength measures did not differ significantly between measured groups. WHR was significantly negatively related to all measured strength indices in obese but not control subjects. While lean body mass was significantly positively related to all measured strength values in obese but not control subjects. Skinfold, girth and breadth measurements were seldom related to all measured strength indices in obese and control women. In addition, isoinertial, isometric and isokinetic strength measures appeared to be very context-specific in both measured groups.

**Key Words:** anthropometry, strength, obese women

## INTRODUCTION

Body size, proportions, physique and composition are factors which influence physical fitness [9, 11]. It has been demonstrated that taller stature advantages over shorter stature in everyday dynamic work activities as well as in exerting force against an external object. While shorter stature is favoured when human body has to be moved against gravity [11]. Furthermore, skinfold thicknesses are routinely used to estimate body composition and are included in physical fitness test batteries [9, 11]. Thus, anthropometry is central to the study of physical fitness in human populations.

Obesity appears to be a major coronary heart disease (CHD) risk factor [5]. Furthermore, longitudinal investigations have demonstrated that the preferential deposition of body fat in the trunk region is independently associated with CHD and related mortality [5]. Numerous studies have linked sedentary lifestyle to low aerobic power (i.e., physical fitness) and increased risk of CHD and related mortality [3, 12].

Obese subjects with larger body size need a higher dynamic and static strength in everyday activities [11, 13]. There are few studies investigating the relationships between anthropometric and strength parameters in children and youths [11]. However, functional correlates in the physical performance of obese subjects merit further consideration. The purpose of this investigation was to determine the possible relationships between anthropometrical and isoinertial, isometric and isokinetic strength indices in middle-aged obese women.

## MATERIALS AND METHODS

### *Subjects*

Eighteen obese (body mass index [BMI]>27.0 kg/m$^2$) and 15 control (BMI<27.0 kg/m$^2$) females participated in this investigation (Table 1). All subjects were premenopausaled women. They had not participated in a regular exercise programme for at least one year prior to the beginning of the study (exercising less than once per week). All subjects were taking no medications and free from musculoskeletal or other diseases based on medical history. They provided informed written consent for the investigation. The study was approved by the Ethics Committee of the University of Tartu.

**Table 1.** Mean (±SD) physical characteristics of obese and control groups

| Variable | Obese (n=18) | Control (n=15) |
|---|---|---|
| Age (yrs) | 36.17±6.14 | 34.13±6.33 |
| Height (cm) | 166.25±8.02 | 165.00±5.57 |
| Weight (kg) | 83.47±9.68 | 61.55±4.96* |
| BMI ($kg/m^2$) | 30.15±3.11 | 22.65±1.54* |
| WHR | 0.81±0.05 | 0.73±0.04* |
| Body fat% | 34.62±4.50 | 21.39±3.87* |
| Fat (kg) | 29.48±8.10 | 13.22±4.46* |
| LBM (kg) | 53.99±6.52 | 48.33±3.96* |

BMI, body mass index; WHR, waist to hip circumferences ratio; LBM, lean body mass. * Significantly different from obese group; $p<0.05$

*Anthropometry*

The heights (Martin's metal anthropometer) and weights (medical balance scale) of the subjects were measured to the nearest 0.1 cm and 0.05 kg, respectively. Three series of anthropometrical measurements on the right side of the body were taken by a trained anthropometrist according to the O-scale physique assessment system [14]. The anthropometrist had previously shown test-retest reliability of $r>0.90$. The Centurion Kit instrumentation was used (Rosscraft, Surrey, BC, Canada). In total, eight skinfolds, 10 girths and two breadths were measured. In addition, the ratio of waist to hip circumferences (WHR) was calculated [10]. The body composition was measured using bioelectrical impedance method (Bodystat 500, UK).

*Measurement of strength*

Strength was measured in isoinertial, isometric and isokinetic contexts [2, 8]. Tests for isokinetic and isometric leg extension strength were completed on a Cybex Isokinetic Dynamometer (Cybex Corporation, Lumex, Bay Shore, USA), while isoinertial strength was measured using one repetition maximum (1RM) tests. Isokinetic testing preceded isometric assessment, which in turn preceded isoinertial assessment. There were, respectively, two and 15 minutes recovery periods between the conclusion of isokinetic and commencement of isometric assessment, and the conclusion of isometric and the commencement of

isoinertial assessment. All subjects were familiarised with the protocol, test velocitY and contraction modalities to be used in isokinetic and isometric testing [2, 8].

Peak isokinetic leg extension torque was determined at the contractile speed of 4.16 rad·sec$^{-1}$. Three individual maximal contractions were completed. Peak torque (Nm) of leg extension strength was defined as the highest non-artifact value obtained. Isometric strength (0 rad·sec$^{-1}$) was determined at an angle of 0.52 rad. from full extension [1]. The 1RM leg extension (LE) was used to assess maximal isoinertial strength of the *quadriceps femoris* muscle. The initial test load was 30% of body weight, additional 2.5 to 5.0 kg being added after every successful repetition.

### *Statistical analysis*

Standard statistical methods were used to calculate mean, standard deviation (±SD) and correlation coefficients. Statistical comparisons between the groups were made using independent t-tests. Significance was set at $p<0.05$.

## RESULTS

Physical profiles of obese and control subjects are presented in Table 1. The groups were not significantly different in terms of age and height. However, obese women were significantly heavier and had significantly higher values for BMI, WHR, body fat%, body fat mass and lean body mass (LBM) than control subjects (Table 1).

There were significant differences in anthropometric characteristics among obese and control groups (Table 2). Obese women demonstrated significantly higher values for all skinfold, girth and breadth measurements.

Table 3 presents the group results for measured isoinertial, isometric and isokinetic strength indices. While isoinertial strength was significantly higher in obese subjects, isometric and isokinetic strength indices did not differ significantly between obese and control women.

**Table 2.** Mean (±SD) anthropometric characteristics of obese and control groups

| Variable | Obese (n=18) | Control (n=15) |
|---|---|---|
| **Skinfolds (mm)** | | |
| Triceps | 28.49±7.52 | 18.42±5.12* |
| Subscapular | 32.61±10.32 | 15.15±6.08* |
| Biceps | 18.67±5.53 | 9.89±2.97* |
| Suprailiac | 35.27±13.86 | 16.10±8.33* |
| Supraspinale | 26.02±8.32 | 12.05±5.65* |
| Abdominal | 39.75±13.73 | 19.46±9.70* |
| Mid-thigh | 42.05±12.03 | 28.48±7.45* |
| Medial calf | 27.67±9.55 | 17.73±4.97* |
| **Girths (cm)** | | |
| Relaxed arm | 32.03±3.05 | 26.70±1.71* |
| Flexed arm | 33.55±3.26 | 27.61±1.89* |
| Forearm | 26.24±1.44 | 23.29±0.75* |
| Wrist | 16.43±0.66 | 14.70±0.73* |
| Chest | 103.64±6.04 | 87.67±5.15* |
| Waist | 87.79±5.98 | 71.15±5.04* |
| Gluteal | 108.53±7.91 | 96.98±3.23* |
| Thigh | 59.40±5.61 | 51.95±3.77* |
| Calf | 40.44±2.71 | 36.53±1.36* |
| Ankle | 23.97±1.35 | 21.97±1.05* |
| **Breadths (cm)** | | |
| Humerus | 6.58±0.54 | 6.23±0.31* |
| Femur | 10.15±0.71 | 9.23±0.30* |

* Significantly different from obese group; $p<0.05$

**Table 3.** Mean (±SD) maximal isoinertial, isometric and isokinetic strength characteristics of obese and control groups

| Variable | Obese (n=18) | Control (n=15) |
|---|---|---|
| Isoinertial strength (kg) | 50.89±18.73 | 35.93±11.18* |
| Isometric strength (Nm) | 169.64±23.23 | 166.44±31.43 |
| Isokinetic strength (Nm) | 19.88±8.47 | 24.45±9.45 |

* Significantly different from obese group; $p<0.05$

Correlations between anthropometric parameters and isoinertial, isometric and isokinetic strength values are presented in Table 4.

**Table 4.** Correlations between anthropometric parameters and maximal isoinertial, isometric and isokinetic strength indices in obese and control (in brackets) groups

| Variable | Isoinertial strength | Isometric strength | Isokinetic strength |
|---|---|---|---|
| Age | –.60* (–.28) | –.65* (–.20) | –.50* (.29) |
| Height | .87* ( .43) | .78* ( .36) | .75* (–.22) |
| Weight | .50* ( .19) | .42 ( .14) | .39 (–.44) |
| BMI | –.23 (–.21) | –.24 (–.22) | –.23 (–.33) |
| WHR | –.63* (–.05) | –.65* ( .26) | –.82* ( .40) |
| Body fat% | –.50* (–.13) | –.40 (–.26) | –.39 (–.41) |
| LBM | .85* ( .27) | .74* ( .29) | .70* (–.17) |
| **Skinfolds** | | | |
| Triceps | –.37 ( .01) | .20 (–.55*) | –.28 (–.57*) |
| Subscapular | –.39 ( .19) | –.39 (–.38) | –.45 (–.64*) |
| Biceps | –.36 (–.26) | –.33 (–.60*) | –.35 (–.55*) |
| Suprailiac | –.17 ( .49) | –.07 (–.03) | –.17 ( .43) |
| Supraspinale | –.35 ( .47) | –.31 (–.10) | –.35 (–.51*) |
| Abdominal | –.36 ( .25) | –.26 (–.29) | –.34 (–.52*) |
| Mid–thigh | –.10 (–.20) | –.06 (–.61*) | –.03 (–.48*) |
| Medial calf | –.17 (–.23) | –.14 (–.73*) | –.11 (–.43) |
| **Girths** | | | |
| Relaxed arm | –.03 (–.02) | .02 ( .05) | –.05 (–.16) |
| Flexed arm | –.07 ( .07) | .01 ( .01) | –.06 (–.16) |
| Forearm | .31 ( .13) | .35 ( .31) | .18 (–.14) |
| Wrist | .37 ( .22) | .30 ( .16) | .28 ( .14) |
| Chest | –.07 ( .06) | –.09 ( .09) | –.17 (–.35) |
| Waist | –.23 (–.07) | –.26 ( .23) | –.41 ( .14) |
| Gluteal | .26 (–.05) | .25 ( .04) | .27 (–.40) |
| Thigh | .12 ( .12) | .14 (–.18) | .17 (–.24) |
| Calf | –.27 ( .18) | .22 ( .01) | .36 ( .00) |
| Ankle | .19 ( .14) | .13 ( .14) | .21 ( .33) |
| **Breadths** | | | |
| Humerus | .47* ( .39) | .38 ( .34) | .44 ( .17) |
| Femur | .22 ( .17) | .15 (–.18) | .21 (–.13) |

BMI, body mass index; WHR, waist to hip circumferences ratio; LBM, lean body mass. *$p<0.05$

It appeared that WHR was significantly negatively related to all measured strength indices in obese but not control subjects. While LBM was significantly positively related to all measured strength indices in obese but not control subjects (Table 4). Skinfold thickness measures were seldom related to isoinertial, isometric and isokinetic strength measures in obese and control women. For example, the thinner skinfolds of mid-thigh and medial calf significantly increased the index of isometric strength in control subjects (Table 4). It appeared that girth values were not influenced by the results of different strength indices in both groups. Similarly, humerus and femur breadth seldom influenced the results of strength tests (Table 4).

## DISCUSSION

It is well known that obesity indices (i.e., BMI, WHR, body fat%) have been negatively associated with perceived fitness [9, 11]. Many studies have investigated the relationships between aerobic physical fitness and anthropometric obesity indices [7, 9]. For example, in a recent study, Jürimäe and Jürimäe [9] demonstrated that high body fat% substantially reduced muscular endurance in obese women. While the improvement in physical fitness increases aerobic capacity, decreases resting heart rate and blood pressure, reduces serum cholesterol and triacylglycerols, and has psychological benefits in both lean and obese people [4, 7]. The possible relationships between strength indices of physical fitness and different anthropometric parameters have not been extensively studied.

The results of the present investigation indicated that isoinertial, isometric and isokinetic strength measures were negatively related to WHR index in obese women ($r=-0.63$ to $-0.82$; $p<0.05$), while no significant relationships between different strength indices and WHR value were observed in control women (see Table 4]. This demonstrates that higher WHR value in obese women has a negative effect on all measured strength indices. It has been demonstrated that certain anthropometric measurements, specifically these indicating central adiposity are independently associated with the development of total CHD and related mortality [5]. While fat deposition in the periphery does not appear to result in an increased risk for CHD [4].

In contrast to aerobic fitness items [9], dynamic strength as measured by 1RM leg extension was significantly higher in obese women in

comparison with age-matched controls in our investigation (see Table 3). Heavier persons have been reported to possess more muscle mass and, therefore, are generally stronger than leaner persons [11]. Similarly, obese subjects presented significantly higher LBM than control subjects in our study (see Table 1). It has been reported that in most obese individuals LBM could account for as much as 40% of the excess weight in some studies [6]. LBM was significantly related to dynamic isoinertial and static isometric strength indices in obese subjects (see Table 4). This positive relation reflects the larger body size of fatter persons [11]. Possibly, obese women need this higher LBM to move their heavier bodies around during everydays activities.

According to the results of our study, only isoinertial strength measure was significantly higher in obese women in comparsion with control subjects. No significant differences were observed between isometric and isokinetic strength indices between studied groups (see Table 3). These results demonstrate that different strength indices are very context-specific. Obese women use higher isoinertial but not isometric and isokinetic leg extension strength in their everydays life. Thus, the quadriceps femoris muscle of obese subjects is not activated and, therefore, trained more isometrically or isokinetically than corresponding muscle of control women. Similarly to the results of this investigation, great specificity has been reported between the modalities of isoinertial, isometric and isokinetic muscle actions in other studies [2, 8].

Correlations between strength and skinfold thicknesses have been reported to be about zero in non-obese people [11]. While in a recent study, endomorphy in combination with supraspinale skinfold thickness characterised the variance in static hand grip strength in obese women by 28% [9]. Similarly to these investigations, skinfold thickness measurements were mostly not related to measured isoinertial, isometric and isokinetic strength indices in both obese and control groups in our study (see Table 4).

In summary, the results of our investigation demonstrated that higher WHR value had a significant negative effect on measured strength indices in middle-aged obese women. While measured skinfold, girth and breadth values were mostly not related to isoinertial, isometric and isokinetic strength indices in obese and control subjects. In addition, different strength measures appeared to be very context-specific.

## ACKNOWLEDGEMENTS

The authors are greatly indepted to researcher Mrs Jelena Gapejeva for help with strength measurements. This study was supported by Grant No. 3021 from the Estonian Science Foundation.

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# MODEL OF THE NEWBORN'S HEAD

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ABSTRACT

Using the data from anthropometic measurements of 292 healthy newborns, born in 1995 in the Women's Hospital of the University of Tartu, an attempt was made to build a model of the newborn's heads. The purpose of the model was to estimate the volume of the newborn's head. The knowledge of the estimated value of the newborn's head is useful for detecting birth traumas and malformations and also for predicting the future adaptation, development and state of health or sickening risks of the newborn.

## 1. INTRODUCTION

Newborn's state of health and body build are tightly interrelated. To estimate the level of intrauterine development of the foetus (see [5, 9 and 14]) and the gestation age (see [7, 8]) several anthropometric and sonographic criteria are necessary. Such criteria are also needed to predict the newborn's weight (see [15]) with the aim of making a program to control the parturition. Anthropometric criteria are also useful for foretelling the *postpartum* adaptation and possible sickening of a newborn, and for reasoning about birth traumas (see [10, 11]).

Recently the number of papers has rapidly increased where besides the birth weight and height also other measurements of the newborn have been used to get additional information about the build of the newborn's body as a whole (see [1, 2, 4, 6 and 13]). It is remarkable that in spite of the large importance of the size, shape and proportions of the newborn's head in estimation of its tone, considerably few attempts have been made to measure the newborn's head in detail. In

most cases only the head's circumference has been measured (see [3 and 12]).

Undoubtedly the knowledge of the newborn's head volume would give additional information for solving all the above mentioned problems. The problem is that it is impossible to measure the head's volume directly. So the purpose of the present study was to estimate the volume of the newborn's head, using head diameters and other measurements known in classical obstetrics. The formulae for estimation of the head's volume have been derived mathematically, and the theoretical considerations have been checked using the data measured on 292 healthy newborns. Both of these parts are represented in the paper. That makes it formally somewhat different from usual papers published in medical journals. In the paper the model-building process, based on statistical data, is described in detail — so the paper has a methodological value, too. The method presented by us is deeply original, and we recommend it for using in maternity hospitals.

## 2. DATA AND DATA ANALYSIS

### *2.1. The data*

To build the model we used the measurements of 292 healthy newborns. The following special anthropometric measurements of a newborn's head were made (see Figures 1A and 1B):

- *circumference of the head* ($p$), see dotted line on A and B;
- *diameter suboccipito-bregmatica* ($d$), see B;
- *diameter fronto-occipitalis* ($a$), see B;
- *diameter mento-occipitalis* ($g$), see B;
- *diameter trachelo-bregmatica* ($h$), see A and B;
- *diameter bitemporalis* ($b_1$), see A;
- *diameter biparietalis* ($b_2$), see A.

Additionally, the values of weight ($w$), height ($l$) and sex ($s$, coded as 1 — girl, 2 — boy) were fixed for all the newborns considered.

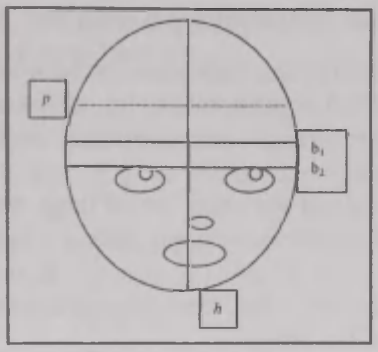


Figure 1 A

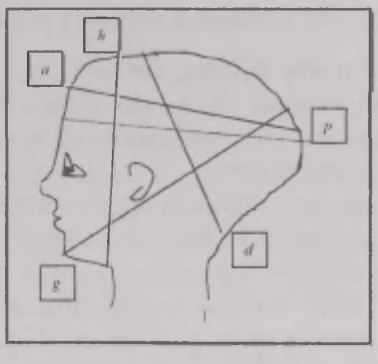


Figure 1 B

*2.2. Checking the correctness of initial data*

The first step was, as usual, checking the correctness of data. Several special statistical methods were used to clean the data from random errors (measurement errors). With this aim the characteristics of kurtosis and skewness were calculated for all variables, and the box-plot was made to characterise the empirical distribution, and, if needed, other quantiles were calculated and plotted as well. Also geometric connections between different dimensions of the head were used in the cases when the values of some measurements were questionable. As a result one measurement error (value g 18.8) was detected in the data used, and it is highly probable that all the other values in the data are correct (in the sense of outliers). All data processing was made using the statistical package SAS. The basic empirical characteristics of the corrected measurements are given in Table 1.

**Table 1.** Basic empirical characteristics of the measurements

| | *W* | *l* | *d* | *a* | *g* | *h* | $b_1$ | $b_2$ | *p* |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 3620.5 | 49.92 | 9.63 | 11.69 | 12.89 | 9.78 | 8.19 | 9.21 | 35.49 |
| SD | 448.7 | 1.944 | 0.413 | 0.505 | 0.515 | 0.494 | 0.409 | 0.422 | 1.218 |
| Min | 2400 | 44 | 8.6 | 10.4 | 11.2 | 8.4 | 6.9 | 7.9 | 32.5 |
| Max | 4854 | 54.5 | 10.8 | 13.3 | 14.3 | 11.4 | 9.4 | 10.3 | 39.5 |
| Skewness | 0.208 | –0.096 | 0.134 | 0.005 | 0.081 | 0.018 | 0.190 | –0.011 | 0.250 |
| Kurtosis | –0.101 | –0.071 | –0.234 | –0.017 | 0.155 | 0.343 | 0.212 | 0.498 | 0.134 |

### *2.3. The correlation structure of head measurements of a newborn*

For model building the next step is to find the dependencies between the variables. It is natural that all head measurements (as all other anthropometric measurements, too) are strongly intercorrelated. Here are three reasons:

- all measurements depend on the size of the child, i.e., a large and heavy child has, naturally, all measurements larger than a small and light one;
- there exists a special structure between the head measurements caused by the geometrical shape of the head;
- there are some dependencies caused by different anthropometric types of newborns.

To discover all types of dependencies we calculated the correlation matrix between all the variables, and then found the partial correlation matrix where the (linear) influences of weight ($p$), height ($l$) and sex ($s$) were eliminated. Both matrices are presented in Table 2. In the upper triangle are the usual and in the lower triangle — the partial correlation coefficients. An asterisk * indicates the significance of the correlation (on the level a 0.05), and a bullet • is placed into the cells where the partial correlations are senseless.

**Table 2.** Correlation coefficients and partial correlation coefficients between the measurements

| | $w$ | $l$ | $d$ | $A$ | $g$ | $h$ | $b_1$ | $b_2$ | $p$ |
|---|---|---|---|---|---|---|---|---|---|
| $S$ | 0.147* | 0.158* | 0.277* | 0.180* | 0.065 | 0.174* | 0.247* | 0.208* | 0.313* |
| $W$ | • | 0.756* | 0.496* | 0.477* | 0.538* | 0.433* | 0.528* | 0.469* | 0.651* |
| $L$ | • | • | 0.458* | 0.406* | 0.475* | 0.359* | 0.420* | 0.394* | 0.520* |
| $D$ | • | • | • | 0.556* | 0.273* | 0.421* | 0.357* | 0.411* | 0.573* |
| $A$ | • | • | 0.398* | • | 0.486* | 0.404* | 0.260* | 0.475* | 0.730* |
| $G$ | • | • | –0.002 | 0.308* | • | 0.405* | 0.437* | 0.392* | 0.532* |
| $H$ | • | • | 0.239* | 0.235* | 0.226* | • | 0.335* | 0.348* | 0.455* |
| $b_1$ | • | • | 0.184* | –0.016 | 0.219* | 0.117 | • | 0.570* | 0.520* |
| $b_2$ | • | • | 0.198* | 0.307* | 0.188* | 0.164* | 0.410* | • | 0.600* |
| $P$ | • | • | 0.333* | 0.623* | 0.298* | 0.228* | 0.228* | 0.415* | • |

### *2.4. Analysing the correlation structure of the newborn's head measurements*

To visualise the structure of head measurements two correlation graphs were made, see Figures 2A and 2B. Graph 2A presents the structure of usual linear correlations between all the variables measured (see Table 2). Here all correlations satisfying the condition $r>0.45$ are indicated as graph edges. The only exception is the quite weak correlation between $S$ and $p$ that is shown as a dotted line to make the graph connected.

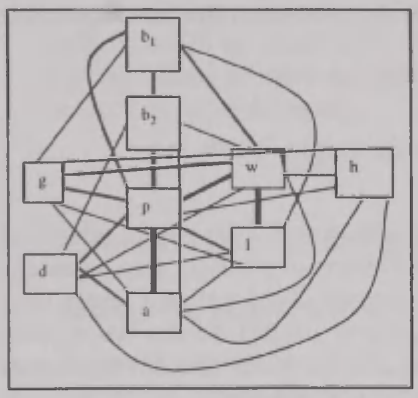


**Figure 2A.** Correlation graph of head and body measurements.

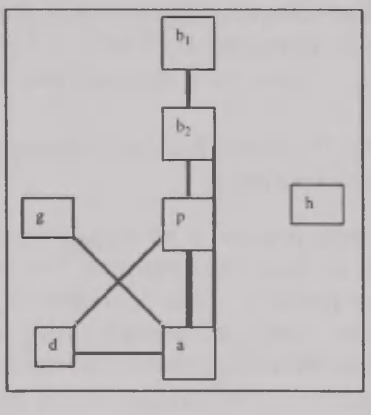


**Figure 2B.** Graph of partial correlations of head measurements by eliminated body measurements.

From here we can see, that the correlations between the head dimensions and weight are somewhat stronger than the correlations of these variables with height. The central position in head measurements belongs to $p$, the *head circumference.* We can see three groups of measurements having remarkable intercorrelations:

- the *head breadth* measurements $b_1$ and $b_2$ build one group;
- the *head depth* measurements $g$, $a$ and $d$ constitute the second group (where one remarkable fact — weak correlation between two diagonals $d$ and $g$ occurs);
- the only head height measurement $h$ has the weakest correlation with $p$ (which is quite understandable), and the correlations of $h$ with diagonals $d$ and $g$ are on the same level.

All the measurements of the first and the second group are, naturally, quite strongly correlated with $p$ (see Figures 1A and 1 B).

Graph 2B presents the same structure after the influence of the sex, weight and height of the child has been eliminated, e.g. the structure of *partial correlations*. We see that all the partial correlations are weaker than the corresponding correlations indicated in Graph 2A. Now the geometrically caused connections between $p$ and $a$, $b_1$ and $b_2$ and also between $b_1$, $b_2$ and $p$ are dominating.

From here it follows, that the breadth measurements ($b_1$ and $b_2$), the depth measurements ($a$, $d$; $g$) and the height dimension $h$ vary quite independently and their relations depend on the anthropometric types of children.

### *2.5. Predicting head measurements by weight, height and sex of the child*

Linear prognoses by weight ($w$), height ($l$) and sex ($s$) were calculated for all head measurements. The coefficients of all regression equations are given in Table 3, where only statistically significant terms have been taken into account (using the level a 0.05). In the last column squared multiple correlation coefficients are given to show the rate of explanation (by weight, height and sex) of variables.

**Table 3.** Parameters of linear models for predicting the measurements by weight, height and sex of the newborn

| Measurement | Parameters of the model | | | | |
|---|---|---|---|---|---|
| | Intercept | Weight | Height | Sex | $R^2$ |
| $a$ | 9.998 | 0.0005 | | 0.114 | 0.23 |
| $d$ | 6.783 | 0.0003 | 0.041 | 0.159 | 0.29 |
| $h$ | 8.275 | 0.0005 | | 0.108 | 0.20 |
| $b_1$ | 6.730 | 0.0005 | | 0.142 | 0.30 |
| $b_2$ | 7.862 | 0.0004 | | 0.121 | 0.23 |
| $p$ | 29.967 | 0.0020 | | 0.508 | 0.50 |
| $g$ | 9.012 | 0.0005 | 0.043 | | 0.29 |

From here the following common conclusions can be made:

- All measurements depend on the weight of the child.
- In average, each kilogram of weight adds about half a centimetre to the value of almost all linear head measurements. Most dependent

on weight is head circumference, increasing about two centimetres with every kilogram of body weight. The influence is statistically significant ($P<0.05$).

- Almost all measurements depend significantly on the sex of the child. On average, if the weight and height are the same, then all measurements of boys are about 1–1.6 mm bigger. Again the most dependent measurement is head circumference, which is about 5 mm larger for boys than for girls (of the same weight).
- For most measurements the additional impact of height is insignificant (in the case of the sample of 292 children).
- The description rate of head measurements by the linear model varies from 20 to 50 per cent. The less dependent measurement is $h$ — the height of the head (face), and the most dependent — the circumference of the head $p$.

## 3. THE MODEL OF THE NEWBORN'S HEAD

### *3.1. Building of a geometrical model*

It seems to be appropriate to use *an ellipsoid* as a model of the head. At first, let us regard the two different views of the head (see Figures 1A and 1B).

On Figure 1A we see that the projection of the head is an ellipse with a longer axis $h$ and a shorter axis $b$. The latter characteristic is not measured immediately, but it can be estimated by different methods. Anyway, it cannot be less than $h_1$ and $b_2$. Also, the circumference $p$ is measured, and the exact value of $b$ can be calculated by $p$ and $a$, using the well-known connection between the two axes of an ellipsoid and its perimeter (circumference). At first we will use the following expression, valid for the case when both axes of the ellipse have an almost equal length,

$$b = 2p/\pi - a. \qquad (1)$$

The second possibility is to use the measurement $b_2$ as an approximation for $b$,

$$b = b_2. \qquad (1')$$

Figure 1B is the view from the side. There are two '*diagonals*' $d$ and $g$, the *'depth of the head'* $a$ and the *'height of the head'* $h$. Let us suppose

that the head consists of two parts, sectioned by line $g$ (see Figure 1B). Both parts can be modelled as half of an ellipsoid, having two axes equal to $g$ and $b$. The third axis is unknown, but we can approximate the sum of two unknown half-axes by the second diagonal $d$. Hence, let $x$ be the unknown half-axis of the *upper half-ellipsoid* and $d - x$ the unknown half-axis of the *lower half-ellipsoid.* Using the well-known formula of the volume of the ellipsoid, we get the volume $V$ of the model head:

$$V = \pi bgd/6. \tag{2}$$

### *3.2. Empirical model for the head's volume by anthropometric measurements of the head*

Using formula (1) for estimation of value $b$, we get the following expression for the head's volume:

$$V_1 = dg(2p - \pi a)/6. \tag{3}$$

This formula contains four parameters to be measured — *diameter suboccipito-bregmatica d, diameter mento-occipitalis g, circumference of head p* and *diameter fronto-occipitalis a* The second version we used for estimating the breadth of head $b$ was its estimation by $b_2$ *(diameter biparietalis):*

$$V_2 = \pi dgb_2/6. \tag{4}$$

Using formula (3) we found that the empirical mean of the volume of child's head (by our data) was 707 $cm^3$ whereas by formula (4) its size is 599 $cm^3$. These values can be considered as *the upper* and *lower limit* of *the estimated head volume.* Another possibility is to regard the head as an ellipsoid with axes $a$ and $b$ (see Figures 1A and 1B). In this case we get a different estimate for the volume, see the following expression for $V_3$:

$$V_3 = \pi abh/6. \tag{5}$$

If in (5) value $b$ is estimated by formula (1), then the empirical mean value of the head volume $V$ calculated by our data using formula (6) is 652.5. This result fits with our assumption that formulae (3) and (4) give the upper and lower limits for the volume.

*3.2. Practical formula for estimating the newborn's head volume*

From the preceding discussion it follows that all formulae derived in section 3.2 can be used for estimation of the volume of the newborn's head. The choice between them should be made taking into account simplicity and reliability of measurements. After a slight modification of formula (3) and eliminating the bias, we receive for practical use the following formula that depends on two diagonals $g$ and $d$ and circumference $p$ only:

$$V = 0.15 \times pgd. \tag{6}$$

*3.4. Practical formula for estimating the head volume of a foetus using ultrasound measurements*

For the cases when it is not possible to use the head circumference, we derive an alternative formula on the basis of formula (4), which includes besides two diagonals $g$ and $d$ also *diameter biparietalis* $b_2$. This formula can be used, e.g., to estimate the head volume of a foetus using the ultrasound measurements. The coefficient has been chosen with the aim to eliminate the bias and to make the formula handy for practical use:

$$V = O.57xb_2 dg. \tag{7}$$

## 4. DISCUSSION

*4.1 Testing the correctness of the models*

The correctness of the models can be checked using correlations between the estimated volume of the head and some other measurements of the child, see Table 4.

**Table 4.** Characteristics of predicted head volumes and their correlations with other measurements

| | Mean | SD | Sex | Weight | Height | Volume 1 | Volume 2 |
|---|---|---|---|---|---|---|---|
| Weight | 3621.45 | 449.25 | • | • | • | • | • |
| Height | 49.95 | 1.93 | • | • | • | • | • |
| Volume 1 | 661.2 | 62.00 | -0.271 | 0.697 | 0.601 | 1 | • |
| Volume 2 | 651.8 | 64.00 | -0.247 | 0.656 | 0.575 | 0.925 | 1 |
| Volume 3 | 708.5 | 68.64 | -0.296 | 0.697 | 0.587 | 0.945 | 0.864 |

Here *Volume 1 is* calculated by formula (6), *Volume 2* by formula (7) and *Volume 3* by formula (3). The columns Mean and SD of Table 4 give the basic characteristics of different estimates for the newborn's head. The following three columns — Sex, Weight and Height present the mutual correlations of volume estimates and anthropometric characteristics of the newborn's body. From here we see that the correlation of the estimated volume of the head with the weight of the child varies between 0.65 and 0.7. The correlations between the estimated volume of the head and the height of the newborn are somewhat lower, varying around 0.57–0.60. The correlations between sex and the estimated volume of the head of size 0.25–0.3 are *statistically significant.*

### *4.2. Conclusions*

From our research the following conclusions can be drawn:

- The following anthropometric measurements of the newborn's head carry information about the anthropometric type, the possible birth traumas and about the head volume of the newborn:
  — *circumference of the head (p),*
  — *diameter suboccipito-bregmatica (d),*
  — *diameter fronto-occipitalis (a),*
  — *diameter mento-occipitalis (g),*
  — *diameter trachelo-bregmatica (h),*
  — *diameter biparietalis* ($b_2$).
- All newborn's head measurements depend on weight and on sex, being systematically bigger in the case of boys than for girls of the same weight. The difference is not large.
- Dependence of head measurements on the newborn's height is weaker than on the newborn's weight.
- It is possible *to estimate the volume of the newborn's head*, using one of the formulae — (3), (5) or (6) Formula (5) is better in the case when the head's circumference is available, formula (6) can be used when *diameter biparietalis* has been measured instead of circumference.

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# APPLYING PATIENTS' HEIGHT AND WEIGHT DATA IN EPIDEMIOLOGICAL STUDIES

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ABSTRACT

In an epidemiological investigation 246 adults (124 males and 122 females) from the city of Tallinn, Estonia, were studied. Their height and weight, and total cholesterol and triglyceride content in blood serum were measured. By means of regression analysis it was shown that, while taking into account only age and sex, the cholesterol level can be predicted only within the range of 8.7%. When height and body mass index were added, the dedetermination of the formula increased to 15.8%. The same could be noticed in the case of triglycerides — 5% and 16.3% respectively. The older, taller and more corpulent a patient is, the greater the higher of their cholesterol and triglycerides level, being higher in men and lower in women.

Consequently, measuring of weight and height should become an obligatory procedure in everyday medical practice. While determining the normal amount of lipids in blood serum, body build should also be taken into consideration besides sex and age.

## INTRODUCTION

One of the final aims of theoretical medicine is finding the individual constitutional peculiarities of sick and healthy persons, establishing the possible norms for them and applying these norms in practice.

Constitution, in its turn, is based on people's body build, and attempts have been made for a long time at systematising and classifying the pertinent data, although no final solution has been achieved yet [1–4].

In order to evolve anthropological classifications appropriate for medical purposes, studies on the internal structure of human body

build have been carried out at the University of Tartu since 1974. First this work was done at the Department of Gynecology and Obstetrics, later — from 1993 — at an autonomous Centre for Physical Anthropology. Body build structure of young and pregnant women, newborns, 15–18-year-old schoolgirls and 16–17-year-old schoolboys has been studied [5–14]. It has been established that the human body as a whole is a linearly well-correlated system. The leading measurements are height and weight, which account for 50% of the variability of all the other measurements, while individual variability makes up 50%. There are no other body measurements besides weight and height that can give a reliable description of the general build of the human body. Variations in body height-weight sizes lead to systematic changes in the length, breadth and depth measurements, circumferences and body proportions. Comparative changes of body proportions in the general sample and in the groups of purely pyknic and leptosomic persons are based on the corresponding values of their body height and weight.

These findings lead to the conclusion that the anthropological whole body primary model may be a classification of body height and weight.

The above mentioned findings have enabled us to apply body build data in obstetrics [15], perinatology [16] and cardiology [17].

In the present paper we attempt to demonstrate the significance of weight and height as the leading bodily characteristics in evaluating the level of blood lipids in epidemiological investigations.

## MATERIAL AND METHODS

The subjects were 246 adults from the city of Tallinn — 124 males and 122 females aged 19.5–46.5 years. Their height and weight were measured, and total cholesterol and triglycerides levels in blood serum were determined.

## RESULTS

The subjects' height ranged from 151 to 193 cm, weight from 44 to 127 kg. The cholesterol content in their blood serum varied from 76 to 474 mg/dl and that of triglycerides from 27 to 246 mg/dl.

Correlation analysis revealed that both sex and age were essentially connected with the cholesterol and triglycerides levels. Cholesterol was in correlation with sex (r=–0.249*), age (r=0.146*), height (r=0.203*) and weight (r=0.365*). Triglycerides were significantly connected with sex (r=–0.152*), age (r=0.155*) and weight (r=0.364*). The correlation with height was statistically insignificant. In our denotation the negative correlation with sex meant that, on an average, women had lower cholesterol and triglycerides levels than men.

Next, let us follow how precisely it is possible to predict cholesterol content when only the age and the sex of the subjects is taken into account.

$$Chol = 202.8 + 1.14\,(Age) - 25.20\,(Sex) \qquad R^2 = 0.087$$

Both variables are significant, although they determine the cholesterol content only within the range of 8.7%.

If we predict cholesterol content only on the basis of height and weight or height and body mass index (BMI), the result is better — 13.3% and 13.5% respectively. Consequently, cholesterol level is higher in taller and more corpulent persons.

If we unite the results of the previous models, we get the regression equation

$$Chol = 37.08 + 0.52\,(Height) + 3.42\,(BMI) + 0.66\,(Age) - 18.44\,(Sex)$$
$$R^2 = 0.158$$

The determination of cholesterol here is 15.8%, thus being the best. Relying on the model, one could state that the older, taller and more corpulent a person is, the higher their cholesterol level. Being a male adds on an average 18 units to the index.

Fairly similar results were obtained when predicting the level of blood triglycerides. Using only age and sex as independent variables, the determination of the model was 5%, only height and weight — 14.3%, only height and BMI — 15%. While uniting the previous models, we achieved the following formula:

$$TG = -23.50 + 0.16\,(Height) + 3.57\,(BMI) + 0.39\,(Age) - 11.56\,(Sex)$$
$$R^2 = 0.163$$

The determination of the model is 16.3%. In conclusion, we might say that the taller, more corpulent and older the patients are, the higher their triglycerides level, whereas in men the index is on an average 12 units higher than in similar women.

The profile of lipids is estimated according their mean values or according to the European Aterosclerosis Association classification of hyperlipidemias. The classes of severity range from A (the mild form) to E (severe hypercholesterolemia or severe hypertriglyceridemia; cholesterol > 300 mg/dl (> 7.8 mmol/l) and/or triglycerides > 500 mg/dl (> 5.75 mmol/l) (Volozh *et al.*).

When dividing the subjects into groups according to the severity classes of hyperlipidemia, we managed to predict that belonging to a respective group was in significant correlation with body build ($R^2$ = 0.147).

In sum, we can conclude that both in epidemiological studies and in therapy patients should be compared on the basis of at least four characteristics — sex, age, height and weight, and when establishing norms for blood lipids, body build should be taken into consideration as well. However, all this requires that height and weight were indispensably measured in everyday medical practice.

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# FOUNDATION OF THE ANTHROPOLOGY SECTION OF THE NATURALISTS' SOCIETY AT THE ESTONIAN ACADEMY OF SCIENCES IN 1939

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On April 19, 1939 a group of members of the Naturalists' Society (J. Aul, H. Haberman, R. Indreko, E. Kumari, K. Pärna, A. Tõnurist, V. Üprus) assembled in order to establish the section of anthropology [1].

Juhan Aul *Dr. Phil. Nat.* (1897–1994) made a presentation, where he focused on the current anthropological research, the necessity to conduct anthropological studies, and the renewed interest in this neglected national (and at the same time international) branch of science. The task of the anthropology section would have been to foster anthropological research, to generate interest in the public at large, and to unite the professionals and amateurs who work in the field of anthropology or related subjects [2].

J. Aul had graduated from the University of Tartu in 1928 with the academic degree of *Mag. Zool.*, and since the autumn of the same year he had started to work at the Institute of Zoology as a junior assistant and since beginning of the next year as a senior assistant [3].

By then the Naturalists' Society at the University of Tartu had been in existence for 75 years. The society had held 656 meetings, where altogether 1309 reports had been made. The largest number of reports had been made in zoology, botany, and geology (390, 181, and 102, respectively). Physiology with 14 and anthropology with 13 reports were the most modest subjects. The latter made up less than 1 per cent of all the reports [4].

J. Aul, a student of zoology, and three of his fellow students of the same speciality at the Faculty of Mathematics and Natural Science were elected as active members of the Naturalists' Society on February 4, 1926 [5].

In addition to studying at the University, J. Aul had taken up teaching natural history at the Tartu Teachers' Seminar since the autumn of the previous year. On the recommendation of the principal J. Tork, he conducted a study of twins that included anthropological data about 40 pairs of twins. From here anthropology was not far away.

J. Aul was a student at the time when Alexander Brandt (1844–1932) *Dr. Med. et Zool.*, Merited Professor of the former University of Kharkov, was teaching anthropology as a *Privatdozent*. It is known now that Aul attended some of his lectures. Claiming that anthropology is not only a science but also a skill that has to be acquired and practiced, Juhan Aul has always emphasized the mastery of measurements. He acquired the measuring techniques under the guidance of Hans Madisson (1887–1955), then senior assistant of the Institute of Forensic Medicine at the University of Tartu and later a professor of eugenics. Madisson had learned it in Finland from Prof. Yrjo Kajava during the Christmas break of 1922 [6]. Such training could have facilitated his first steps in anthropology.

The student association 'Raimla' had organized a joint field trip of representatives of various branches of science to Sõrve in the summer of 1927. Student Juhan Aul together with E. Kant, K. Orviku, and H. Mühlberg conducted anthropological, geological, geomorphological, and zoogeographical studies there. This project lasted for two summers [7]. The main results of the anthropological study of the Sõrve people by J. Aul *Mag. Zool.* were published in French on 44 pages in the Reports of the Naturalists' Society at the University of Tartu. Prof. V. V. Bunak, Head of the Institute of Anthropology at the University of Moscow, gave a brief overview of this article in the first and second issue of the 1930 volume of the *Russian Anthropological Journal* [8].

The annual field trips of J. Aul that focused mainly on anthropological but also zoological problems began in the summer of 1927. Most research grants were provided by the Naturalists' Society, but some were funded by the University and the Culture Foundation. In the years 1935–1937 he had been the University-funded scholar in anthropology [3].

J. Aul *Mag. Zool.* managed to make seven presentations at the general meetings of the Naturalists' Society: some anthropological data about the people of Sõrve (1929), the life and work of Lamarck, about the anthropological impact of the world war on the Estonian islanders (1933), about the objective classification of systematic

quantitative features and the application of the relevant method to the assessment of an organism as an entity in the form of individual curves (1934), about the anthropological composition of the people of Viljandi county (1935), a survey of the anthropological composition of the people of West Estonia (1936), about the anthropology of Estonian Swedes and their anthropological impact on the Estonians (1937).

He made four presentations at the meetings of the Tallinn branch of the Naturalists' Society: some tasks of anthropology (1933), concerning the racial types of Viljandi county and Western Estonia (1935, 1936), if and to what extent the Swedes have influenced the Estonians anthropologically (1937).

The zoology section of the Society listened to three reports by him: some data about our amphibians (1932), concerning an interesting osteal find in Estonia (1933), about the Stone Age skulls at Lüganuse (1934).

Over the period of only 13 years, from 1926 through 1939, Juhan Aul had managed to make altogether 17 reports at the Society; 15 of them were on anthropology.

The Reports of the Naturalists' Society include the following publications by him: about the anthropology of the Muhu people (1932), about the anthropological impact of the world war on Estonian islanders (1934) [9].

In the years 1933–1938 J. Aul was a member of the editorial board of the popular-scientific journal *Estonian Nature*. This journal published two of his articles on zoology: about the spadefoot frog and the true frogs, and a brief communication: a garden dormouse found in Tartu county; three articles on anthropology: about the height of the Estonian male, about the weight of the Estonians and the problem of slenderness and stockiness, one brief communication: about the hair colour of the Estonians and one item of information: about the Second International Congress of Anthropological and Ethnological Sciences in Copenhagen in 1937; one article on paleoanthropology: about the finds of human bones from the younger Stone Age.

In addition, *Estonian Nature* published a number of short summaries of his longer articles published elsewhere (seven articles on anthropology and one on paleoanthropology). On three occasions J. Aul expressed his opinion about the longer articles by S. Ehrhardt, L. Poska-Teiss, and H. Madisson.

It is known that in 1929 Juhan Aul *Mag. Zool.* and seven members of the Naturalists' Society conceived the idea of organizing Natural-

ists' Days in order to bring together and to inspire the naturalists to work toward common causes and to solve various problems. During the first two Estonian Naturalists' Days (in 1931 and in 1934) J. Aul was a member of the organizing committee. At the First Estonian Naturalists' Days he made a presentation in the biology section on the anthropology of the people of Muhu Island; at the Second Estonian Naturalists' Days — a report at the plenary session on the younger Stone Age human being in Estonia; at the Third Estonian Naturalists' Days in Tallinn in 1937 — a report on the anthropology of the Estonians.

Since 1933 J. Aul as a member of the Naturalists' Society advised on amphibians and reptiles. During the last four years he was a member of the International Committee for the Unification of Anthropological Technology.

In 1937 Juhan Aul *Mag. Zool.* was awarded the Kreenbalt prize of 500 Estonian kroons for his anthropological research [10]. By then he had measured more than 15,100 Estonians and a few hundred non-Estonians. By comparison, in those countries where similar measurements had been made the corresponding numbers were as follows: Sweden 47,300, Norway 11,700, and Switzerland 35,500. Thus, one can conclude that proportionally to the population the Estonian data were the most complete [11].

By then Estonia was the county whose population was best measured anthropologically in the world, but not researched yet because the processing of the huge data collection would require some more time.

On March 19, 1938 Juhan Aul *Mag. Zool.* was awarded the academic degree of Doctor of Natural Sciences for his dissertation *Anthropological Characteristics and Racial Origin of the Estonians of West Estonian Counties*. It was followed by an eight-month anthropological study trip to Poland, Germany, and Switzerland (from August 1, 1938 to April 1, 1939) [6].

After the presentation of Juhan Aul the meeting resolved (on April 19, 1939) to establish the section of anthropology. The request for the establishment of the section was submitted to the society's board with the signatures of all those people who had attended the meeting. On April 27, 1939 the request was discussed at General Meeting No. 776 of the Naturalists' Society, where it was accepted [1].

In connection with the extension of the activities of the Naturalists' Society (established in 1853) and the further specialization of research there was a need for new sections already at the beginning of the 20th

century. As the first section the lake section was set up in 1905. Since then the society had formed a large number of various sections, committees, and other structural units. The establishment of new sections became especially popular since 1920 when the relevant provision was added to the statutes of the society.

The section of nature conservation was set up in 1920, the section of ornithology in 1921, that of botany in 1928, geology in 1931, entomology in 1937, etc. [7]. However, the establishment of the anthropology section was somewhat delayed.

The first meeting of the anthropology section was held together with the Naturalists' Society on May 11, 1939. This meeting confirmed Juhan Aul as the chairman of the section. He made a presentation *Observations and Impressions concerning the Organization of the Research and Teaching of Anthropology in some Foreign Countries*. Dr. V. Üprus was elected as the vice-chairman of the section, A. Tõnurist was elected as the secretary [2].

The future work of the section was to be carried out in three directions: scientific reports (mostly introducing new research results), field trips with the purpose of collecting new material, and publication [1].

Already June saw the first comprehensive anthropological field trip with the support of the Naturalists' Society – the collection of anthropological materials in three rural municipalities of Iisaku Parish. Juhan Aul, the chairman of the section, took part in it as well. The section began the registration of anthropo-osteological finds [7]. By the end of the year the anthropology section had 15 members. Another meeting was held, where the section chairman made a presentation on *The impact of lifespan on anthropological features*. In the same year he participated in the First World Congress of Anthropologists in Copenhagen [9].

After his habilitation lecture *About the Methodological Significance of Age-Related Changes in Anthropological Characteristics* the University Council awarded Dr. Juhan Aul for the first time in the University's history the title of a docent (Associate Professor) in anthropology and the respective rights on October 3 of the same year. Next semester he started his lectures on anthropology at the University [6].

The establishment of the anthropology section of the Naturalists' Society in 1939 became possible thanks to Juhan Aul's thirteen years of very active work in anthropology. The section continued to work successfully under his guidance during the next half-century.

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# IS THERE A RELATIONSHIP BETWEEN SHRINKAGE AND BONE MINERAL DENSITY OF THE LUMBAR SPINE IN HEALTHY 27-YEAR-OLD MALES AND FEMALES?

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ABSTRACT

As part of the Amsterdam Growth and Health Longitudinal Study, the relationship was studied between spinal shrinkage (SS) and lumbar bone mineral density (BMD) and the L5/S1 disc area (DA).

In 93 randomly selected healthy males and females between the age of 28–31 years SS was measured with a stadiometer. Also video recordings were made of two markers denoting the lumbar spinal region of the subject in order to determine shrinkage in the lumbar spine. The actual shrinkage experiment consisted of a loaded phase followed by an unloaded one. During the unloaded phase the subjects had to stand still while three consecutive stature measurements were taken simultaneously with video recordings of two video markers. During the loaded phase the subjects had to stand three minutes wearing a waistcoat containing an extra weight equal to 25% of their body weight, while in between again stature measurements and video recordings were taken. BNM measurements of L2, L3 and L4 took place two years previously at the age of 26–29 years.

No significant correlations were found between BMD or L5/S1 disc area and motion segment stiffness or creep rate, calculated either from the stature data or the video data. For stature and video data, multiple regression analysis with creep rate as the dependent variable and sex, body weight, body height, DA, BMD and SS as the independent variables resulted in no significant predictor of the creep rate. With motion segment stiffness as the dependent variable and sex, body weight, body height, DA, BMD and creep rate as the independent variables, the SA significantly explained 13.2% of the variance of SS ($p = 0.029$) as calculated from the stature data. BMD significantly

explained 20% of the variance of the SS (p=0.02) calculated from the video data.

In conclusion, a significant t-elation was found between L5/S1 disc area and SS of the lumbar spine, and also between BMD and the SS of the lumbar spine.

**Key words:** young adults, loading of spine, lumbar bone density, stiffness of spine

## 1. INTRODUCTION

Several studies have shown that compression forces on the lumbar vertebrae that occur when lifting can be strong enough to induce micro-fractures of the vertebral endplates (Jäger & Luttmann, 1992). It is generally assumed that these micro-fractures contribute to the development of low back pain (van Dieën, 1993). As a parameter of functional load of the spine, measurement of spinal shrinkage can be used. This measurement reflects the visco-elastic deformation of the spine as induced by compression forces. Therefore, in an ergonomic evaluation of working situations, measurement of spinal shrinkage can possibly be used as an indicator of the risk of low back pain due to compression forces.

On the average, stature decreases throughout the day from 0.83% (Leat *et al.*, 1986) to 1.1% (Tyrrell *et al.*, 1985). Recovery of stature takes place during the night. Stature loss is the result of spinal shrinkage based on height loss of the intervertebral discs, which is the result of two processes. With compression, water bound by the high proteoglycan content, is driven out of the discs (osmosis). This fluid loss is supposed to be responsible for about two thirds of the total height decrease of the discus (Adams & Hutton, 1983) and consists of two components: expulsion of water from the annulus and from the nucleus. The second process due to compression is visco-elastic deformation of the motion segment based on a sidewards expansion (bulging) of the annulus and the vertebral endplates. Broberg (1993) found this deformation to be responsible for 25% of the loss of disc height.

The mechanical model of spinal shrinkage under constant compression can be illustrated by two springs (Figure 1).

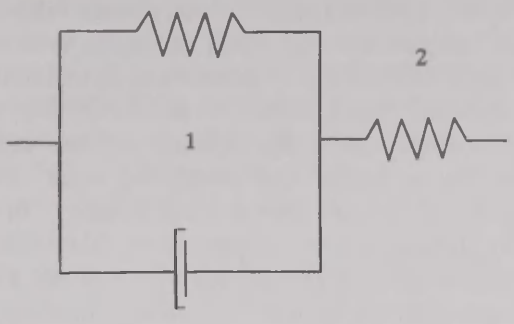


**Figure 1.** Mechanical model of the motion segment under constant compression (van Dieën, 1993). 1 = spring; 2 = damped spring

When the motion segment is considered to be a visco-elastic structure, a constant load will result in a continuous deformation at a decreasing rate, called creep.

Figure 2 shows the relationship between creep and the duration of spinal loading. After certain duration of loading, the creep reaches an equilibrium (A). This equilibrium is reached with a certain velocity, called the relative shrinkage velocity or creep rate (labda). Both shrinkage or creep, and creep rate depend on the stiffness of the spinal motion segments and seem to increase with ageing (van Dieën & Toussaint, 1993; van Dieën *et al.*, in press).

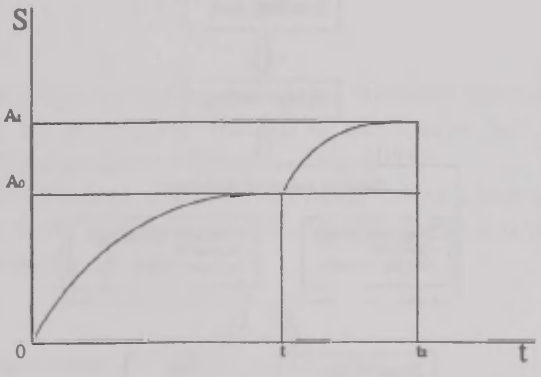


**Figure 2.** Expected relation between shrinkage (S) and duration (t) of the protocol used in this study, with an unloaded and a loaded phase

As predicted by this model an approximately linear relationship can be found between compression and spinal shrinkage with axial loading, of which the slope (stiffness$^{-1}$) is determined individually (Tyrrell *et al.*, 1985; Troup *et al.*, 1985; Althoff *et al.*, 1992). The stiffness of a spinal motion segment probably depends on the stiffness of the annulus fibres, the endplates and underlying bone (Reuber *et al.*, 1984; Happey *et al.*, 1980). The interrelationships of a low bone mineral density (BMD) and disc degeneration (Keller *et al.*, 1987), a reduced stiffness of the cancellous bone (Rice *et al.*, 1988), and the finding that sidewards expansion is increased in degenerated discs (Reuber *et al.*, 1984), make it plausible that the gross behaviour of the spine is related to these processes. Furthermore, a decreasing diameter of the annulus fibres is found with ageing (Happey, 1980), which suggests that the age of the individual influences the stiffness. In a literature review van Dieën and Toussaint (1993) a large inter-individual variation in shrinkage was found. Van Dieën *et al.* (1993) found that spinal shrinkage was significantly higher in 40 year-olds than 20 year-olds. Besides this age effect shrinkage is also dependent both on the intensity and duration of loading. Independently of age, considerable inter-individual variation in shrinkage was also found, which still remains to be explained. A model of spinal shrinkage with possible influences on the motion segment shrinkage is presented in Figure 3.

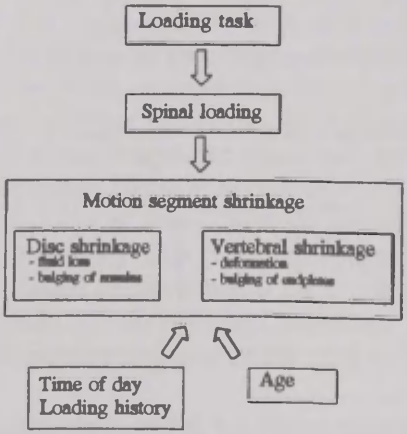


**Figure 3.** Model of spinal shrinkage with possible influences on the motion segment shrinkage

Since the loss of height of the vertebral segments is partly an osmotic process (expulsion of water from the discus), it depends on the pressure inside the disc (intradiscal pressure). Intradiscal pressure equals the compression force divided by the disc area. As a result, the disc area influences the loss of height of the spinal motion segments (Althoff *et al.*, 1992). However, van Dieën *et al.* (in press) found no significant relation between the L5/S1 disc area and the absolute or relative shrinkage.

Factors that are known to influence spinal shrinkage are the time of the day, loading history, age and sex. However, other, still unstudied factors may play an important role. One of the factors possibly contributing to the large inter-individual differences might be the bone mineral density (BMD) of the lumbar vertebrae (lumbar 2, 3 and 4) of the individual.

Individuals with a low BMD are expected to exhibit a greater height loss due to a lower total stiffness of the motion segment (Figure 3).

The purpose of this study is to investigate the relationship between shrinkage of the lumbar spine on the one hand and the bone mineral density of the L2-L4 vertebrae and the area of the lumbar disc on the other hand in healthy 27-year-old males and females.

## 2. METHODS

### *2.1. Subjects*

Ninety-three subjects (healthy males and females) were randomly assigned from the population (n=180) of the Amsterdam Growth and Health Longitudinal Study (Kemper *et al.*, 1985).

The BMD (Welten *et al.*, 1994) at L2-L4 of these subjects was measured in 1991 (age between 26–29) and spinal shrinkage (SS) in 1993 (age between 28–31).

### *2. 2. Instrumentation*

The measurement of SS *in vivo* is based on the measurement of stature (Figure 4). The stadiometer is an apparatus, which was developed to measure changes in the length of the spinal column by measurements of body stature. Therefore, it contains a measuring device in connec-

tion with a length-transducer. This device is placed on the head of the subject for repeated measurements of height. In this experiment a second measuring device was used, which consisted of two cameras adjustable in height, one taking pictures from the side of the position of a marker attached on the level of the Spina Iliaca Anterior Superior (SIAS) and the other taking pictures from behind the stadiometer through a gap, of a marker attached on the back on the level of Th 12. This resulted in two sorts of shrinkage data: data obtained by the stature measurements ("stature" data) and data concerning shrinkage actually occurring in the lower back (between Th12 and the SIAS) obtained by the video measurements ("video" data).

Body stature must be measured in an individually standardised posture to obtain reproducible measurements. For this purpose the stadiometer contains a number of aids (van Dieën, 1993):

1. Four force plates to place the feet on, in order to control the weight distribution over the left and right forefeet and heels;
2. Supports of adjustable height and depth for the control of the curvature of the spine at L4, Th7, C4 and the head;
3. A mirror and ski glasses with horizontal marks to control the position of the head in the saggital plane;
4. The stadiometer consists of a two-piece wooden back support, at a right angle to a base plate, which is tilted backwards 12° to make a relaxed posture possible and thus minimise muscle tension.

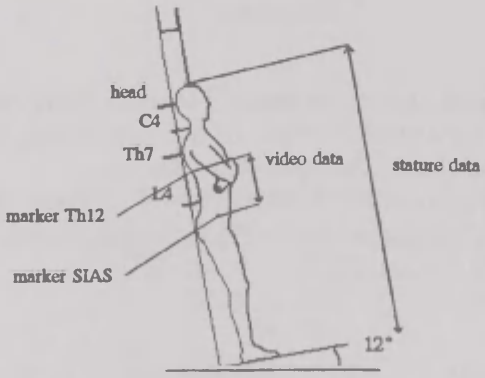


**Figure 4.** Measurement of spinal shrinkage on the stadiometer (for details see text).

*2.3. Procedure*

After performing anthropometric measurements, the deepest point of the lumbar and cervical lordoses, and the most prominent point of the thoracal kyphosis were marked with an eye pencil. Also two markers were placed on the subject, one on the hip at the height of the SIAS and one on the back at the height of Th12.

The shrinkage measurements were carried out according to the following procedure. The subjects had to wear ski glasses to prevent variations in the position of the head in the saggital plane. The contour of the glasses was drawn on the face of the subject to prevent the glasses from moving during the experiment, and the subject was given the instruction to make a line on the glasses coincide with one of the horizontal lines drawn on the mirror. Next, the subject took his/her place on the stadiometer by first placing the feet on the force plates and then leaning backwards, placing the points marked on the back carefully on the corresponding supports of the stadiometer, from lumbar level to head level. The arms were crossed over the chest (Figure 4). During this positioning the examiners gave feedback to the subject and made corrections if necessary. The cameras and the head measuring device were then adjusted to the right height. Each of the video markers (Th12 and SIAS) had to be clearly visible at the same time as two reference markers, in order to be able to calculate the height loss in the different parts of the spine from the video recordings.

The weight distribution under the feet was displayed on a computer and controlled in such a way that a measurement could only be taken when the weight on each of the four force plates differed less than 20 N from the reference values obtained at the first measurement.

It was only after full control of posture and the subject confirming that the lines on the glasses and the mirror coincided that the height measuring device was placed on the subject's head. At this moment samples could be made simultaneously with the video cameras and the height measuring device.

The actual shrinkage experiment consisted of two phases: an unloaded phase, followed by a loaded phase. The purpose of the unloaded phase was to eliminate the effect of the previous activities. During the unloaded phase the subjects had to stand 10 times 2 minutes on both legs while in between three consecutive height measurements were taken. Three consecutive measurements were taken to restrict the effect of measurement errors. In between these three measurements the subjects had to move forwards from the leaning position

and reposition against the wooden support. These 10 measurements were followed by the loaded phase, during which the subjects had to put on a waistcoat containing a weight equal to 25% of their body weight. With the waistcoat, the subjects had to stand 6 times 3 minutes while again three measurements were taken each trial. This resulted in a total of 48 measurements for each subject taken over a period of about 75 minutes.

### *2.4. Measurement of bone mineral density (BMD)*

Two years earlier, bone mineral density (BMD) of L2-L4, expressed in $g \cdot cm^{-2}$, was measured by Dual X-ray Absorptiometry (DF-XA) using a Norland XR-26 as described earlier by Kemper *et al.* (1992a). The resulting values of BMD were at that time studied in relation to the daily physical activity and dietary habits during the youth of the subjects (Kemper *et al.*, 1992b). The age between 26 and 31 is supposed to be the age when bone mineral density is at its peak (Kemper *et al.*, 1995).

These values were used in the present study to establish a possible relationship with shrinkage.

### *2. 5. Anthropometry*

The following anthropometric measurements were taken: body height, body weight and ankle, knee, wrist and elbow widths (left and right).

Disc area of L5/S1 (DA) was estimated from the anthropometric measurements with the method described by Colombini *et al.* (1989).

### *2.6. Data analysis*

For data analysis the median of each three concomitant shrinkage measurements obtained at each trial was chosen to intercept the influence of outliers. From both stature and video measurements labda (creep rate) and the stiffness of the lumbar motion segments were calculated. Stiffness was calculated by dividing the weight of the waistcoat by the creep during the loaded phase (stress divided by strain: s/e). The video measurements made it possible to determine shrinkage actually occurring within the spine. Creep curves based on these measurements were made, consisting of 10 values for the

unloaded period and 6 for the loaded period. An exponential curve as defined by equation (1) (van Dieën, 1993) and as seen in Figure 1, was fitted on the stature data and the video data for the shrinkage between Th12 and SIAS height. A separate fit was performed for the unloaded and loaded phase.

$$S = A_0 \cdot (1 - e^{-lt}) + A_1 \cdot (1 - e^{lt1}) - A_0 \cdot (1 - e^{lt2}) \qquad (1)$$

In this equation, the variable S stands for the total shrinkage, e for strain, coefficient A stands for the equilibrium deformation ($A_0$ for the unloaded phase, $A_1$ for the loaded phase), labda (l) stands for the creep rate, i.e. the rate at which this equilibrium deformation is approached and t stands for the time. Because of limited measurements, labda could not be estimated for the loaded phase and was assumed to equal labda as calculated for the unloaded phase. Both coefficient labda and stiffness were related to the L5/S1 disc area and the lumbar BMD (1991) of the subject. This was done separately for the stature and the video data.

### *2.7. Statistics*

Pearson correlations were calculated between BMD and DA on the one hand and labda and stiffness on the other hand. A separate regression analysis was performed for labda and stiffness as dependent variables. A 5% level of significance was chosen.

### *2. 8. Selection of valid data*

An example of a curve fitting is shown in Figure 5. After performing the curve fitting for all 93 subjects, a selection of fitted curves had to be made for further data analysis. This was necessary because a great number of fitted curves did not resemble the expected curve fitting seen in Figure 6. Two criteria were used for this selection. The first criterion was that the range determined by the three shrinkage measurements, divided by the total shrinkage, was smaller than 0.7 for the stature data and 0.4 for the video data. The rationale for the use of this ratio was that a certain range of measurements will be more fatal for the reliability of a curve fitted on a small total shrinkage than for a curve fitted on a large total shrinkage. The higher total shrinkage, the less the influence of the range of measurements on the reliability of

the curve fitted on these measurements. With respect to the stature data the 93 subjects were selected on the base of the magnitude of this range/creep, which resulted in the graph shown in Figure 6. It can be seen that the ratio first increased linearly (this was the case for 42 subjects) till a certain threshold. The increase of the ratio became unproportionally high for the remaining 51 subjects. The second criterion was that the curve fitted on the data had to more or less resemble the exponential curve as seen in Figure 6. This means that subjects with a curve fitting resulting in a linear relationship between duration and shrinkage in any of the two phases, were excluded from further analysis, based on the argument that a linear relationship implies an infinite shrinkage. Since it is not known whether labda is the same during recovery and shrinkage, and since labda for the loaded phase was assumed to equal labda during the unloaded phase, subjects who "grew" during the unloaded phase instead of shrinking, were also excluded from further data analysis.

The application of both criteria resulted in a total of 36 subjects (13 men and 23 women) for further analysis of stature data and 26 subjects (18 men and 8 women) for further analysis of video data.

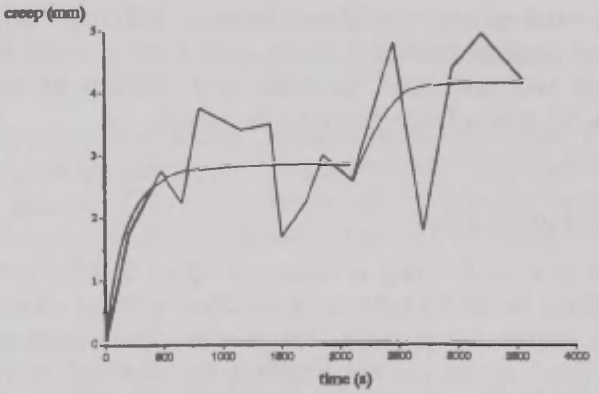


**Figure 5.** A typical example of a fitted curve. This curve (dotted line) was fitted on the video measurement data (solid line) of subject 9533

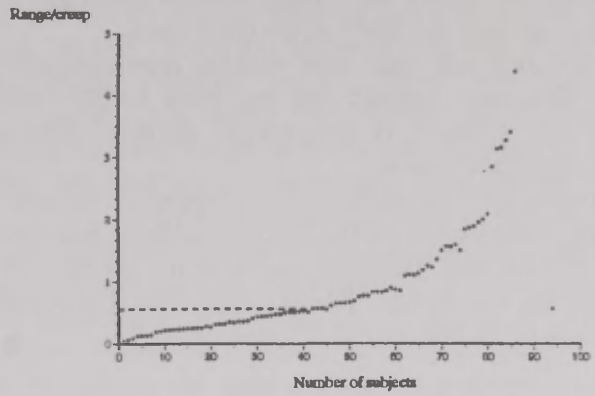


**Figure 6.** Range divided by total creep (stature data) in order of magnitude for all 93 subjects. The dotted line indicates a threshold above which the ratio increases non-linearly

## 3. RESULTS

Table 1 shows the means and standard deviations for calculated and measured variables for all selected subjects per sex. The mean body weight and body height of the male subjects are more than 10 kg, respectively 10 cm higher than that of the females.

**Table 1.** Means and standard deviations of calculated and measured variables for the subjects concerning the stature data and those concerning the data obtained by video recording

| | Video (N=26) | | Stature (N=36) | |
|---|---|---|---|---|
| Sex | MALE n=18 | FEMALE n=8 | MALE n=13 | FEMALE n=23 |
| Age (years) | 29.1±0.78 | 29.5±0.71 | 29.2±0.83 | 29.1±0.69 |
| Body weight (kg) | 78.5±9.9 | 64.2±4.1 | 77.2±8.9 | 63.1±6.5 |
| Body height (cm) | 184.3±7.1 | 172.4±6.7 | 181.8±8.6 | 170.8±6.8 |
| Lumbar BMD ($g\,cm^{-2}$) | 1219.3±163.3 | 1156.6±143.3 | 1180.2±107.5 | 1186.7±144.8 |
| L5/S1 DA ($cm^2$) | 22.4±2.5 | 16.7±1.1 | 19.7±5.6 | 20.3±15.3 |
| Labda ($mm\,s^{1}$) | 0.0016±0.0026 | 0.0007±0.0010 | 0.0017±0.0027 | 0.0007±0.0021 |
| Stiffness ($N^{-1}$) | 175.7±605.2 | −27.0±196.6 | 62.3±181.7 | 80.1±354.4 |

No significant correlations were found between BMD and DA on the one hand and stiffness and BNO on the other hand.

For both stature and video data, multiple regression analysis with labda as a dependent variable and sex, body weight, body height, BMD, DA and stiffness as independent variables, resulted in no significant predictor of labda.

With motion segment stiffness as a dependent variable and sex, body weight, body height, BMD, DA and labda as independent variables, DA significantly explained 13.2% of the variance of stiffness ($p=0.02$) for the stature data. For the video data, BMD significantly explained 20% of the variance of stiffness ($p=0.02$).

## 4. DISCUSSION

### *4.1. Subject selection for data analysis*

As a result of enormous variability in the quality of fitted creep curves, a stringent selection had to be made for further data analysis. The result of this selection was a severe restriction of the number of subjects useful for complete data analysis (36 for the stature data, 26 for the video data). This is 39 and 28% respectively, of the original group of 93 subjects. There were probably two major disadvantages in the study design, accounting for this large variability in the fitted creep curves. These two drawbacks were imposed by the limited possibilities to integrate new tests in a complex longitudinal study. The first and probably most important disadvantage in the design was that the subjects were not trained before the experiment, which is crucial for the reliability and reproducibility of shrinkage measurements (van Dieën, 1993). The reason why the subjects could not be trained was lack of time. The other restriction of the study was that the shrinkage experiment was not planned early in the morning, which would prevent other tests within the study to interfere with the results of the shrinkage experiment.

One of the selection criteria was the range/creep ratio. A drawback of this criterion is that subjects showing less creep will drop out sooner than subjects showing higher creep values. However, our greatest concern were labda and stiffness, which did not differ significantly between the selected subjects and the dropouts. Furthermore, reliable curve fitting is only possible for subjects showing significant

total creep and not for subjects showing no creep or even an increase of stature or "growth". Since it is not known whether labda is the same during recovery and shrinkage, and since labda for the loaded phase is assumed to equal labda during the unloaded phase, subjects who "grew" during the unloaded phase instead of shrinking, were excluded from further data analysis. Of the subjects who met the range/creep criterion, 9 of the 42 showed such an increase in stature or negative creep for the stature data, while 8 of the 32 showed a negative creep for the video data. A cause for this finding could have been the above mentioned second restriction in the study design: the participation schedule of the Amsterdam Growth and Health Study. The subjects arrived in the morning and spent a whole day performing a number of tests, one of which was the shrinkage experiment. Two thirds of the subjects measured had already performed one or two of the following tests: in the morning a (sub) maximal running test on a treadmill and in the afternoon the Moper-fitness test. This means that a number of subjects (24 of 36) had already performed a test prior to the shrinkage measurement, during which loading of the spine had occurred. White & Malone (1990) and Carrigg & Hillemeyer (1992) conclude that running does significantly axially load the spine. In other words, during the following shrinkage experiment the spinal motion segments of these subjects could have been recovering from axial loading, resulting in either an increase of spinal column length and thus of stature, or in a nonsignificant shrinkage. Recently, Hoe *et al.* (1994) demonstrated that steady running produced an almost 2.5 times greater loss in stature than standing and quiet walking. However, in the present study no significant difference was found in total creep between the subjects who were measured early in the morning and the subjects who had already performed a (sub)maximal test or Moper-fitness test. So probably the unloaded phase was long enough to eliminate the effects of previous activities and time-of-day effects. Therefore the finding of a negative creep cannot be explained by the interference of previous activities. A possible explanation for subjects exhibiting a negative creep may be that each time that the measurement was taken, the subjects were recovering from the preceding 2 minutes of standing. Althoff *et al.* (1992) state that unloading of the spine as a result of no longer standing upright during measurement on a stadiometer, is very small (less than 1.5% of the body weight) and that in their study it took only about 30 seconds to perform a measurement. Therefore they conclude that the measurement error due to unloading of the spine is negligibly small. It is not clear, however,

whether they performed one or three measurements each trial, but in view of the very short period it is more likely that only one measurement was performed. In the present study, three consecutive measurements took about 1–2 minutes, which is almost as long as the loading period. These 1–2 minutes were needed because the subjects had not been trained. Furthermore, unloading during the loaded phase of the experiment was considerably higher, since the waistcoat, containing a load equivalent to 25% of the body weight, was taken off for each measurement.

### *4.2. BMD and stiffness*

The mean BMD of the selected subjects was higher than that of the original study population (N=182) of the Amsterdam Growth and Health Longitudinal Study (males and females ±1200 and 1172, respectively, compared to ±1150 and 1150) (Kemper *et al.*, 1992b). BMD independently explained 20% of the variance of the stiffness calculated from the video data.

However, BMD was no significant predictor of the stiffness calculated from the stature data. An explanation for the difference in these findings might be that for the video measurements stiffness was calculated from the creep actually occurring in the lumbar vertebrae, i.e. the same site where the BMD measurement was also taken, while for the stature measurements stiffness was calculated from a total stature deformation.

Another important remark must be made about the validity of the measurement of the BMD by DEXA. Measurement of BMD by DEXA does not provide a real density calculated from volume divided by mass and thus expressed in $g \cdot cm^{-3}$, but an areal density expressed in $g \cdot cm^{-2}$ (Kemper *et al.*, 1995). Although scanning with DEXA takes place through the bone, this bone volume cannot be measured and therefore the detected amount of bone mass in that volume is divided by the frontal area over which scanning takes place, resulting in a BMD in $g \cdot cm^{-2}$. Measurement of a true BMD expressed in $g \cdot cm^{-3}$ is only possible using Quantitative Computed Tomography (QCT), which provides the possibility of scanning the bone in three dimensions and thus of measuring the volume of the bone too (Goodwin, 1991; Bailey, 1993).

*4.3. DA and stiffness*

In this study DA only significantly explained 13.2% of the variance in stiffness for the stature data. This is in line with the study of Althoff *et al.* (1992), who found a (weak) negative linear relationship between the decrease of stature in $mm \cdot kg^{-1}$, in other words the inverse of stiffness, and DA. Van Dieën (1993) found no relationship between the DA and absolute creep. In an in vitro study Koeller *et al.* (1984) found an increase of both mean disc height and disc area down the spine and an increase in axial deformation from disc Th8-9 to disc L4-5 with loading. This increase of axial deformation or decrease of stiffness was nearly linear and depended mainly on the mean disc height. They conclude that axial deformation and stiffness are predominantly determined by disc height and thus the length of the annulus fibres and not by DA. They also suggest that the cause of the minimal influence of the disc area on the stiffness is the construction of the intervertebral disc. More studies have found that the stiffness of the motion segment varies with the spinal level, the stiffness being lowest in the lower lumbar segments and highest in the middle and lower thoracic segments; however, in some of these studies no corrections were made for DA, which also varies with spinal level (van Dieën & Toussaint, 1993).

No significant correlations were found between BMD or DA and labda. From the regression analysis no significant predictive value was found of either BMD or DA on labda calculated from the stature and video data. Sex was no significant predictor of labda either. This is in disagreement with the findings of Keller *et al.* (1987), who found a significant higher creep rate for men compared to women. In the same study a significant positive correlation was found between labda and bone mineral content (BMC) (r=0.02). However, their study was an in vitro study dealing with only 5 male and 4 female isolated motion segments, which makes a comparison difficult.

Based on the findings of this study the model of spinal shrinkage (Figure 1) can be completed (Figure 7) by adding BMD and DA to the factors influencing shrinkage of the spinal motion segment. Gender seems not to be an important factor in SS. A loading task, like standing with a waistcoat, causes spinal loading resulting in a deformation of the intervertebral discs and the vertebrae. The shrinkage occurring in the disc is a result of fluid expulsion and bulging of the annulus fibres, whereas shrinkage occurring in the vertebra is the result of bulging of the endplates and possibly a deformation of the more bony

structures of the vertebra. Factors influencing the shrinkage of the motion segments are the time of the day, loading history, age, disc height and possibly DA, and the BMD of the vertebrae. Therefore, when the measurement of spinal shrinkage is used to evaluate the compression forces on the spine as a result of different loading tasks, it is of great importance that subjects are matched on these factors, because of their influence on stiffness. In addition, because of the great inter-individual variability in creep rate, the loading task must be long enough for each subject to reach a shrinkage equilibrium. Else, differences in spinal shrinkage between different tasks cannot be ascribed to the difference in compression forces, but just as well to the fact that some subjects may have achieved a shrinkage equilibrium, while others have not as a result of their lower individual creep rate.

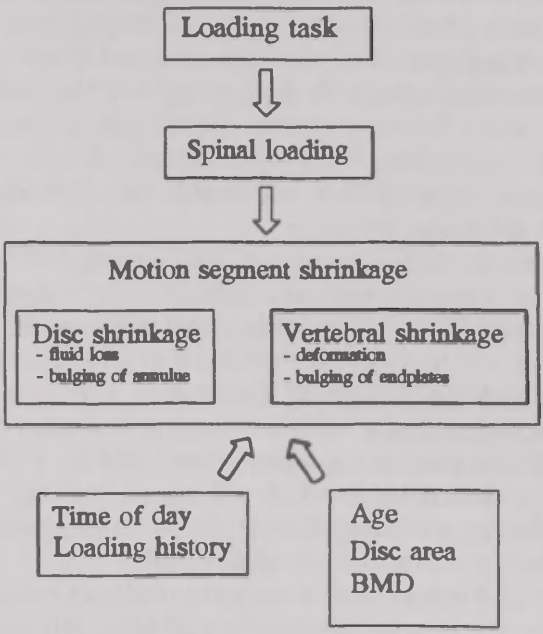


**Figure 7.** Final model of spinal shrinkage, including to age also disc area and bone mineral density (BMD).

## 5. CONCLUSIONS

In conclusion, in this study the estimated DA of L5/S1 significantly explained 13% of the variance in the stiffness of the spine, as calculated from stature measurements. The BMD of the lumbar vertebrae L2, L3 and L4 significantly explained 20% of the stiffness of the lumbar motion segments, as calculated from video measurements of shrinkage of the lumbar spine. However, more studies are needed in which subjects are trained for shrinkage measurement in advance to provide stronger evidence for a relationship between either BMD or disc area with shrinkage parameters such as the creep rate and the stiffness of the spinal motion segments.

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# RELATIONSHIPS BETWEEN BIOELECTRICAL IMPEDANCE AND ANTHROPOMETRIC VARIABLES IN 9–11-YEAR-OLD CHILDREN (PRELIMINARY RESULTS)

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ABSTRACT

The aim of the study was to investigate the relationships between anthropometric parameters and body impedance in different frequencies in 9–11-year-old children. In total, 67 boys and 53 girls were studied. Nine skinfolds, 13 girths, 8 lengths and 8 breadths/lengths were measured. Body impedance was measured with a multiple-frequency impedance device (MULTISCAN 5000, Bodystat, UK). The results of the correlation analysis between the used anthropometric parameters and body impedance of 5 KHz (extracellular water), 50 KHz (total body water) and 200 KHz (intracellular water) indicated that only 8 girths correlated significantly with body impedance in boys. While in girls 7 girths, transfere chest and humerus and femur breadths correlated significantly with body impedance. In girls forward stepwise multiple regression analysis indicated that only wrist, arm and gluteal girths were selected from the anthropometric parameters. These values characterised 44.8% of the total variance in body impedance at 50 KHz in boys. In girls the girth parameters characterised less of the total variance (18.1–21.9%).

**Key words:** bioelectric impedance, anthropometry, children

## INTRODUCTION

Bioelectrical impedance analysis (BIA) is a contemporary method for measuring of body composition variables such as total body water, fat mass and fat-free mass [7]. The theoretical basis for the BIA method

was proposed in the 1970s and 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 bioelectrical conductors is taken to be body height [5, 6]. New impedance devices are able to measure body impedance at more than one frequency (usually 50 KHz), ranging from low (about 1 KHz) to very high (>1MHz). The currently accepted technique of BIA involves, besides the measurement of height, the placement of two pairs of conductive electrodes — on the ankle and on the wrist. A low AV current of set frequency is then passed through the body and the impedance to this current is measured as the voltage drop from one point of the body to another [1]. With height, this impedance value is incorporated in regression equations to predict the volume of the conductive component of the body [8]. It is possible that other anthropometric parameters can influence body impedance as well. Only in one study, of marginally undernourished adolescents and young adults, other anthropometric variables than height, such as weight, skeletal diameters, skinfolds and age have been included into regression equations [2]. Grieve and Henneberg [4] have indicated that the concept of conductor length is vague — height is not the true conductor length when using the four-electrode wrist-to-ankle method of BIA. The true length of the conductor is better represented by the sum of acromial height and arm length. The aim of this study was to investigate the relationships between anthropometrical parameters and body impedance at different frequencies in 9–11-year-old children.

## METHODS

The subjects of this study were 67 boys and 53 girls, at 9–11 years of age. The children were from several schools in Tartu, Estonia. In school the children participated in 2–3 physical education lessons per week. The study was approved by the Medical Ethics Committee of the University of Tartu.

Body height was measured using a Martin metal anthropometer (±0.1 cm) and body mass using an electronic scale (±0.5 kg). BMI ($kg \cdot m^{-2}$) was calculated. In total, 9 skinfolds (triceps, subscapular, biceps, iliac crest, supraspinal, 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 troch-tibial lat-

eral, calf, ankle), 8 lengths (acromial-radial, radial-stylion, midstylion-dactylion, iliospinal-box height, trochanterion box height, trochanterion-tibial lateral, tibial-lateral to floor, tibial medial-sphyrion tibial) and 8 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 $r>0.90$. The CENTURION KIT instrumentation was used (Rosscraft, Surrey, BC, Canada). Skinfold thicknesses were measured on the right side of the body using Holtain (Crymmych, UK) skinfold callipers. Body impedance was measured with a multiple-frequency impedance device (MULTISCAN 5000, BODYSTAT Ltd, UK).

Standard statistical methods were used to calculate the mean (x) and standard deviation (±SD). Statistical comparisons between boys and girls were made using independent t-tests. Forward stepwise multiple regression analysis was used to present the influence of different anthropometric parameters to body impedance. Significance was set at $p<0.05$.

## RESULTS

The results of the correlation analysis between the used anthropometric parameters and body impedance at 5 KHz (extracellular water), 50 KHz (total body water) and 200 KHz (intracellular water) are presented in Table 1. Only 8 girths from 13 correlated significantly with body impedance in boys. In girls, 7 girths, transfere chest and humerus and femur breadth correlated significantly with body impedance.

**Table 1.** Correlations between anthropometric parameters and impedance at 5.50 and 200 KHz in boys and girls

| | Boys (n = 67) | | | Girls (n = 53) | | |
|---|---|---|---|---|---|---|
| | 5 KHz | 50 KHz | 200 KHz | 5 KHz | 50 KHz | 200 KHz |
| **Skinfolds** | | | | | | |
| Triceps | –0.04 | –0.03 | –0.04 | –0.19 | –0.18 | –0.19 |
| Subscapular | –0.18 | –0.18 | –0.19 | –0.05 | –0.08 | –0.09 |
| Biceps | –0.16 | –0.15 | –0.15 | –0.12 | –0.13 | –0.14 |
| Iliac crest | –0.26[x] | –0.23 | –0.23 | –0.18 | –0.17 | –0.17 |
| Supraspinal | –0.24 | –0.21 | –0.20 | –0.11 | –0.10 | –0.11 |
| Abdominal | –0.20 | –0.18 | –0.18 | –0.08 | –0.07 | –0.08 |

| | Boys (n = 67) | | | Girls (n = 53) | | |
|---|---|---|---|---|---|---|
| | 5 KHz | 50 KHz | 200 KHz | 5 KHz | 50 KHz | 200 KHz |
| Front thigh | −0.13 | −0.12 | −0.12 | −0.13 | −0.13 | −0.17 |
| Medial calf | −0.07 | −0.04 | −0.04 | −0.20 | −0.19 | −0.21 |
| Mid-axilla | −0.25[x] | −0.21 | −0.22 | −0.15 | −0.13 | −0.13 |
| **Girths** | | | | | | |
| Head | −0.07 | −0.13 | −0.15 | −0.19 | −0.26 | −0.28[x] |
| Neck | −0.45[x] | −0.46[x] | −0.46[x] | −0.33[x] | −0.41[x] | −0.42[x] |
| Arm (relaxed) | −0.53[x] | −0.57[x] | −0.60[x] | −0.33[x] | −0.38[x] | −0.40[x] |
| Arm (flexed and tensed) | −0.42[x] | −0.53[x] | −0.56[x] | −0.36[x] | −0.41[x] | −0.42[x] |
| Forearm | −0.49[x] | −0.54[x] | −0.56[x] | −0.39[x] | −0.43[x] | −0.41[x] |
| Wrist | −0.57[x] | −0.63[x] | −0.64[x] | 0.08 | 0.03 | 0.02 |
| Chest | −0.26[x] | −0.25[x] | −0.27[x] | −0.17 | −0.14 | −0.13 |
| Waist | −0.34[x] | −0.38[x] | −0.40[x] | −0.22 | −0.25 | −0.26 |
| Gluteal | −0.38[x] | −0.40[x] | −0.41[x] | −0.37 | −0.41 | −0.42 |
| Thigh 1 | 0.02 | 0.01 | 0.03 | −0.07 | −0.04 | −0.03 |
| Thigh 2 | 0.04 | 0.01 | −0.01 | −0.37[x] | −0.43[x] | −0.45[x] |
| Calf | 0.11 | 0.08 | 0.07 | −0.38[x] | −0.45[x] | −0.45[x] |
| Ankle | 0.17 | 0.14 | 0.13 | −0.43[x] | −0.48[x] | −0.48[x] |
| **Length** | | | | | | |
| Acromial-radial | 0.21 | 0.20 | 0.19 | −0.08 | −0.18 | −0.15 |
| Radial-stylon | 0.19 | 0.19 | 0.18 | 0.04 | 0.08 | 0.04 |
| Midstylon-dactylion | 0.21 | 0.19 | 0.18 | −0.09 | −0.18 | −0.16 |
| Ilospinal-box height | 0.04 | 0.08 | 0.09 | −0.12 | −0.16 | −0.14 |
| Trochanterion-box height | 0.00 | 0.02 | 0.02 | −0.00 | −0.08 | −0.06 |
| Trochanterion-tibial lateral | 0.17 | 0.16 | 0.14 | −0.16 | −0.24 | −0.20 |
| Tibial-lateral to floor | 0.20 | 0.20 | 0.19 | −0.07 | −0.12 | −0.09 |
| Tibial medial-spyrion tibial | 0.23 | 0.22 | 0.21 | 0.02 | −0.02 | 0.01 |
| **Breadths/Lengths** | | | | | | |
| Biacromial | 0.17 | 0.15 | 0.14 | 0.03 | 0.03 | 0.06 |
| Biiliocristal | 0.20 | 0.18 | 0.16 | −0.09 | −0.12 | −0.12 |
| Foot length | 0.19 | 0.17 | 0.16 | −0.18 | −0.27 | −0.25 |
| Sitting height | −0.08 | −0.08 | −0.09 | −0.24 | −0.33[x] | −0.34[x] |
| Transverse chest | 0.17 | 0.13 | 0.10 | −0.33[x] | −0.35[x] | −0.34[x] |
| A-P chest depth | 0.21 | 0.25[x] | 0.25[x] | −0.00 | −0.01 | −0.02 |
| Humerus | 0.22 | 0.20 | 0.19 | −0.36[x] | −0.43[x] | −0.43[x] |
| Femur | 0.23 | 0.23 | 0.23 | −0.32[x] | −0.37[x] | −0.36[x] |

x$p<0.05$

Forward stepwise multiple regression analysis (Table 2) indicated that only wrist, arm and gluteal girths were selected from the anthropometrical parameters. These values characterised 44.8% of the total

variance in body impedance at 50 KHz in boys. In girls, the girth parameters characterised less of the total variance (18.1–21.9%).

**Table 2.** Results of forward stepwise multiple regression analysis (independent variables: bioelectrical impedance at 5.50 and 200 KHz).

| | Intercept | F | $R^2$ | p |
|---|---|---|---|---|
| **Boys** | | | | |
| 5 KHz | 1230.7 | 35.62 | 0.320 | <0.0000 |
| Wrist girths | –44.81 | | | |
| 50 KHz | 1111.4 | 20.34 | 0.448 | <0.0000 |
| Wrist girth | –51.32 | | | |
| Gluteal girth | 5.20 | | | |
| Arm girth (flexed and tensed) | –9.78 | | | |
| 200 KHz | 922.6 | 27.51 | 0.531 | <0.0000 |
| Wrist girth | –40.09 | | | |
| Arm girth (relaxed) | –20.48 | | | |
| Gluteal girth | 7.76 | | | |
| **Girls** | | | | |
| 5 KHz | 1130.5 | 7.46 | 0.219 | <0.0014 |
| Ankle girth | –23.0 | | | |
| Transverse chest | –1.32 | | | |
| 50 KHz | 1135.1 | 13.75 | 0.189 | <–0.0005 |
| Calf girth | –26.30 | | | |
| 200 KHz | 1104.5 | 6.39 | 0.181 | <0.0031 |
| Calf girth | –38.87 | | | |
| Ankle girth | 28.53 | | | |

## DISCUSSION

The results of this study indicate that several girth measures from among the measured anthropometrical parameters correlated significantly with body impedance values measured at different frequencies. The results of this study are in agreement with the investigation of Conlisk *et al.* [2], who recommended to add other anthropometrical parameters than only height to different body composition regression equations. Surprisingly different length parameters did not influence body impedance significantly. It is possible that relative large area sections of children's body a difference in lengths parameters cannot

cause a significant change in impedance. Stepwise multiple regression analysis indicated that especially the girths with small hand areas (e.g. wrist, arm) had the largest influence on impedance parameters. However, de Koning (3) demonstrated that variables representing the muscle area of the arm or the leg were the best predictors of body impedance. The results of our investigation are in good agreement with the study of van Langendonck *et al.* [9] who concluded that the accuracy of BIA to estimate body composition will be enhanced when variables are incorporated into the regression equations which have the highest impact on body resistance, such as muscle areas of limbs.

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# FIRST EXPERIENCE OF APPLICATION OF OMRON BF 300 BODY FAT MONITOR TO MEMBERS OF A TARTU SPORTS CLUB

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ABSTRACT

The aim of the study was to investigate body fat percentage and amount of body fat in kilograms in the members of a Tartu sports club.

For body fat content analyses an OMRON® BF 300 Body Fat Monitor was used. The participants in the study were 321 members of a Tartu sports club (172 males with a mean age 31.0±12.84 years, height 180.9±7.20 cm, weight 82.7±13.0 kg, body mass index 25.24±0.27, body fat percentage 16.98±6.54, amount of body fat 14.71±7.32 kg, and 149 females with a mean age 27.0±10.44 years, height 166.3±5.57 cm, weight 61.7±10.91 kg, body mass index 22.27±3.62, body fat percentage 22.75±6.71, amount of body fat 14.67±7.16 kg). The sample was divided into age groups: below 20 years, 20–29 years, 30–39 years, 40–49 years, and 50 years and more. Statistical analysis showed that in parallel with the increase of the age body fat percentage, amount of body fat, body mass index and weight increased. Height decreased with age. Our results coincide with previous investigations of American and Estonian populations where body composition of young and middle-aged men and women was studied. The BIA method with OMRON® *BF 300* Body Fat Monitor is simple and comfortable to use in population investigations out of laboratory conditions.

## INTRODUCTION

In medical practice the nutritional state has frequently been assessed empirically — normal, thin or obese [13].

The WHO [11] recommends that body mass index (BMI) be used as an indicator of the deposition of excess energy as fat in adult men and women. Body mass index is calculated as follows: $BMI=W/H^2$ where

W is body weight in kilograms and H body height in meters. The normal range of BMI is from 18.50 to 24.99. BMI 25.00–29.99 means first grade overweight; BMI 30.00–39.99 is second grade overweight and over 40 — third grade overweight. However, using BMI to classify individuals according to fatness can also lead to misclassification. The proportion of bones, muscle mass and fluid to body weight differs individually. The percentage of body fat increases with ageing and is higher in women than in men [3]. Overweight is connected with increased prevalence of hypertension, blood lipids increase and diabetes mellitus. Spontaneous weight reduction by 10 percent would correspond to a 20 percent reduction in the risk of coronary heart disease [1].

From the end of 1998 there has been an opportunity in Estonia for body composition analyses with an OMRON BF 300 Body Fat monitor. That device measures the percentage and total amount of fat contained in the human body. It works according to the BIA (Bioelectrical Impedance Analysis) method [4, 5, 2, 9]. Extremely weak electrical current is sent through the human body tissues for analysing the electrical resistance of the body. Since fat tissues have little to no electric conductivity it is possible to determine the ratio of fat tissue as compared to other tissues. The instrument weighs below 500 grams and uses 4 AAI batteries as energy supply. Up to now exact measurement has been very costly and could be carried out only under laboratory conditions (underwater weighing methods, ultrasound, Dual Energy X-ray Absorptiometry).

The aim of the present investigation was to study the body mass index, fat percentage and body fat mass of the members of a Tartu sports club.

## MATERIAL AND METHODS

The participants in the present study were 321 members of a Tartu sports club (172 males, mean age 31.0±12.84 years, height 180.9± 7.20 cm, weight 82.7±13.0 kg, body mass index 25.24±0.27, body fat percentage 16.98±6.54%, amount of body fat 14.71±7.32 kg, and 149 females, mean age 27.0±10.44 years, height 166.3±5.57 cm, weight 61.7±10.91 kg, body mass index 22.27±3.62, body fat percentage 22.75±6.71%, amount of body fat 14.67±7.16 kg). For measuring of height the sportsmen were asked to take off their shoes. Using a Martin

anthropometer, height was measured to the nearest 0.1 cm. Weight was measured in light clothes (T-shirt and shorts). Weight was measured to the nearest 0.1 kg with a Phillips electronic device. For body composition analysis an OMRON BF 300 Body Fat Monitor was used.

For analysing the investigation results the subjects were divided into age groups: below 20 years, 20 to 29 years, 30 to 39 years, 40 to 49 years, and 50 years and more. By their social status the participants were school and university students, white-collar workers and entrepreneurs of various professions with a sedentary lifestyle and a lot of mental stress.

The data were processed on a personal computer using the statistic package Systat for Windows. Experience and recommendations of the Tartu University Centre for Physical Anthropology were taken into consideration. According to recommendations from literature we computed multiple linear regression equations for predicting body fat from various anthropometric measurements [15, 17, 7].

## RESULTS

To characterise the anthropometric changes due to age, Tables 1 and 2 give the results of the anthropometrical investigation separately for males and females. The tallest males were in the group of 20–29-year-olds. Males in the older age groups were shorter. The weight changed in the opposite direction. The lowest mean weight was in the youngest group; after the age of 30 the weight increased by more than 12 kg, and the increase in the weight continued until 50 years of age. It was remarkable that the increase in body mass index was in parallel to the increase of body fat content in kilograms and body fat percentage increase and the increase in age. Females' anthropological data analysis shows that their height was biggest at the age of 20–29 years. The females in all the following age groups were somewhat shorter. The weight increased in parallel to the increase in age, particularly after the age of 40. Body mass index, body fat in kilograms and body fat percentage also increases after the age of 30 years.

**Table 1.** Men's anthropometric variables in different age groups

| No | Age in years | n | Height | Weight | Body mass index | Fat percent | Fat kg |
|---|---|---|---|---|---|---|---|
| 1. | below 20 | 29 | 178.1±1.29 | 70.1±2.15 | 22.0±0.56 | 13.3±0.95 | 9.6±1.14 |
| 2. | 20–29 | 70 | 182.7±0.83 | 82.8±1.39 | 24.8±0.36 | 13.8±0.63 | 12.1±0.76 |
| 3. | 30–39 | 29 | 181.9±1.79 | 87.5±2.15 | 26.4±0.56 | 17.7±0.94 | 16.4±0.81 |
| 4. | 40–49 | 21 | 180.4±1.52 | 89.4±2.53 | 27.4±0.66 | 22.6±0.13 | 20.8±1.35 |
| 5. | over 50 | 23 | 177.8±1.45 | 86.2±2.42 | 27.3±0.63 | 24.3±1.05 | 21.2±1.26 |
| 6. | total | 172 | 180.9±7.2 | 82.7±13.0 | 25.2±0.27 | 16.9±6.54 | 14.7±7.32 |

**Table 2.** Women's anthropometric variables in different age groups

| No | Age in years | n | Height | Weight | Body mass index | Fat percent | Fat kg |
|---|---|---|---|---|---|---|---|
| 1. | below 20 | 30 | 165.8±1.02 | 58.8±1.81 | 21.4±0.56 | 21.6±0.93 | 13.1±1.05 |
| 2. | 20–29 | 72 | 166.9±0.66 | 59.1±1.17 | 21.1±0.36 | 19.7±0.61 | 11.9±0.68 |
| 3. | 30–39 | 26 | 166.7±1.09 | 63.5±1.94 | 22.8±0.60 | 24.8±1.04 | 16.3±1.17 |
| 4. | 40–49 | 14 | 164.4±1.48 | 70.2±2.64 | 25.7±0.82 | 30.2±1.36 | 22.1±1.53 |
| 5. | over 50 | 7 | 163.6±2.10 | 77.2±3.74 | 28.8±1.16 | 36.4±1.92 | 28.8±2.16 |
| 6. | total | 149 | 166.3±5.57 | 61.7±10.91 | 22.3±3.62 | 22.8±6.71 | 14.7±7.16 |

Multiple linear regression equations Table 3 also show that by anthropometrical variables and age it is possible to predict body fat percentage and body fat in kilograms.

**Table 3.** Multiple linear regression equations for predicting men's and women's fat percentage and body fat kilograms

| No | Variables | Multiple regression equation | Multiple $R^2$ percent |
|---|---|---|---|
| | **Men's fat percentage** | | |
| 1. | a — age | Fat % = 6.506+0.333a | 43.5 |
| | b — height | Fat %= –10.341+0.327c | 41.2 |
| | c — weight | Fat %= –21.021+1.492d | 60.4 |
| | d — body mass index | Fat %= –14.242+0.186a –0.022b+1.154d | 71.2 |
| | **Men's fat kg** | | |
| 2. | a — age | Fat kg = 4.014+0.340a | 36.1 |
| | b — height | Fat kg = –23.428+0.457c | 63.9 |
| | c — weight | Fat kg = –32.851+1.867d | 75.5 |
| | d — body mass index | Fat kg = –50.591+0.144a+0.111b+1.597d | 81.1 |

| No | Variables | Multiple regression equation | Multiple $R^2$ percent |
|---|---|---|---|
| | **Women's fat percentage** | | |
| 3. | a — age | Fat % = 12.517+0.378a | 35.2 |
| | b — height | Fat % = –7.115+0.483c | 61.6 |
| | c — weight | Fat % = –14.291+1.659d | 80.5 |
| | d — body mass index | Fat % = 11.474+0.104a–0.152b+1.514d | 84.6 |
| | **Women's fat kg** | | |
| 4. | a — age | Fat kg = 4.515+0.376a | 30.5 |
| | b — height | Fat kg = –22.581+0.602c | 84.2 |
| | c — weight | Fat kg = –27.922+1.908d | 93.6 |
| | d — body mass index | Fat kg = –37.253+0.062a+0.059b+1.819d | 94.3 |

## DISCUSSION

Recently A. Landõr and co-workers [8] published an anthropometric investigation of selected South-Estonian population. We used their data for comparison.

We compared our data of fat percentage in males obtained with the help Omron® Body Fat monitor and A. Landör and co-workers' data obtained by J. Parizkova's skinfold thickness method. Omron® *BF 300* Body Fat Monitor was first used in Estonia from the end of 1998, and no previous data were available. In our groups fat percentage increased with age and was smallest in the age group of 10–19 years and highest in the group over 50 years (24.28±1.05%). In the three youngest age groups our data show a smaller percentage of fat (at the age of 10–19 years by our data 13.28±0.95% vs. 14.1±4.6% by A. Landõr and co-workers; 20–29 years 13.82±0.63% vs. 16.5±5.2%; 30–39 years 17.71±0.94% vs. 18.0±5.5%). At the age over 40 we found higher fat percentages were than A. Landõr and co-workers (40–49 years by our data 22.64±0.13% vs. 19.1±4.4% by A. Landõr and co-workers; over 50 years 24.29±1.05% vs. 19.1±4.0%). The normal fat percentage for males is 10–19 percent. Our results confirm a previous investigation by M. L. Pollock and co-workers (1976), which showed that at the age of 18–24 years fat percentage was 13.4±6.0 and in middle-aged men 24.7±5.9%. J. W. Wilmore and A. R. Behnke [18] found young men's fat percentage to be 14.35±6.18. Both investigations used the hydrostatic weighing technique to evaluate body density and Siri's formula to estimate the percentage body fat. Thus we may conclude that, according to our study, fat percentage increases with age.

By our data the male heights were the biggest in the age group of 20–29 years (182.7±0.8 cm). A. Landõr and co-workers had found the biggest height in age the group below 21 years (181.6±17.4 cm). By L. I. Tegako's (1998) investigations in Belarus, males were tallest at the age of 19 (178.93±5.28 cm). H. Greil's (1997) study of East German population found the maximum male height at the age of 20 years (178.1±6.6 cm). We may state that our maximum height data were the biggest that we have found in literature. By our investigation, the mean height of males in the age groups of 30–39 and 40–49 was also bigger than in A. Landõr and co-workers' investigation (30–39 years 181.9± 1.29 vs. 180.5±16.3, and 40–49 years 180.4±1.52 vs. 180.1±16.4 cm). By L. I. Tegako's (1998) and H. Greil's (1997) studies, heights of males in these age groups were smaller. It is remarkable that in investigations in Estonia male height also increased after the age of 20 years while in Belarus maximum heights were found at the age of 19 years and in East Germany at the age of 20 years.

As far as weight is concerned, the males of Tartu sports club were heavier than those studied by A. Landõr and co-workers (20–29 years 82.81±1.38 vs. 77.9±10.5 kg; 30–39 years 87.47±2.15 vs. 82.8±14.5 kg; 40–49 years 89.4±2.53 vs. 82.9±11.5 kg; over 50 years 86.22±2.42 vs. 83.1±12.5 kg). In L. I. Tegako's (1998) and H. Greil's (1997) studies the weight of males in these age groups was smaller. Males with maximum weight were in the 40–49 years age group; A. Landõr and co-workers also obtained the same result. L. I. Tegako's (1998) investigations showed the maximum weight in the 51–55 years age group (75.73±12.84 kg) and H. Greil's (1997) study in the age group of 40–45 years (79.5±10.8 kg). So the maximum weight of our males surpasses that of the males of East Germany and Belarus.

As for women, then fat percentage in our youngest group was higher than in the study of Landõr and co-workers (21.62±0.93% vs. 20.8±5.37%). In the age group of 20–29 years fat percentage was smaller in our study (19.67±0.61% vs., 20.8±5.31% in A. Landõr and co-workers' study). In all the older female groups we had higher fat percentage indices: 30–39 years 24.80±1.04% vs. 23.7±6.12%; 40–49 years 30.24±1.36% vs. only 23.2±5.54% by A. Landõr and co-workers; over 50 years 36.37±1.92% vs. 25.9±5.92%.

In young women Katch and Michael [6] also reported fat percentage values of 21.5% and Sloan *et al* [14] 22.9%.

Now let us analyse females' earlier and present anthropological data. We found that the height of females was smaller in the two

younger groups — up to 19 years and 20–29 years. By our investigation, height in the first female age group was 165.8±1.01 cm vs. A. Landõr and co-workers' 167.5±15.8 cm, and in the second age group (20–29 years) 166.9±0.66 cm vs. A. Landõr and co-workers' 168.7±15.8 cm. In the age group 30–39 years our females' height was 166.7±1.09 cm vs. 166.2±18.2 cm in A. Landõr and co-workers' investigation, and also in the age group of 40–49 years by our data the females height was 164.4±1.49 cm vs. 164.1±21.4 cm. The weight of females at the age of over 50 years was 163.6±2.10 cm in our investigation vs. A. Landõr and co-workers' 164.1±24.8 cm.

The weight up to 19-year-old females in our investigation was 58.85±1.80 kg. It was smaller than in A. Landõr and co-workers' study (59.6±7.9 kg). The weight of 20–29-year-old females in our investigation was 59.12±1.17 kg, which was also smaller than A. Landõr and co-workers' study (63.4±10.9 kg). In the two older female age groups our investigations showed bigger weight (70.16±2.65 kg vs. 65.9±9.66 kg). Over 50-year-old females weight in our study was 77.24±3.74 kg; in A. Landõr and co-workers' study it was smaller (71.9±11.0 kg). Both studies demonstrated that weight as well as body mass index and fat percentage increase with age.

O. Volozh *et al.* [16] from Tallinn also investigated BMI values in men and women and also found that BMI mean values increase with ageing.

The reasons for the many anthropometrical differences between our study group and A. Landõr and co-workers' study may lie in different populations. Our sample was connected with certain hobby, but A. Landõr and co-workers' material was nearer to the general population.

The method of bioimpedance analysis using OMRON® Body Fat Monitor for body fat assessment is very simple and comfortable to use and can be recommended for population investigations in Estonia as well.

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# DIETARY INTAKE AND BODY STRUCTURE OF GIRLS FROM SECONDARY SCHOOLS OF TARTU

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The nutritional recommendations for a standard person (a man weighing 70 kg, woman 60 kg) do not take into account the body build type, where height has an important role. The aim of the investigation was to study nutrient intake of 15–18-year-old schoolgirls in connection with their body structure.

## MATERIAL AND METHODS

A school-based cross-sectional study, using anthropometric measurements (779 girls) and a questionnaire about food frequency and 24-hour recalls (708 girls) [9], was performed in all Tartu Estonian-language secondary schools in 1995/1996. The study was a part of the project "The evaluation of nutrition habits indicators for physical development and health of the pupils of Tartu" financed by the Health Protection Foundation and Central National Health Service.

The age of the girls was from 15 to 18 years. Their average weight was 58.1±8.3 kg, average height 166.2±5.8 cm, and body mass index (BMI) 21.1±2.7.

On the basis of the standard deviation (SD) of the main anthropometric parameters — height and weight — the investigated girls were systematised into 5 classes:
3 classes with concordance between height and weight:
**I class** (*small*) — subjects with small height and weight; n=129;
**II class** (*medium*) — subjects with medium height and weight; n=127;
**III class** (*big*) — subjects with big height and weight; n=107;

and 2 classes with disconcordance between height and weight:
**IV class** (*pycnics*): subjects with small height and medium or big weight and subjects with medium height and big weight; n=198;

**V class** (*leptosomes*) — subjects with big height and small or medium weight and subjects with medium height and small weight; n=218 [6].

Nutrient intake was determined using the program Micro-Nutrica (*Micro-Nutrica*, 1997). The statistical package SAS 6.12 was used for data processing. The $p<0.05$ level was selected as the criterion of statistical significance.

## RESULTS

The main anthropometric characteristics of height and weight SD classes (height, weight, BMI) are shown in Table 1.

**Table 1.** Anthropometric parameters of 15–18-year-old schoolgirls by height and weight SD-classes

| | | Height (cm) | Weight (kg) | BMI ($kg/m^2$) |
|---|---|---|---|---|
| Small | $\bar{x}$ | 159.07 | 49.20 | 19.44 |
| n=160 | Min | 147.70 | 34.50 | 15.03 |
| | Max | 163.40 | 54.85 | 22.90 |
| | SD | 3.25 | 3.71 | 1.34 |
| Medium | $\bar{x}$ | 166.50 | 58.19 | 20.99 |
| n=160 | Min | 163.30 | 53.20 | 19.05 |
| | Max | 169.30 | 63.50 | 23.29 |
| | SD | 1.69 | 2.40 | 9.68 |
| Big | $\bar{x}$ | 173.87 | 69.88 | 23.13 |
| n=136 | Min | 169.20 | 61.65 | 19.61 |
| | Max | 186.60 | 91.30 | 30.84 |
| | SD | 3.44 | 6.47 | 2.21 |
| Pycnics | $\bar{x}$ | 162.55 | 62.85 | 23.77 |
| n=225 | Min | 150.10 | 53.05 | 20.18 |
| | Max | 168.90 | 85.95 | 32.37 |
| | SD | 3.67 | 6.60 | 2.16 |
| Leptosomes | $\bar{x}$ | 169.28 | 54.37 | 18.96 |
| n=282 | Min | 163.20 | 42.45 | 14.96 |
| | Max | 182 00 | 63.40 | 21.96 |
| | SD | 3.82 | 4.53 | 1.23 |
| Statistically significant differences | $p<0.05$ | 1& 2, 3, 5 | 1& 2, 3, 4 | 4&1. 5; |

There were no statistically significant differences in weight between small and the leptosomic, in height between small and pycnic, in BMI between big and pycnic girls. Body mass index characterises body stoutness, not the body as whole, as it does not express size. Big and pycnic girls did not differ by BMI, although they differ by their body type and height.

The mean of daily intake of energy and nutrients is shown in Table 2.

**Table 2.** The mean daily intake of energy and nutrients of 15–18-year old schoolgirls

| Macronutrients | $\bar{x}$ | Min | Max | SD |
|---|---|---|---|---|
| Energy (kcal) | 1705.74 | 319.00 | 5940.00 | 734.30 |
| Proteins (g) | 53.25 | 5.60 | 197.30 | 24.16 |
| Fat (g) | 63.75 | 4.30 | 280.10 | 36.21 |
| Carbohydrates (g) | 223.77 | 42.30 | 894.90 | 96.68 |
| Protein intake to the total energy intake (%) | 12.87 | 3.44 | 28.28 | 3.11 |
| Fat intake to the total energy intake (%) | 32.91 | 6.87 | 58.79 | 8.62 |
| Carbohydrates intake to the total energy intake (%) | 54.22 | 24.91 | 84.65 | 9.33 |

The mean daily intake of energy was 1705.7±734.3 kcal, being lower than recommended by the Estonian Nutrition Recommendation (2150 kcal) [3]. As compared to the data of earlier studies [11, 8, 1], the energy intake was lower in this study. In comparison with the data of neighbouring countries, Estonian girls had lower daily energy intake than Finnish 15-year-old girls and Swedish girls [10].

The lower energy and nutrient intake could be explained by changes in nutritional behaviour and lifestyle, underestimation in recalls or using different methods for assessment.

There were significant differences in mean daily intake of energy by different body build types (Table 3).The greatest consumers of daily energy were small girls (1840.6±757.3 kcal). Pycnics were the least consumers of daily energy (1525.94±757.26 kcal), there were statistically significant differences with small, medium and leptosomic girls.

Energy intake in relation to body weight by body build types (Table 4) had significant differences — small girls consumed significantly more energy per body weight (34.1±16.6kcal) than pycnics and big girls (resp. 26.1±10.7 and 27.3±13.1 kcal). Energy intake per kilogram of body weight in pycnics was significantly lower than in medium and leptosomic girls (resp. 31.6±16.5 and 30.6±11.9 kcal). The

higher intake of calories in relation to body weight could be accounted for by higher basal metabolic rates in underweight subjects [2].

**Table 3.** The mean daily intake of energy and nutrients of 15–18-year old schoolgirls by body build classes

| Height-weight SD classes | Statis-tics | Energy (kcal) | Proteins (g) | Fats (g) | Carbohy-drates (g) | The relative contributions to the energy of | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | proteins (%) | fats (%) | carbo-hydrates (%) |
| 1. Small | $\bar{x}$ | **1840.6** | **55.9** | **72.7** | **234.0** | **12.7** | **34.6** | **52.7** |
| n=129 | Min | 536.0 | 16.5 | 14.6 | 42.3 | 6.8 | 11.7 | 28.6 |
| | Max | 4502.0 | 147.1 | 245.7 | 627.2 | 26.4 | 58.8 | 78.9 |
| | SD | 757.3 | 23.4 | 41.0 | 96.0 | 3.1 | 9.1 | 9.5 |
| 2. Medium | $\bar{x}$ | **1794.5** | **55.2** | **65.4** | **240.3** | **12.7** | **32.2** | **55.1** |
| n=127 | Min | 418.0 | 8.0 | 10.2 | 56.6 | 7.3 | 12.8 | 32.6 |
| | Max | 5940.0 | 172.0 | 200.6 | 894.9 | 22.4 | 53.7 | 78.9 |
| | SD | 876.1 | 26.7 | 39.0 | 121.9 | 2.8 | 8.5 | 9.0 |
| 3. Big | $\bar{x}$ | **1631.6** | **50.9** | **57.1** | **222.9** | **12.9** | **31.2** | **55.96** |
| n=107 | Min | 319.00 | 5.60 | 12.20 | 43.20 | 3.44 | 13.10 | 40.36 |
| | Max | 5004.00 | 128.10 | 192.40 | 809.60 | 24.39 | 48.67 | 76.70 |
| | SD | 751.93 | 23.61 | 33.52 | 106.89 | 3,40 | 7,69 | 8,25 |
| 4. Pycnics | $\bar{x}$ | **1525.94** | **48.93** | **56.05** | **201.07** | **13.06** | **32.49** | **54.45** |
| n=190 | Min | 440.00 | 6.70 | 6.50 | 69.70 | 6.15 | 11.34 | 24.91 |
| | Max | 3698.00 | 123.90 | 195.10 | 470.60 | 22.48 | 56.14 | 80.42 |
| | SD | 564.94 | 20.68 | 29.79 | 74.56 | 3.18 | 8.86 | 10.11 |
| 5. Leptosomes | $\bar{x}$ | **1774.39** | **55.73** | **67.82** | **229.06** | **12.96** | **33.67** | **53.36** |
| n=210 | Min | 506.00 | 11.80 | 4.30 | 59.50 | 5.86 | 6.87 | 30.43 |
| | Max | 5881.00 | 197.30 | 280.10 | 631.20 | 28.28 | 56.66 | 84.65 |
| | SD | 727.41 | 25.38 | 36.30 | 91.05 | 3.13 | 8.47 | 9,01 |
| Statistically significant differences | p<0.05 | 4&1, 2, 5 | | 4&1, 5; 3&1 | 4&2 | | | |

**Table 4.** The mean daily intake of energy and nutrients of 15–18-year old schoolgirls by body build classes in relation to body weight

| | 1. Small | 2. Medium | 3. Big | 4. Pycnics | 5. Leptosomes | P<0.05 |
|---|---|---|---|---|---|---|
| | n=121 | n=113 | n=99 | n=171 | n=192 | |
| Energy kcal/kg | 34.1±16.6 | 31.6±16.5 | 27.3±13.1 | 26.1±10.7 | 30.6±11.9 | 1&3; 4&1, 2, 5 |
| Protein g/kg | 1.0±0.5 | 1.0±0.5 | 0.9±0.4 | 0.8±0.4 | 1.0±0.4 | 1&3, 4 |
| Fat g/kg | 1.3±0.8 | 1.1±0.7 | 1.0±0.6 | 1.0±0.5 | 1.2±0.6 | 1&3, 4 |
| Carbohydrates g/kg | 4.3±2.2 | 4.3±2.3 | 3.7±1.9 | 3.4±1.4 | 4.0±1.6 | 1& 4, 2&4 |

The mean daily intake of protein was 53.3±24.2 g, which contributed 12.9% to the total energy intake. There was no difference between the five body build classes in the consumption of proteins. The daily intake of proteins per kilogram of body weight by small girls was significantly higher (1.0±0.5 g/kg) than by big and pycnic girls (resp. 0.9 g/kg, 0.9 g/kg).

The mean daily intake of fat was 63.8±36.2 g, which contributed 32.9% to the energy intake. Pycnics were the least consumers of daily fat (56.0±29.8 g) — a significant difference with smalls and leptosomes. There was also a statistically significant difference in the intake of fat between big (57.1±33.5 g) and small girls (72.6±41.0 g). The intake of fat in relation to body weight was significantly higher in the group of small girls (1.3 g/kg) than among the big and pycnic girls (1.0 g/kg 1.0 g/kg).

The mean daily intake of carbohydrates as the main source of energy for the organism was 223.8±96.7 g, which contributed 54.2% to the energy intake. The daily intake of carbohydrates was smallest in the group of pycnics (201.07±74.56 g), showing a significant difference with mediums (240.3 g). Pycnics were significantly lower consumers of carbohydrates in relation to body weight (3.4 g/kg) than medium and small girls (resp. 4.3 and 4.3 g/kg).

Protein, fat and carbohydrates intakes in relation to the total energy intake were statistically similar in every body type (Table 3). The intake of macronutrients, expressed as a percentage of total calories, was in accordance with national nutrition recommendations. As compared with earlier studies [8], the proportion of proteins from energy intake showed the same level, the share of fats has decreased and the share of carbohydrates has increased.

The energy and nutrient intake affirm the findings of food consumption frequency — pycnics eat less and seldom then the representatives of the other body build types [4, 5].

Though individual differences in nutrient intake were great, different body build types revealed different tendencies in dietary intake. The results of the study indicate the requirement for additional investigations and special dietary recommendations for pycnics as the potential risk group.

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# PHYSICAL ACTIVITY, BODY MASS INDEX AND RISK FACTORS FOR CORONARY HEART DISEASE IN RURAL ISLANDERS

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ABSTRACT

Physical activity and fitness have important health promoting effects with respect to atherosclerosis and coronary heart disease (CHD) in particular.

The aim of this study was to assess physical activity, obesity and CHD factors in rural islanders. A total of 33 women (43.7±16.3 years) and 17 men (45.5±16.4 years) from Saaremaa Island volunteered to participate in a check-up of health.

The study included an interview for recording physical activity and lifestyle. Body height, body weight and blood sampling for serum lipid analysis was performed. Risk for CHD was estimated basing on Risk Tables of the European Society of cardiology (1994).

The physical activity of most subjects of the study was high or moderate, being related mainly to household and field work for females and to agriculture and fishing for males.

In the group of females only 1/3 of the subjects had normal weight, while another 1/3 were obese. Among men the distribution of body mass index was quite similar to that for the group of females. Overweight, elevated serum lipids and arterial hypertension were the main risk factors for CHD among females. Nine women had moderate (10–20%) and one had high (>20%) individual risk for CHD according to Risk Tables. In the group of males, moderate risk for CHD was found in 3 men and high risk in 4 men. The main risk factors for CHD in males were overweight, smoking and arterial hypertension.

**Key words:** body mass index, physical activity, risk factors for coronary heart disease, rural population

The characteristics and functions that are indicative of health or disease states are either morphological or functional [9]. Cardiovascular function and carbohydrate and lipid metabolism are the key health-related functions of coronary heart disease (CHD) [4, 11].

A number of reliable epidemiological studies indicate that physical activity and fitness have important health promoting effects with respect to atherosclerosis and CHD in particular [1, 6]. These effects appear to be partially independent and partially associated through the effects on hypertension, obesity and non-insulin dependent diabetes [9].

CHD is the leading cause of death among the population of Estonia [12]. For preventive medicine, one of the highest priorities is to achieve a major decrease in CHD and other manifestations of atherosclerosis. The goal of reducing cardiovascular risk factors can be accomplished only by implementation of health education efforts, directed toward all age groups, actions on the part of the government and supranational agencies and heart health programs for local communities [2, 3, 5].

A number of studies have shown that most city dwellers need little muscular effort at work and in other daily activities. However, the physical activity and health-related fitness of rural residents has been studied less often.

The aim of this study was to assess physical activity, obesity and CHD risk factors in rural population. Within the project *Human and Environmental Health in Estonian Islands* we carried out a study of volunteers from among the adult population of Vätta Peninsula (Saaremaa Island).

## PATIENTS AND METHODS

The whole adult population of the peninsula of Vätta was invited to participate in a medical check-up at the surgery of the local family doctor. A total of 33 women (43.7±16.3 years) and 17 men (45.5±16.4 years) volunteered (37% of the adult population of the Vätta Peninsula) to participate in the study.

The study included an interview for recording physical activity and lifestyle. To characterize physical activity, the following categories were used:

1. High — physical activity 3 or more times a week (long distance walk, hard physical work etc.).

2. Moderate — physical activity 1–2 times a week.
3. Low — physical activity less than once a week.

Body height, body weight and blood pressure measurements were taken, and blood sampling for serum lipid analysis was performed. Body mass index (BMI=$kg \cdot m^{-2}$) was calculated.

The following categories of BMI were used:
<19 underweight, 19–24 normal weight, 24.1–27.0 slight overweight, 27.1–30.0 moderate overweight, 30.1–40.0 obesity, >40 severe obesity.

Total plasma cholesterol, low density (LDL) and high density (HDL) cholesterol and triglycerides were measured at the laboratory of Kuressaare Hospital.

Risk for CHD was estimated according to the guidelines of the European Atherosclerotic Society (1992) and Risk Tables of the European Society of Cardiology (1994). Individual educational "Risk Monitor" protocols (Leaning Methods International, 1993) were used to explain the risk factors posing the greatest threat to health. Recommendations for health promotion and modifications of lifestyle risk factors for CHD were provided.

Statistical analysis was performed using the statistical package Statistica. Mean values and standard deviations for normally distributed data were calculated and paired t-test was employed. To establish associations between variables, Spearman correlation analysis was performed.

## RESULTS

Distribution of the subjects according to physical activity is presented in Table 1.

**Table 1.** Physical activity of female and male subjects

| Physical activity category | Female n=33 | Male n=17 |
|---|---|---|
| 1. High | 12 | 8 |
| 2. Moderate | 18 | 8 |
| 3. Low | 3 | 1 |

Physical activity of most subjects in this study was high or moderate and was related mainly to household and field work for females and to agriculture and fishing for males.

Table 2 shows the distribution of subjects according to BMI categories.

**Table 2.** Distribution of subjects according to BMI categories

| BMI ( $kg \cdot m^{-2}$ ) | Category | Females n=33 | Males n=17 |
|---|---|---|---|
| <19 | underweight | – | – |
| 19–24 | normal | 11 | 5 |
| 24.1–27.0 | slight overweight | 7 | 4 |
| 27.1–30.0 | moderate overweight | 3 | 5 |
| 30.1–40.0 | obesity | 11 | 3 |
| >40 | severe obesity | 1 | – |

Body mass index (BMI) is the most frequently used clinical measure for determination of relative fatness. In the group of females only 1/3 of the subjects had normal weight, while another 1/3 were obese. Among men the distribution of BMI was quite similar to that of wormen.

Risk for coronary heart disease according to Risk Tables of the European Society of Cardiology (1994) is presented in Table 3.

**Table 3.** Risk for CHD in study groups

| Risk for CHD (%) | Category | Female n=33 | Male n=17 |
|---|---|---|---|
| >40 | very high | – | – |
| 20–40 | high | 1 | 3 |
| 10–20 | moderate | 10 | 4 |
| 5–10 | mild | 1 | 3 |
| <5 | low | 21 | 7 |

Most females and males had a low risk for CHD. Ten females had a moderate and one had a high risk for CHD. In the group of males, 4 men had a moderate and 3 men had a high risk for CHD.

The averange distribution of risk factors for CHD was similar in both groups, differences between the groups were significant only with respect to smoking (Table 4).

Overweight, elevated serum lipids and arterial hypertension were the main risk factors for CHD among females. Nine women had moderate (10–20%) and one had high (>20%) individual risk for CHD according to Risk Tables of the European Society of Cardiology. In the group of men, moderate risk for CHD was established in 3 men

and high risk in 4 men. Main risk factors for CHD in males were overweight, smoking and arterial hypertension.

**Table 4.** Risk factors for CHD among females and males (x±SD, min–max)

| Risk factors for CHD | Female n=33 | Male n=17 |
|---|---|---|
| 1. Age (years) | 43.7±16.3 | 45.5±16.4 |
| | 18–74 | 18–70 |
| 2. Physical activity (1–3) | 1.7±0.6 | 1.6±0.6 |
| | 1–3 | 1–3 |
| 3. BMI ($kg \cdot m^{-2}$) | 27.8 ±5.9 | 26.8±4.3 |
| | 20–44 | 20–36 |
| 4. Systolic BP (mm Hg) | 132.0±28.5 | 134.7±14.8 |
| | 96–202 | 117–166 |
| 5. Diastolic BP (mm Hg) | 75.2±11.3 | 79.3±13.4 |
| | 44–96 | 60–116 |
| 6. Cholesterol (mmol/l) | 5.7±1.4 | 5.0±1.2 |
| | 3.7–9.5 | 2.9–7.1 |
| 7. LDL (mmol/l) | 3.7±1.4 | 3.1±1.3 |
| | 1.6–7.2 | 0.3–4.5 |
| 8. HDL (mmol/l) | 1.3±0.2 | 1.2±0.2 |
| | 0.9–1.7 | 0.8–1.6 |
| 9. Triglycerides (mmol/l) | 1.1±0.5 | 1.2±1.0 |
| | 0.5–2.7 | 0.3–3.9 |
| 10. Smoking (1–3)* | 1.0±0.3 | 1.4±0.7 |
| | 1–2 | 1–3 |
| 11. Risk of CHD (%) | 17±10.1 | 22±12.6 |
| | 4–31 | 5–38 |

*$p<0.05$

Lifestyle risk factors, particularly BMI and smoking, were related to the serum level of lipids in the group of men. Correlation was found between BMI and serum LDL (mmol/l) ($r=0.54$; $p<0.05$) and between smoking and elevated triglycerids ($r=0.45$; $p<0.05$). Age-adjusted high blood pressure was established in the group of females ($r=0.81$; $p<0.001$) and males ($r=0.72$; $p<0.001$).

## DISCUSSION

Regular physical activity has a positive impact on health promotion, functional capacity and well-being of individuals and populations [4, 6, 11]. Lack of physical activity and fitness are associated with obesity and cardiovascular diseases [8, 9]. This study provides evidence that physical activity, mainly in the form of housework and farm work does not provide protection against arterial hypertension, elevated serum lipids and obesity, especially with advancing age. Hard physical work will develop musculoskeletal fitness and strength and endurance of muscles. Sufficient strength and endurance of arms and legs is imperative in retaining proficient functioning in most daily activities. Aerobic fitness is the most important component of health-related fitness, expressed through respiratory, cardiovascular and metabolic functions. Aerobic exercise influences favourably other modifiable risk factors for CHD: obesity, high blood pressure and high blood cholesterol level [5, 6]. Giving up smoking, eating less of saturated fat and increasing aerobic exercise activity form key approach that would decelerate atherosclerotic process and development of CHD among the studied rural population.

Besides the individual educational "Risk Monitor" protocols, delivered to every subject, two educational Health Days were organised for the population of Vätta Peninsula.

The study demonstrated a surprisingly low level of awareness of the risk factors for CHD among the adult population of rural islanders. The results of the study confirmed a moderate prevalence of the major risk factors of CHD among females and males. In conclusion, it can be pointed out that physical activity in the form of housework does not provide protection against the main risk factors for CHD.

Individual counseling on the basis of health profile protocols turned out to be a useful educational tool in individual health education, which can help to modify lifestyle and reduce cardiovascular risk factors.

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# PECULIARITIES OF PHYSICAL DEVELOPMENT AND PHYSICAL PERFORMANCE IN ESTONIAN PUBERTAL GIRLS AT DIFFERENT BIOLOGICAL AGES

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ABSTRACT

Estonian pubertal girls (n=238, 68 of them 13-year-old and 170 15-year-old) were investigated somatometrically, and their physical working capacity and basic physical abilities as speed, speed-power, endurance were determined. Correspondence between physical development and biological age (BA) was established by Tanner scale and calculated by Klimt's formula. For the assessment BA by body mass and height growth curves of percentile distribution of Estonian children were used. According to BA the subjects were divided into 3 groups: I group with retardation of somatometric development, II group of medium physiologic development, III group of accelerated physiologic development.

We established a tendency towards acceleration in the younger group and towards retardation in the older group. The accelerants of the 13-year-old group were characterised by relatively broad pelvis circumference and less developed muscle mass in absolute as well as in relative values. The subgroups of retardants have a small body mass and body mass index (BMI). All girls in that subgroup have a low level of individual physical performance capacity expressed in MET's. In the younger group a significant negative correlation (r=–0.767) was found between physical performance capacity and BA. At the age of 15 it became insignificant.

Estonian girls of pubertal age showed a rising rate of development deflections in combination with lowered levels of physical performance.

**Key words:** physical development, physical performance, adolescents, biological age

## INTRODUCTION

Physiological and anatomic values during maturation in puberty are very heterogeneous and exhibit a high degree of interindividual variability. The rate of development of a particular physiological variable in the same age-group differs significantly from one child to another. A difference of up to ± 2 years between biological and calendar age is considered to be normal [5]; there can be various endogenic and exogenic causes for it.

The mechanisms that drive biological maturation are multiple, complex and resistant to simplistic explanations [15]. Children inherit genetic information from their parents and resemble their mothers or fathers both in size and in physical characteristics. The genetic contribution is assumed to be approximately 60%. At the same time the dynamics of development of physical performance depends significantly on the amount of physical activity [10] and the rate of biological maturation [12].

Thus a young person who is advanced in one indicator of biological maturity will be highly likely to show early development in the others as well. Up to the present there are not enough data about the peculiarities of physical development and physical performance of Estonian pubertal girls. The aim of our study is to elucidate the relationships between physical performance and physiological development in Estonian pubertal girls in connection with differences in biological age and maturation.

## MATERIAL AND METHODS

A total of 238 (68 13-year-old and 170 15-year-old) Estonian girls from secondary schools of South Estonia (representativeness 90%) were investigated. The rules of an epidemiological study were followed. Anthropometrical measurements (25 body measurements, 11 skinfolds) were carried out according to the classical methods of Martin [13]; 20 indices, the amount of subcutaneous fat [11], muscle mass by Matiegka and corrected muscle mass [13] were calculated.

Sexual maturity was evaluated by a five-stage rating system of Tanner [17]. The methods for determination of biologic age are numerous [4, 16]. X-ray examination of the ossification status of bones is the most exact method, but is not practicable for massive screening studies. An alternative is to use homogeneous and representative eth-

nic data-base curves of different forms of maturity for different sex- and age-groups, where the value of $x \pm 2\sigma$ or 10–90 percentiles is considered to be normal. In school medicine and especially in evaluation of standards for estimation of values of physical performance, Klimt [7] suggested that the index of age for school sports or biological age should be used. This is based on considering the differences in body height and mass indices in comparison with the ethnic standard curves. The correspondence between physical development and biological age was calculated by Klimt's formula [7]

$$BA = \frac{2 \times chronological\ age + age\ by\ body\ mass + age\ by\ height}{4}$$

For the assessment of BA by body mass and height were used growth curves of percentile distribution for Estonian children [5]. The calculated biological age correlates with the stage of sexual maturity by Tanner's scale (r=0.73) [8].

The levels of physical working capacity were determined by the functional test of $PWC_{170}$ using submaximal loads on the veloergometer under electrocardiographic control [3]. School sports for the estimation of basic physical abilities as speed — 30 m flying start run, speedpower — standing long jump and endurance — mile run, were carried out. The data were processed using the methods of multivariate statistical analysis by the statistical programme "Statistica".

## RESULTS AND DISCUSSION

The subjects were divided into 3 groups according to differences in biological maturity:

I group with retardation of rates of physiological development;
II group with medium rates of physiological development;
III group with accelerated physiological development.

Distribution by biological development is presented in Table 1.

We can see comparatively equal distribution of girls into groups with some tendencies towards acceleration in the younger group and a bigger share of mediums and retardants in the older group.

Similar data on the physical development of Estonian pubertal girls are available in another study [6], where also the retention of devel-

opment of secondary sexual characteristics in 17-year-old Estonian girls was noticed.

**Table 1.** Distribution (%) of girls by status of biological development

| Chronological age in years | Distribution by biological age (%) | | |
|---|---|---|---|
| | retardants | medium | accelerants |
| 13<br>n=68 | 14 | 61 | 25 |
| 15<br>n=170 | 18.7 | 68.8 | 12.5 |

Table 2 represents the data of height, body mass index (BMI) of Estonian girls in the studied age-groups that coincide with the results of other studies [18].

**Table 2.** Height, body mass and BMI in the studied age-groups of Estonian girls.

| | 13 | | | | 15 | | | | Significance |
|---|---|---|---|---|---|---|---|---|---|
| | x | σ | M–m | V | x | σ | M–m | V | |
| Height (cm) | 158.0 | 7.37 | 169.2–139.2 | 4.6 | 165.1 | 6.5 | 180.2–140.4 | 3.9 | <0.05 |
| Body mass (kg) | 51.2 | 9.34 | 70–28 | 18.2 | 54.6 | 9.34 | 91.5–28.2 | 17.1 | <0.05 |
| BMI (kg/m$^2$) | 18.94 | 2.56 | 15.53–25.99 | 13.5 | 20.01 | 2.82 | 14.35–33.1 | 14.1 | <0.05 |

Table 3 gives the same anthropometric parameters in the groups studied in comparison with different somatometric development. The mean values of the principal anthropometric measurements were significantly different in all subgroups of both age-groups. The values of 13-year-old girls with acceleration are comparable to the values of the group of medium rate of development in 15 year-old girls, and the values of 15-year-old girls with retardation with the medium subgroup of 13-year-old girls.

The dispersion curves used to characterise individual anthropometric peculiarities demonstrated that the somatotype of 13-year-old accelerants differs significantly from the age-matched control-group as well as from that of the 15-year-old girls. They are characterised by broad hips and relatively low development of muscle tissue.

The 15-year-old retardants are characterised by a lower BMI and level of subcutaneous adipose tissue both in absolute and in relative values. The proportional differences between the age groups were statistically insignificant.

**Table 3.** Basic statistics of 13- and 15-year-old girls' anthropometric measurements and indices according to biological development

| | 13-years | | | | | | | 15-years | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | retardants | | medium | | accelerants | | signifi-cance | retardants | | medium | | accelerants | | signifi-cance |
| | x | σ | x | σ | x | σ | | x | σ | x | σ | x | σ | |
| 1. body mass (kg) | 35.8 | 5.17 | 46.6 | 4,08 | 59.83 | 7.91 | 1:2,3 2:3 | 43.7 | 5.34 | 55.6 | 6.42 | 63.4 | 9.1 | 1:2,3 2:3 |
| 2. height (cm) | 146.7 | 8.82 | 158.9 | 4.04 | 165.0 | 2.39 | 1:2,3 2:3 | 157.6 | 5.89 | 165.9 | 4.79 | 173.1 | 5.34 | 1:2,3 2:3 |
| 3. sitting height | 77.63 | 4.71 | 83.3 | 2.91 | 87.7 | 1.5 | 1:2,3 2:3 | 80.5 | 3.53 | 86.3 | 3.45 | 89.3 | 3.13 | 1:2,3 2:3 |
| 4. upper limb length | 64.0 | 4.17 | 69.3 | 2.75 | 71.6 | 1.16 | 1:2,3 2:3 | 70.4 | 4.49 | 72.9 | 4.78 | 73.2 | 6.6 | 1:2,3 |
| 5. lower limb length | 69.0 | 4.14 | 75.5 | 3.67 | 77.2 | 2.57 | 1:2,3 2:3 | 77.0 | 4.67 | 79.8 | 4.12 | 84.0 | 5.08 | 1:2,3 2:3 |
| 6. biacromial breadth | 32.7 | 2.27 | 35.2 | 1.19 | 36.6 | 1.41 | 1:2,3 2:3 | 34.6 | 1.76 | 36.3 | 1.75 | 37.8 | 1.9 | 1:2,3 2:3 |
| 7. chest breadth | 21.7 | 1.9 | 23.5 | 1.2 | 26.0 | 2.28 | 1:2,3 2:3 | 23.6 | 1.64 | 25.1 | 1.67 | 26.1 | 1.59 | 1:2,3 2:3 |
| 8. chest depth | 14.9 | 1.15 | 16.4 | 2.39 | 18.2 | 2.23 | 1:3 | 16.2 | 1.17 | 17.4 | 1.32 | 17.9 | 1.32 | 1:2,3 2:3 |
| 9. abdomen breadth | 18.9 | 1.61 | 21.3 | 1.51 | 23.9 | 3.35 | 1:2,3 2:3 | 20.9 | 2.23 | 22.4 | 1.85 | 23.1 | 2.16 | 1:2,3 |
| 10. abdomen depth | 14.9 | 1.15 | 16.4 | 2.39 | 18.54 | 2.43 | 1:2,3 2:3 | 15.3 | 1.76 | 16.3 | 2.02 | 17.8 | 2.84 | 1:2,3 2:3 |
| 11. pelvis breadth | 24.1 | 1.81 | 26.1 | 1.78 | 29.1 | 2.08 | 1:2,3 2:3 | 25.4 | 2.23 | 27.5 | 1.52 | 28.4 | 1.56 | 1:2,3 2:3 |
| 12. upper chest circumf. | 69.9 | 5.25 | 76.0 | 4.12 | 85.7 | 6.7 | 1:2,3 2:3 | 75.3 | 4.42 | 81.6 | 4.48 | 84.2 | 4.39 | 1:2,3 2:3 |
| 13. abdomen circumf. | 63.7 | 3.42 | 72.2 | 4.52 | 78.2 | 11.4 | 1:2,3 2:3 | 65.7 | 6.55 | 72.7 | 4.94 | 77.7 | 8.1 | 1:2,3 2:3 |
| 14. pelvis circumf. | 75.3 | 4.67 | 83.2 | 4.11 | 92.8 | 6.15 | 1:2,3 2:3 | 78.7 | 6.87 | 86.4 | 7.02 | 89.9 | 8.07 | 1:2,3 2:3 |
| 15. arm circumf. | 20.3 | 1.95 | 22.1 | 1.83 | 25.4 | 1.56 | 1:2,3 2:3 | 21.4 | 2.05 | 24.0 | 2.1 | 24.8 | 2.94 | 1:2,3 |
| 16. prox. thigh circumf. | 44.3 | 3.64 | 48.3 | 3.43 | 55.5 | 3.54 | 1:2,3 2:3 | 46.8 | 4.86 | 52.3 | 4.66 | 55.2 | 6.25 | 1:2,3 2:3 |

| | 13-years | | | | | | | 15-years | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | retardants | | medium | | accelerants | | signifi-cance | retardants | | medium | | accelerants | | signifi-cance |
| | x | σ | x | σ | x | σ | | x | σ | x | σ | x | σ | |
| 17. dist. thigh circumf. | 40.8 | 3.09 | 43.9 | 3.68 | 49.9 | 2.42 | 1:2,3 2:3 | 42.0 | 4.71 | 47.0 | 4.28 | 48.5 | 5.58 | 1:2,3 |
| 18. lower leg circumf. | 20.5 | 0.88 | 21.9 | 1.54 | 23.3 | 1.2 | 1:2,3 2:3 | 21.3 | 1.51 | 22.7 | 1.65 | 23.2 | 1.78 | 1:2,3 |
| 19. mean skinfold thickness (mm) | 6.62 | 1.77 | 8.16 | 1.86 | 13.8 | 6.4 | 3:1,2 | 9.1 | 3.58 | 10.6 | 3.4 | 11.7 | 4.6 | 1:2,3 |
| 20. chest skinfold | 3.08 | 1.2 | 4.2 | 1.4 | 9.5 | 5.9 | 1:3 2:3 | 8.23 | 3.81 | 8.86 | 3.76 | 9.43 | 3.69 | – |
| 21. subscapular skinfold | 6.33 | 2.8 | 8.0 | 2.88 | 10.4 | 6.4 | 1:3 2:3 | 7.39 | 3.19 | 9.43 | 3.44 | 10.45 | 4.31 | 1:2,3 |
| 22. relat. upper limb length | 43.6 | 0.6 | 43.6 | 1.07 | 43.4 | 0.6 | – | 44.7 | 2.89 | 44.0 | 2.92 | 42.2 | 3.78 | 3:1,2 |
| 23. relat. lower limb length | 47.1 | 0.7 | 47.6 | 1.67 | 46.8 | 2.08 | – | 48.9 | 1.82 | 48.1. | 1.79 | 48.4 | 2.01 | 1:2 |
| 24. relat. biacromial breadth | 22.3 | 22.2 | 22.2 | 0.78 | 22.2 | 2.75 | – | 22.0 | 0.91 | 21.9 | 1.05 | 21.8 | 1.31 | – |
| 25. relat. chest breadth | 14.7 | 1.1 | 14.8 | 0.71 | 15.8 | 1.8 | 3:2 | 15.0 | 1.01 | 15.1 | 1.01 | 15.0 | 1.2 | – |
| 26. relat. upper chest circumf. | 47.7 | 0.7 | 47.9 | 2.45 | 51.9 | 4.52 | 3:1,2 | 47.9 | 3.15 | 49.2 | 2.83 | 48.7 | 3.5 | 1:2 |
| 27. relat. pelvis circumf. | 51.3 | 1.29 | 52.4 | 2.65 | 56.3 | 4.28 | 3:1,2 | 50.0 | 4.63 | 52.2 | 4.32 | 52.1 | 5.72 | 1:2 |
| 28. relat. arm circumf. | 13.8 | 1.0 | 13.9 | 1.3 | 15.4 | 1.2 | 3:1,2 | 13.6 | 1.41 | 14.5 | 1.34 | 14.4 | 2.05 | 1:2,3 |
| 29. relat. prox. thigh circumf. | 30.2 | 2.1 | 30.4 | 2.32 | 33.6 | 20.5 | 3:1,2 | 29.8 | 3.29 | 31.6 | 2.91 | 32.1 | 4.29 | 1:2 |
| 30, relat. calf circumf. | 20.0 | 0.7 | 20.1 | 1.89 | 21.3 | 1.3 | – | 19.9 | 1.73 | 20.7 | 1.35 | 20.5 | 2.1 | 1:2 |

| | 13-years | | | | | | | 15-years | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | retardants | | medium | | accelerants | | signifi-cance | retardants | | medium | | accelerants | | signifi-cance |
| | x | σ | x | σ | x | σ | | x | σ | x | σ | x | σ | |
| 31. biacromial breadth / pelvis breadth | 1.45 | 0.16 | 1.45 | 0.17 | 1.43 | 0.1 | – | 1.37 | 0.11 | 1.32 | 0.74 | 1.33 | 0.78 | 1:2,3 |
| 32. biacromial breadth / upper chest circumf. | 0.47 | 0.02 | 0.46 | 0.02 | 0.43 | 0.03 | 3:1,2 | 0.46 | 0.03 | 0.45 | 0.02 | 0.44 | 0.02 | – |
| 33. body mass index | 16.8 | 1.12 | 18.5 | 1.53 | 22.0 | 3.2 | 3:1,2 | 17.62 | 2.2 | 20.21 | 2.22 | 21.32 | 3.9 | 1:2,3 2:3 |
| 34. Rohrer index | 1.13 | 0.1 | 1.16 | 0.01 | 1.3 | 0.21 | 3:1,2 | 1.12 | 0.15 | 1.22 | 0.12 | 1.24 | 0.27 | 3:1 |
| 35. muscle mass* | 17.8 | 3.4 | 23.0 | 3.2 | 29.8 | 2.6 | 1:2,3 2:3 | 27.3 | 5.59 | 35.8 | 6.4 | 40.5 | 8.29 | 1:2,3 2:3 |
| 36. corrected. muscle mass** | 15.27 | 2.52 | 19.53 | 2.67 | 23.55 | 3.12 | 1:2,3 2:3 | 18.54 | 2.6 | 23.55 | 3.12 | 26.67 | 4.32 | 1:2,3 2:3 |
| 37. relat. mass of subcutaneous adipose tissue | 14.3 | 5.3 | 18.9 | 4.6 | 24.1 | 7.8 | 3:1,2 | 13.7 | 4.79 | 14.8 | 4.25 | 15.5 | 5.56 | – |

* muscle mass by Matiegka's formula

** corrected muscle mass

The mean levels of indices of physical working capacity and basic physical abilities (Table 4) progress in adolescents in general with ageing, as it has been estimated before [9]. Table 5 gives the indices of physical performance of girls of different calendar age. $PWC_{170}$ mean levels in the 13-year and 15-year age groups are the lowest in the subgroups of retarded girls. At the same time the mean results measured by grip-test (left hand), standing long jump, 30 m sprint and 1 mile endurance run do not differ significantly between the two age groups. The speed and speedpower qualities are insignificantly higher in retardants of both groups. Individual physical performance capacity in MET's was higher in the girls of the older group. Negative correlation (r=–0.79) was found in the younger group of girls between physical performance capacity expressed in MET's and biological age (Figure 1), but at the age of 15 it became insignificant. $PWC_{170}$ had positive correlations (r=0.50...0.40) with general body dimensions: height and body mass. Individual physical performance capacity in MET's in the younger group had negative correlations with body height (r=–0.96), mass (r=–0.80) and total body fat (r=–0.50). Lowered levels of $PWC_{170}$ indices in 13-year-old retardants are probably connected with disproportionate development, particularly with insufficient development of muscle mass and with slowness of biological maturation. Retardation in the development of pubertal girls is connected with low weight, increased microbaric status and low levels of physical performance.

**Table 4.** Values of physical working capacity ($PWC_{170}$) and basic physical abilities of Estonian girls in studied age groups

| | 13 years | 15 years |
|---|---|---|
| | $x \pm \sigma$ | $x \pm \sigma$ |
| $PWC_{170}$ (kgm/min) | 375.8±149 | 599.2±180.4* |
| Handgrip right (kg) | 24.91±4.36 | 29.11±7.2* |
| Handgrip left (kg) | 23.36±4.64 | 24.86±7.14 |
| 30 m flying start run (s) | 4.83±0.4 | 4.67±0.31 |
| Standing long jump (m) | 1.72±0.19 | 1.85±0.35* |
| Mile run (min, s) | 8.06±0.59 | 8.24±0.56 |
| MET | 6.57±0.78 | 8.02±1.4* |

* Between groups significance ($p<0,05$)

**Table 5.** Indices of physical performance in different age groups

| | 13 years | | | | 15 years | | | |
|---|---|---|---|---|---|---|---|---|
| | retarded | medium | accelerated | significance | retarded | medium | accelerated | significance |
| | x±σ | x±σ | x±σ | | x±σ | x±σ | x±σ | |
| $PWC_{170}$ (kgm/min) | 281,1 ±49,4 | 351,8 ±74,0 | 372,7 ±42 | 1:2,3 | 473,51 ±116,0 | 615,8 ±125,0 | 654,0 ±218,1 | 1:2,3 |
| Handgrip right (kg) | 20,5 ±4,92 | 26,2 ±3,43 | 24,6 ±4,9 | 1:2,3 | 25,3 ±5,3 | 29,9 ±6,6 | 31,8 ±8,16 | 1:2,3 |
| Handgrip left (kg) | 17,5 ±8,0 | 24,4 ±3,7 | 24,8 ±2,7 | 1:2,3 | 21,38 ±5.8 | 25,8 ±6,7 | 29,78 ±6,6 | 1:2,3 2:3 |
| 30 m flying run (s) | 4,25 ±0,27 | 4,87 ±0,36 | 4,87 ±0,53 | – | 4,63 ±0,33 | 4,63 ±0,27 | 4,80 ±0,4 | – |
| Standing long jump (m) | 1,69 ±0,6 | 1,69 ±0,2 | 1,78 ±0,23 | – | 1,77 ±0,14 | 1,82 ±0,14 | 1,79 ±0,2 | – |
| Mile run (min, s) | 7,23 ±0,07 | 8,16 ±0,9 | 8,0 ±1,35 | 1:2 | 7,59 ±0,52 | 8,47 ±0,51 | 8,47 ±0,52 | 3:1,2 |
| MET | 7,45 ±0,46 | 6,99 ±0,6 | 5,62 ±0.35 | 1:2,3 2:3 | 8,44 ±1,27 | 8,06 ±1,34 | 4,8 ±0,4 | 3:2,1 |

Overweight problems in young people are mostly connected with multiple disorders in hormonal regulation and disharmonious physical development [6, 10].

Drastic differences in the somatometric measurements of adolescent girls lead to a need for differentiating and individualising the loads, means and standards of habitual and organised physical activity for estimation of the corresponding values [7].

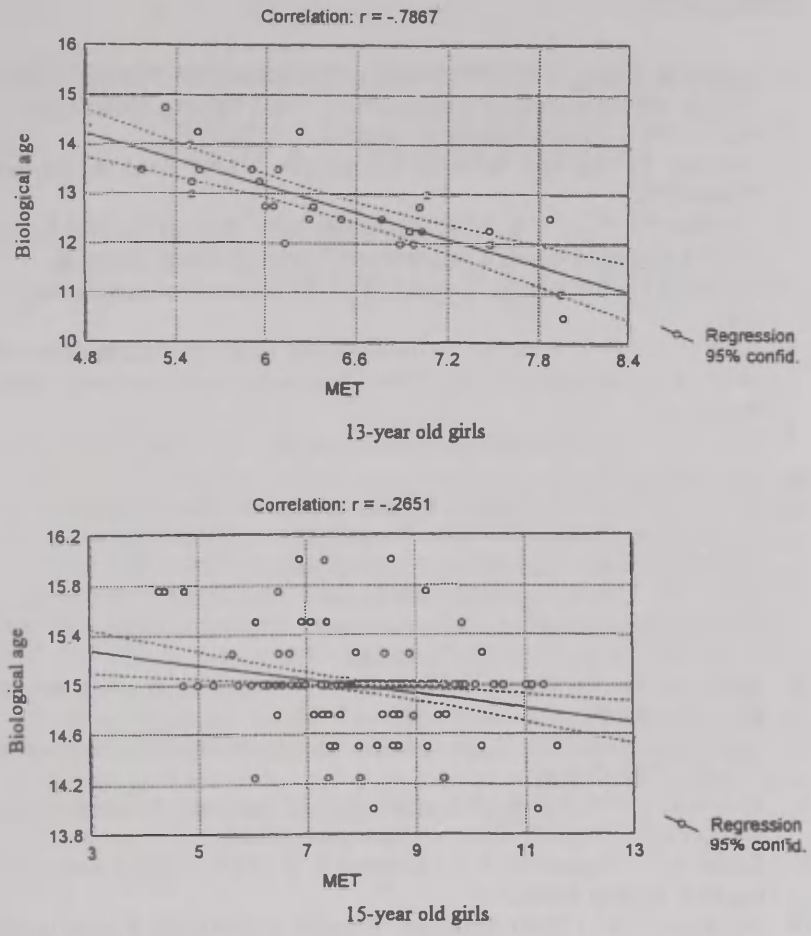


**Figure 1.** Relationships between individual physical performance capacity (MET) and biological age in Estonian girls.

## CONCLUSIONS

Physiological and motor performance findings in Estonian girls of pubertal age showed an increasing rate of development deflections in combination with lowered levels of physical performance.

Habitual and organised physical activity of girls needs differentiation and individualisation of loads, means and standards for estimation of the corresponding values during pubertal age.

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# MITOTIC ACTIVITY IN INTACT ORGANS OF RATS AFFECTED BY DMBA IMPLANTS IN THE ABDOMINAL CAVITY

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ABSTRACT

DMBA-containing pellets were implanted below the spleen into the abdominal cavity of rats to give rise to a background of local epithelial and mesenchymal malignant tumours. Cell proliferation and mitotic activity was investigated in intact organs: small intestine, oesophagus, liver, the glomerular zone and the fascicular-reticular zone of the adrenal gland during a one-year experiment. DMBA causes changes in the mitotic index (MI — number of mitoses per 1000 cells), which appear regardless whether the DMBA treatment has resulted in tumour formation or not. The experiment demonstrates that the MI changes were different in different organs and mostly higher than the changes in the control group. No DMBA induced changes in cell proliferation could be observed in the oesophagus.

## INTRODUCTION

Mitotic activity is one of the well-investigated indicators of cell proliferation. Cell proliferation and mitotic activity have been studied in relationship with chronobiology [9, 27, 8, 38, 44, 46], ageing [45], antibacterial treatment [44], infection [43], as observed in oesophagus and intestine, in hyperinsulinemic liver [10], in tumour by stress [52], in liver by x-ray [29]. Many authors have investigated manifestations of carcinogenic and co-carcinogenic activity in the origin and growth of tumours. Local cell proliferation increases and so does mitotic activity, which is measured and expressed by a rise in the proliferation index or the mitotic index [5, 3, 7, 40, 48, 57]. Some scientists have reported on treating tumours with inhibitory chemicals resulting in a

decrease of mitotic activity and regression of the tumour. The slowing of the tumour growth is largely due to the reduced mitotic activity [16, 20, 21, 35, 42]. The most important factor in tumour regression is hormone therapy [16, 21, 35].

Experimental Dimethylbenz(a)anthracen (DMBA) induced cancerogenesis is well known and thoroughly investigated. There are several special experimental models explaining the DMBA effects. DMBA can be administered intragastrically through a probe [1, 11, 13, 19, 32, 33, 49, 60, 62]; by local cutaneous and mucosal DMBA application [25, 58]; by intrabronchial submucosal treatment by bronchoscopy [30]; intravenously [22, 53]; orally with food [6, 26, 31]; by subcutaneous injections [14]; by local intraductal mammary injections [54, 55]; by intramuscular injections into the neck region [61]. Methods of implanting cancerogenic foreign substances [8] and transplants in subcutaneous tissue [41, 50], in the spleen [36], in sublingual submucosa [12], in the bladder [4], in the pylorus [51] have been described by authors of experimental research.

DMBA has an effect on cell proliferation and mitotic activity. DMBA induced stimulation of liver cell proliferation has been examined in small, viviparous fish who are susceptible to induction of liver tumours and measured by the mitotic index [48]. DMBA induces stimulation of the mitotic activity of melanocytes as well as cutaneus hyperpigmentation [57]. Iversen et al. in their study have shown that there is a significant difference between the influences of small and large DMBA doses. Higher DMBA doses will result in a reduction in DNA synthesis and mitotic activity in the epidermis [23]. When DMBA is applied in the solution form, mitotic activity is at first reduced because of the toxicity of DMBA [17, 59]. When a tumour develops, the rate of cell proliferation, i.e. the cell proliferation index rises [3, 59]. Apart from the well-known tumorigenic effect and cell proliferation stimulating effect, DMBA also causes inflammation [7]. DMBA treatment has been reported to simultaneously accelerate epithelial keratinization and inhibite epithelial mitotic activity [15].

All studies of mitotic activity in cancerogenesis have paid attention to the localization of the tumour. The aim of the present paper is to study the activity of cell division and to determine the level of mitotic activity in different intact organs of rats in the process of DMBA induced local cancerogenesis. Attention will also be paid to the types of tumours and to local reactive changes to the tumours and the pellet.

## MATERIAL AND METHODS

The experiments were carried out on 112 white rats. Tumours were induced by a cancerogen, DMBA. The reactive DMBA ($C_{18}H_{10}(CH_3)_2$) was purchased from Fluka AG, Buchs SG in Switzerland. Beeswax, whale's fatty alcohol, activated carbon and a cancerogenic substance were blended into a mixture, and by means of a special instrument pellets of a strictly equal diameter (2 mm) and mass (3.7 mg), each containing 0.038 mg of DMBA, were shaped.

DMBA-containing pellets were implanted into the abdominal cavity of 72 rats in the Experimental Group. The pellets were placed below the spleen at the level of the upper apex of the left kidney. The Control Group consisted of 40 untreated rats. The rats in the Control Group were also operated on, but the implanted pellet did not contain DMBA.

The animals were executed after the interval of 3–4 months, 6–8 months, 9–10 months and 12 months since the implantation of the pellets. Pieces of tissue for further investigation were taken from the local tumour tissue or pellet together with the surrounding tissue, from the small intestine, from the oesophagus, from the liver and from both the glomerular and the fascicular-reticular zones of the adrenal gland.

The samples of tissue were fixed in 10% solution of neutral formalin and embedded in paraffin. Histological sections were made, which were stained with haematoxylin and eosin in routine use, with picro fuchsin and haematoxylin after van Gieson's method, with alcian blue. Immunohistochemic reactions with anti-desmin and anti-vimentin were also made. The specific intermediate filament that forms the cellular cytoskeleton was histochemically identified on DAKO tissue markers anti-vimentin and anti-desmin applied in an indirect method. Avidin-biotinyl immunohistochemical staining technique was used with DAB (3.5 diaminobenzidine) chromogen. Some of the diagnosed tumours could also be assessed macroscopically. Tumour size was measured in centimetres and all tumours were graphically shown by the largest diameter.

Particles of pellets (foreign body), connective tissue with sclerosis, granulation tissue, connective tissue with pieces of foreign body inside, areas of degeneration and lymphocytic infiltration around pellets were depicted on histotopograms drawn according to the method suggested by A. Truupõld [56]. According to this method all fields of vision were scanned horizontally and vertically by means of a microscope that was provided with an ocular network and a preparation

shifter (object-lens 8×0.020; ocular 7). The results of the observations (the contours of the pellet, connective tissue, lymphocytic infiltration, granular tissue, degeneration) were marked on a graph where 64 $cm^2$ corresponds to one field of the ocular network. A computerised map with areas bearing differentiating markers was composed from these histotopograms. The image analysing system Image Pro 3.0 with Materials Pro was used to analyse these maps. All fields of the maps were automatically scanned. The computer program read the map and produced the percentage of different squares for every object on the map. Microsoft Excel 5.0/7.0 and Sigma Statistic ware used to calculate statistical data..

Mitotic activity was determined in the epithelium of the small intestine, in the oesophageal epithelium, in hepatocytes and in the suprarenal glomerular and fascicular-reticular zones. Proliferation was measured by counting mitotic figures in the histological sections and expressed by the mitotic index (MI), i.e. the number of mitosis per 1000 cells in ‰ in the organ. Mitoses were counted in the fields of vision (object-lens 40×0.65; ocular 7). In the small intestine cells and mitoses were counted in 50 crypts, in the adrenal glands in 50 fields of vision, in the liver in 100 fields of vision and in the oesophagus in the cross-section. All the results were statistically analysed by means of Statgraphics and Microsoft Excel 5.0/7.0. p signifies the degree of statistical significance and r the presence of correlation.

## RESULTS

### Background

#### *Tumorigenesis*

0.038 mg of DMBA in the Experimental Group in these experimental conditions brought about the formation of tumours in 42 rats out of 72 in the Experimental Group. No tumours were noticed 3–4 months after the beginning of the experiment. In the period of 6–8 months 17 tumours were found in the Experimental Group. Three tumours could be detected macroscopically. In the 9–10 months of the experiment 10 tumours were found in 14 experimental animals (3 macroscopically diagnosable). After 12 months 15 tumours we found in 22 animals, and 8 were macroscopically detectable.

The size of the tumours varied — from 0.5 cm in diameter to 8×7×4 cm, noticed in the ninth month from the beginning of the experiment. Figure 1 shows all macroscopically detectable tumours presented by their largest dimensions. The tumours were nodular, of dense consistency, the surface of cut slices was whitish greyish pink with brownish and reddish nidi, in places with necrotic nidi and haemorrhage and even vacuols filled with fluid or pus. Smaller nodular tumours were with greyish pink cut surface. Larger tumours had spread into the peritoneal and the retroperitoneal cavity, the thoracic cavity, and they had coalesced with spleen, intestine, left kidney and mesenterium.

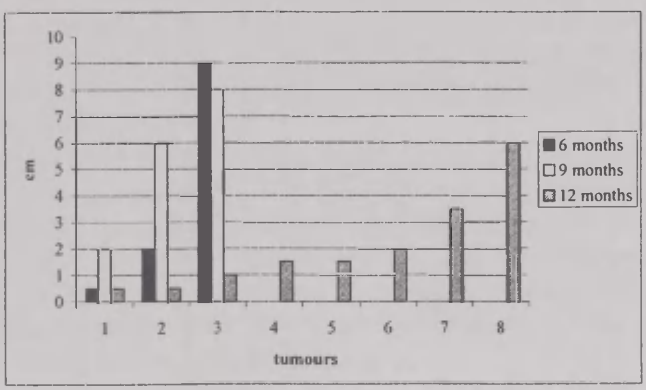



**Figure 1.** Macroscopic evaluation of tumorigenesis after DMBA pellet grafting into the abdominal cavity

Table 1 presents microscopic findings of tumorigenesis after DMBA grafting into the abdominal cavity. Microscopically the tumours were of different structure. In most cases the parenchyma consisted of fibroblast-like spindly cells and collagen fibres, the amount of which was different in different parts of the tumour. The cells and fibre fascicles were intersected and they were of different shape and size, the nuclei were hyperchromatic with thick chromatin lumps. Atypical mitoses were evident. Between the cells there were collagen fibres which formed fascicles of different thickness. Between the fascicles there were irregular groups of infiltrated round cells. Blood vessels and perivascular connective tissue formed stroma. On the basis of the characteristic histological structure, the diagnosis of fibrosarcoma could be given. In 32 cases out of 42 tumours fibrosarcoma was found. There were also big elongated multinuclear myosymplast-like

**Table1.** Microscopic types of tumours after DMBA pellet grafting into the abdominal cavity

| Method | n | 3–4 months | n | 6–8 months | n | n | 9–10 months | n | n | 12 months | n | Total n of tumours |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control Group n=40 | 8 | – | 14 | – | | 6 | – | | 22 | – | – | – |
| Experi-mental Group n=72 | 0/17 | – | 17/19 | *fs | 10 | 10/14 | *fs | 5 | 15/22 | *fs | 10 | 42/72 |
| | | | | *rms | 3 | | *rms | 1 | | *pleom.s | 2 | |
| | | | | *fs+rms+adc | 1 | | *pleom.s | 1 | | *lipos | 1 | |
| | | | | *fs+adc | 2 | | *fs+adc | 1 | | *fs+adc | 1 | |
| | | | | *pleom.s | 1 | | *fs+rms | 1 | | *adc+fs+rms | 1 | |

n — number of tumours / number of rats in the group

fs — fibrosarcoma; rms — rabdomyosarcoma; adc — adenocarcinoma; pleom.s — pleomorphic cell sarcoma; lipos — liposarcoma.

atypical formations present. Their cytoplasm was vacuolated in places and in places homogenous. Fascicles of myofibrils could be observed in myosymplasts. The nuclei were of different shape and hyperchromatic. Histological changes suggested rhabdomyosarcoma. Rhabdomyosarcoma was found in seven cases, in four cases it was single rhabdomyosarcoma and in three cases rhabdomyosarcoma occurred in combination with other types of tumour, e.g. fibrosarcoma with rhabdomyosarcoma in 1 case, in 2 other cases fibrosarcoma, rhabdomyosarcoma and adenocarcinoma with the cells located in groups, and displaying polymorphous light-coloured nuclei. In 4 cases fibrosarcoma was combined with adenocarcinoma. In one case we found fat-like tissue with irregular size of atypical cells and it was liposarcoma. One more type of tumour was observed in 5 cases of experiments. These were cases of pleomorphic cell sarcoma with cells of very different shape and size, having also hyperchromatic nuclei of different chromatin content.

Histochemical reactions with anti-vimentin and anti-desmin confirmed the diagnoses of fibrosarcoma and rhabdomyosarcoma in our study. There was a specific intermediate filament forming the cellular cytoskeleton. Antibodies reacted strongly with vimentin or desmin and labelled cells of mesenchymal or muscular origin. DAB chromagen produced an insoluble brown product that stained the nuclei of corresponding tumour cells brownly.

*Reactive changes*

In the preparations we also investigated what changes had taken place in the pellet and in the tissue around it. We observed that the pellets were either intact or divided into segments by connective tissue. The foreign bodies presented themselves under the microscope as structureless black mass. The areas containing foreign bodies were encapsulated by connective tissue.

Collagen fibres and their fascicles surrounded the foreign bodies concentrically. Polyblasts, big and light epithelioid cells and fibroblasts with lymphocytes could be observed in some places of the connective tissue. This was young connective tissue — granular tissue. In other places hyalinosis could be seen. Atypical cells — the beginning of tumours — could be noticed with arising tumours, around the foreign bodies, located next to or inside the connective tissue. The pellet could not be found in large tumours; it had been

encased by the tumour, which made it impossible to study the areas next to the pellet for reactive changes.

The reactive changes in the Experimental Group and the Control Group are presented in percentage in Table 2. There was more lymphocytic infiltration in the Experimental Group as compared with the Control Group (maximum 5.05%). It is of interest to mention that the rate of lymphocytic infiltration in the Experimental Group was smaller in rats with tumours (1.52%–3.24%) than the rate in rats without tumours (4.57%–5.05%), but the difference was not statistically significant.

Organisation, i.e. proliferation of connective tissue was more present in the Experimental Group than in the Control Group. The largest value was 34.91% in the Experimental Group. It was recorded 12 months after the implantation of DMBA.

**Table 2.** Local reactive changes (in %) to the implantation of DMBA containing pellets

| | 3–4 months | | 6–8 months | | | 9–10 months | | | 12 months | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ex | C | Ex | | C | Ex | | C | Ex | | C |
| % | | | – | + | | – | + | | – | + | |
| 1 | 3.45 | 0 | 5.05 | 2.79 | 1.25 | 4.57 | 1.52 | 0.26 | 4.61 | 3.24 | 0 |
| 2 | 12.09 | 1.00 | 6.75 | 3.03 | 1.64 | 3.32 | 8.13 | 3.08 | 16.66 | 1.75 | 0.42 |
| 3 | 41.95 | 9.06 | 34.04 | 31.30 | 17.43 | 22.88 | 22.72 | 24.52 | 34.91 | 31.49 | 24.19 |
| 4 | 37.56 | 72.59 | 54.15 | 39.49 | 52.7 | 69.23 | 43.34 | 52.14 | 43.80 | 54.76 | 45.45 |
| 5 | 0.07 | 0.27 | 0 | 0.55 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 1.93 | 17 | 0 | 21.05 | 26.98 | 0 | 24.46 | 0 | 0 | 8.75 | 33.37 |

1 lymphocytic infiltration; 2 granulation tissue; 3 connective tissue and sclerosis; 4 foreign bodies; 5 haemorrhages, necroses, degenerations; 6 connective tissue inside pieces of foreign bodies; – without tumor; + with tumor; Ex experimental group; C control group

## Mitotic activity

Data expressing the level of mitotic activity in different organs both in the Experimental and the Control Groups expressed by the mitotic index (MI) are given in ‰ in Table 3.

MI in the small intestine in the third months from the beginning of the experiment was 81.2‰. In comparison with the Control Group (MI=74.1‰) the statistical difference was not significant ($p>0.05$). But in the sixth and ninth months a significant rise in the mitotic

activity in the epithelial cells could be observed, the MI values being 147.0‰ and 119.3‰ respectively ($p<0.001$). By the twelfth month the mitotic activity had dropped back to the level of the Control Group and even lower, being 56.6‰. The difference between the Control Group and the Experimental Group was statistically significant ($p<0.01$). Figure 2A presents the range of changes.

No statistically significant changes took place in the oesophageal epithelium. There was a small decrease present in the Experimental and the Control Groups, yet it was not statistically significant ($p>0.05$) (Figure 2B).

After 3 months from the beginning of the experiment, mitotic activity of hepatocytes in the Experimental Group (MI = 1.4‰) was close to that in the Control Group (MI=1.3‰) ($p>0.05$), but afterwards it began to rise, remaining on a higher level than in the Control Group (MI=3.9–4.6‰, $p<0.001$) (Figure 2C).

In the zones of the adrenal gland the changes has a different nature. In the glomerular zone, a significant rise occurred in the third month of the experiment. The MI in the Experimental Group was 0.64‰ and 0.25‰ in the Control Group ($p<0.05$). Then the mitotic activity of the Experimental Group decreased to the level of the Control Group; another rise took place in the twelfth month of the experiment (Figure 2D). In the fascicular-reticular zone a significant rise in the MI value occurred only in the twelfth month of the experiment — the MI was 0.91‰ in the Experimental Group and 0.46‰ in the Control Group ($p<0.05$) (Figure 2E).

We also studied the correlation of mitotic activity. The mitotic index of different organs shows single cases of both positive and negative correlations between the MI values of the small intestine and of the other organs: so in the third month of the experiment the correlation of MI(small intestine) and MI(liver) $r=0,609$, $p<0,01$; MI(small intestine) and MI(glomerular zone of the adrenal gland) $r=-0.588$, $p<0.05$; in the sixth month of the experiment the correlation of MI(small intestine) and MI(liver) $r=-0.532$, $p<0.05$; in the twelfth month of the experiment the correlation of MI(small intestine) and MI(fascicular-reticular zone the adrenal gland) $r=-0.529$, $p<0.05$.

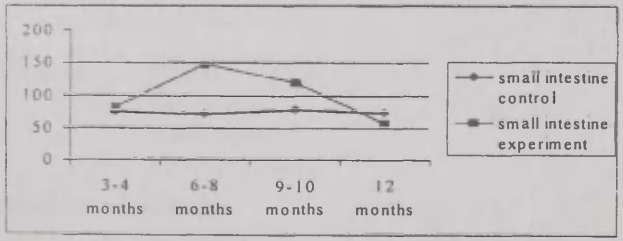
The mitotic activity in rats with and without tumours in the Experimental Group was also compared. The only differences occurred in the correlation between the values of the liver and the fascicular-reticular zone of the adrenal gland in the twelfth month of the experi-

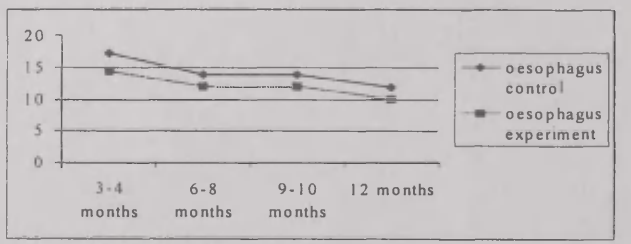
**Table 3.** Mitotic Index (in o/oo) in different stages of the experiment

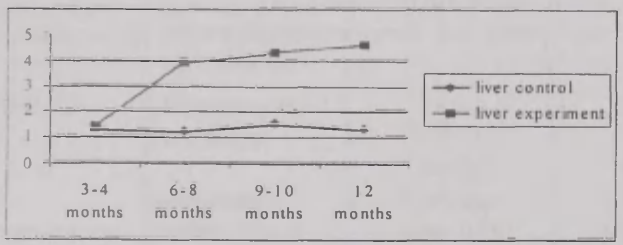
| | | 3 months | 6 months | 9 months | 12 months | total |
|---|---|---|---|---|---|---|
| Number of rats | **control** | 8 | 8 | **6** | **18** | 40 |
| | **experiment** | **17** | **19** | **14** | **22** | 72 |
| | *with tumour | | 17 | 10 | 15 | |
| | *without tumour | | 2 | 4 | 7 | |
| Small intestine | control | 74.1+–8.2 | 70.9+–4.7 | 77.1+–7.2 | 72.9+–4.9 | |
| | experiment | 81.2+–6.6 | 147.0+–3.2 | 119.3+–4.6 | 56.6+–3.2 | |
| | | p>0.05 | p<0.001 | p<0.001 | p<0.01 | |
| | *with tumour | | 146.7 | 122.8 | 54.6 | |
| | *without tumour | | 149.5 | 112.1 | 60.7 | |
| Oesophagus | control | 17.1+–1.3 | 13.8+–1.3 | 13.8+–2.6 | 11.8+–1.6 | |
| | experiment | 14.3+–1.2 | 12.0+–1.2 | 11.9+–1.9 | 9.9+–1.0 | |
| | | p>0.05 | p>0.05 | p>0.005 | p>0.05 | |
| | *with tumour | | 12.4 | 12.6 | 8.4 | |
| | *without tumour | | 8.5 | 10.3 | 13.1 | |
| Liver | control | 1.3+–0.3 | 1.2+–0.2 | 1.5+–0.2 | 1.3+–0.2 | |
| | experiment | 1.4+–0.2 | 3.9+–0.4 | 4.3+–0.2 | 4.6+–0.4 | |
| | | p>0.05 | p<0.001 | p<0.001 | p<0.001 | |
| | *with tumour | | 4 | 4.6 | 5.4 | |
| | *without tumour | | 2.7 | 3.7 | 2.6 | |
| | | | | | p<0.001 | |

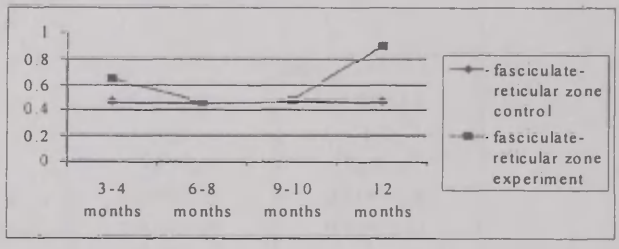
| | | 3 months | 6 months | 9 months | 12 months | total |
|---|---|---|---|---|---|---|
| Glomerular zone | control | 0.25+–0.06 | 0.20+–0.07 | 0.25+–0.02 | 0.22+–0.01 | |
| | experiment | 0.64+–0.09 | 0.24+–0.05 | 0.45+–0.16 | 0.45+–0.06 | |
| | | p<0.05 | p>0.05 | p>0.05 | p<0.01 | |
| | *with tumour | | 0.25 | 0.47 | 0.49 | |
| | *without tumour | | 0.1 | 0.39 | 0.37 | |
| Fascicular-reticular | control | 0.46+–0.11 | 0.45+–0.05 | 0.47+–0.04 | 0.46+–0.03 | |
| zone | experiment | 0.64+–0.06 | 0.45+–0.05 | 0.47+–0.08 | 0.91+–0.19 | |
| | | p>0.05 | p>0.05 | p>0.05 | p<0.05 | |
| | *with tumour | | 0.46 | 0.43 | 1.2 | |
| | *without tumour | | 0.39 | 0.57 | 0.28 | |
| | | | | | p<0.05 | |

* with tumour — MI in the Experimental Group with tumour development,
* without tumour — MI in the Experimental Group without tumour development.



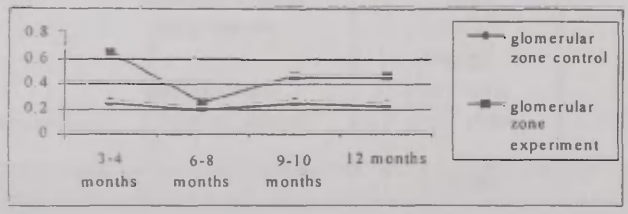




**Figure 2.** Mitotic index (MI) per 1000 cells in different organs during a one — year experiment of DMBA pellet graffing into the abdominal cavity

ment. The MI value for hepatocytes in rats with tumour was higher than the corresponding value in rats without tumour — 5.4‰ and 2.6‰ respectively ($p<0.001$); while comparing the values for MI in the fascicular-reticular zone the picture was about the same: in rats with tumour the MI was 1.2‰, in rats without tumour — 0.28‰ ($p<0.05$).

## DISCUSSION

We found that DMBA induces changes in mitotic activity. From other studies we had learned that DMBA was able to induce local changes in mitotic activity. Some authors had found MI that increases [3, 5, 24, 30, 37, 40, 48, 57], while some other authors had found that mitotic activity decreases [15, 17]. In our paper we have mentioned that different organs react differently to DMBA presence in the organism. A persistent rise in mitotic activity was observed in the liver. Iversen et al. have reported that higher doses of DMBA will lead to an initial reduction in mitotic activity [23]. At first the decrease is due to the toxicity of DMBA and damage caused by DMBA, and later an increase in mitotic activity takes place [15, 17, 59] .Shultz et. al. found that the mitotic index was the highest on the final days of the experiment, and some doses could even be lethal to the viviparous fish, but sublethal doses would increase mitotic activity [48]. 0.038 mg of DMBA did not cause visible intoxication in rats. The high MI values in the liver may be due to the detoxication process. The data demonstrate that all changes in mitotic activity occurred locally. But our investigation is the first to suggest that the DMBA effect on cell proliferation can be wider as we could observe different changes in mitotic activity take place in intact organs far from the place of DMBA treatment.

Independent changes took place in the organs. There was no general correlation between the MI values of different organs. MI values were lower in the first months of the experiment. Stress by inhibition of mitotic activity can explain the finding, and higher mitotic indexes can be seen when the organs began to recover from the stress [52]. It is also possible that the amount of active DMBA may be small, as the DMBA release from carbon pellets is slow. No cell proliferation was observed in the oesophagus after DMBA implantation. But MI values changed in the small intestine, the liver and the adrenal glands. The

MI values in the small intestine rise for a long time, but finally cell proliferation is inhibited. Pozharisski found an increase in the mitotic index in the large intestine in the third month after the systemic application (injections) of DMBA [39]. Similar MI increases in the intestine have been found after injections of other cancerogenic agents [2]. The MI values in the liver rose and then continued high. Changes in MI values did not depend on whether tumours developed or not after DMBA treatment, the only exceptions being the liver and the fascicular-reticular zone of the adrenal gland which had higher MI values in rats with tumours. MI values did not depend on whether the tumour was macroscopic or microscopic, i.e., they did not depend on the size of the tumour.

The background in the study of MI values by DMBA tumorigenesis included different types of localised malignant mesenchymal and epithelial tumours which had developed around DMBA pellets. We found that 0.038 g of DMBA would induce the formation of tumours in a period of 6 months from the start of the experiment under our experimental conditions. The tumours developing after DMBA implantation originated from the epithelium [50, 51] and from the mesenchyma [12, 36, 61]. Our experiment induced mesenchymal and epithelial types of tumours occurring together in one and the same experimental animal. The most frequent histological form encountered in our experiment was fibrosarcoma.

Organisation process in its different stages from granulation tissue to hyalinosis as well as lymphocytic inflammation could be observed in the study. These reactive changes were very similar to those reported on in our previous studies where DMBA pellets had been implanted in enucleated adrenal glands and later transplanted into the abdominal cavity [34]. Inflammatory reaction due to a foreign body inhibited the development of a tumour, the tumour in its turn reduced the inflammatory reaction induced by the foreign body [47]. The idea that there is a relationship between inflammatory processes and the development of cancer is as old as its elusive. There exists a number of possible mechanisms, e.g. macrophages are also thought to influence cancer development in addition to their role in the generation of active oxygen radicals [18]. DMBA has the ability of inducing inflammation [7].

The results of this study suggest that DMBA promotes systemic cell proliferation regardless the magnitude and kind of reactive changes to DMBA or tumours that may develop due to DMBA influence.

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# EPIDEMIOLOGY OF EATING BEHAVIOUR AND BODY BUILD IN 17–23-YEAR-OLD ESTONIAN STUDENTS

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ABSTRACT

Despite many nutritional studies, the relations between nutrition and body build are not quite clear. This study is dealing with students' eating behaviour, as they are more exposed to risk factors and disturbed eating. The total number of subjects were 759 entrants or students of the University of Tartu, aged from 17 to 23 years. For assessment of nutrition a questionnaire was used, and daily energy and nutrient content were calculated from a 24-hours menu. The frequency of eating certain foodstuffs, and daily energy and nutrient content were compared in 5 SD-classes according to height and weight. The relations between nutritional variables and anthropometric data were investigated by multivariate analysis. In accordance with previous studies, irregularity of eating and slightly lower energy content than recommended was found in our study group as well. There were also some differences in food consumption and nutrient content per 1 kg of body weight between different body build classes. The energy and nutrient content were predicted by body measurements to the extent of 3–12%.

## INTRODUCTION

Nutrition has attracted attention of many researchers in recent years. The eating behaviour and food nutrient content are changing, and the frequency of restrained eating has been rising, especially in students, who are exposed to many risk factors — time shortage, living on their own, dissatisfaction with one's appearance, eating junk food, low

level of knowledge about healthy dietary habits. Like a Taiwan study showed, the knowledge, attitudes and practices of senior medical students are poor. On a 10-point scale, the average score of students on general and clinical nutritional knowledge was 5,99±1,51 and 5,15±1,77, respectively. The percentage of correct answers in questionnaires was 60% and 52%, respectively. [7] A study of European students also showed that the level of practice of healthy dietary habits was low. In multivariate analysis, gender, dieting status, and dietary health beliefs were significant predictors of healthy dietary habits. [21] The results of a study of USA students confirm this. 76% of the USA college students reported that they ate the same foods day after day. A high percentage of body dissatisfaction was found — 50% of the students who were rated underweight on the basis of their BMIs classified themselves as overweight [5]. Investigating the food habits of university students from Spain, it was found that fish, dairy products and fruit were consumed in quite satisfactory quantities but cereals and vegetables were consumed less frequently than recommended. Multiple regression analysis showed no differences in concern about nutrition with respect to the sex or body mass index of the subjects. A certain difference was found between the knowledge of nutrition and actual behaviour. Although fat and cholesterol were a concern in theory, the consumption of foodstuffs such as meat and eggs was quite high [17]. In French students connection was found between the BMI and food habits. Especially respondents with a lower BMI showed a low frequency of snacking and a high regularity of having breakfast. Differently from the Spanish study there were no differences between theoretical knowledge and dietary practice among French students. Avoiding fat and cholesterol, efforts to eat fruit and fibre were often reported as examples of "healthy" behaviour [11]. Unhealthy dietary habits are closely related to a temporary or chronic deficit of necessary nutrients. An investigation of students from Granada University showed that among women the mean intake of zinc, some vitamins and minerals was below 80% of the Spanish recommendations [19].

A relatively lower daily energy content is often found in subjects with a higher BMI. In a Brazilian study the energy intake value was found to be lower than the recommended dietary allowances; the averages found for protein intake were above the recommended level. The values for anthropometric measurements were in general higher than those found in other Brazilian studies [1]. Among dental students entering the University of Montreal the average energy content was slightly lower than recommended. The ingestion of lipids was just

below the national recommendation, while the ingestion of proteins, calcium and iron was higher. More subjects in this study were found in lower range of the body mass index, but this could be due to the participation of a significant number of female students from Asia, who were in the low body weight index group as a rule [8]. Attempts are made to explain the connection of bigger weight and BMI with smaller intake of food energy by psychological factors. Namely, this group expresses greater dissatisfaction with their body weight. This can cause a wish for dieting and attempts to conceal some of the amount of food eaten while filling the questionnaire. The relative disconcordance of energy intake may also be caused by the different types of metabolism in people with different body builds. Therefore, also different norms of energy and nutrients should be established for people with different body builds.

Investigating the correlations between anthropometric parameters, energy consumption and recommended body weight of subjects, researchers have reached the conclusion that, while studying the eating habits and actual intake of foodstuffs, definitely the subjects' BMI and concern about their body weight should be taken into account. These factors influence essentially the answers received by questioning [16]. According to the Spanish study, all the subjects whose BMI was 25 or bigger considered themselves obese, and 71.7% of them also followed a diet. Underestimation of the food amount consumed occurred relatively more often in the case of the bigger BMI [15]. Subjects with a BMI below 24 underestimated the amount of their daily food by 4.8%, in the case of subjects with a BMI over 24 the same indicator was up to 20.4% [14].

Underestimation of the food amount among the subjects with bigger weight is obviously connected with the psychological factor. Satisfaction with one's body weight is to some extent connected with social factors, self-esteem and the BMI. At the same time, regression analysis has shown that awareness of one's body is not determined by independent variables [12]. While studying the correlations between psychological factors and the BMI, researchers have reached the conclusion that emotions are strongly correlated with body build, and eating disorders may be part of general frustration [6]. Low self-esteem, dissatisfaction with one's body and depression related to nutrition have been found particularly often in Asian studies. So, a comparative study of Chinese students and US students of Chinese extraction found that the Chinese expressed considerably more often dissat-

isfaction with their weight and height. They had lower self-esteem, suffered from symptoms of depression and took less exercise [4].

The studies of correlations between body build and eating habits have also yielded contradictory results. According to the studies of European university students, the BMI of young women is generally low (20.5 on the average), with small differences between different countries. Among other things, the researchers connect the low BMI with the high socio-economic status of the subjects. Nevertheless, many young women consider themselves overweight. The wish to lose weight and dieting are relatively widely spread (44% and 14% of subjects respectively), but these indicators differ considerably by countries. For students participating in the study, dieting most often consisted in omitting snacks and meals. For example, the students on diet omitted breakfast by half more often than those who were not dieting. The same study also referred to eating disorders [2]. A study of Swedish students found more overweight subjects than expected and more eating disorders [3]. The latter have been associated with the low leptin level in underweight women [20].

To counterbalance the studies that showed an influence of the BMI on the formation of eating habits and answers of the questionnaire, the authors studying the nutrition of patients with chronic obstructive pulmonary disease did not find any correlation between the breathing parameters and blood gases on the one hand, and body weight, skinfolds, BMI, average energy consumption at rest, upper arm circumference, and transferrin, albumin and lymphocytes values on the other hand [13].

A study of Estonian students in 1995–1996 revealed that students eat irregularly. Their choice of food is imbalanced; the nutrient content of the food does not correspond to recommendations. Young women get 86% of the food energy recommended [18].

Studying the nutrition of secondary school girls in Tartu, the authors found that the daily intake of food energy was considerably smaller in pycnics than in small, medium and leptosomic girls. At that the proportion of fats, proteins and carbohydrates in the daily food energy of girls with different body build types did not differ [9].

The aim of the present study was to establish connections between body build and nutrition and to characterise students' eating behaviour considering the peculiarities of their body build.

## MATERIAL AND METHODS

The sample included 759 young women — entrants or students of the University of Tartu. To characterise their body build, 37 body measurements and 10 skinfolds were taken according to the classical method of R. Martin [10]. 372 of them filled a questionnaire about their socio-economic status, eating habits and frequency of consumption of foodstuffs. The nutrition of 147 subjects was studied by the method of a 24-hour questionnaire. The daily intake of food energy and nutrients was calculated by the program Micro-Nutrica. The subjects were divided into five SD classes according to their height and weight, and frequency of the consumption of nutrients and food energy content both in absolute numbers and per kilogram of body weight were compared between different classes. The daily energy and nutrient content of food was studied by correlation analysis as well. The SAS software packet was used for data analysis.

## RESULTS

According to the standard deviation of height and weight the young women were divided into five SD-classes of height and weight: small, medium, big, pycnic and leptosomic. The body height and weight and body mass index of these classes are presented in Table 1.

The data about the subjects' socio-economic status were obtained by a questionnaire. 75.5% of the respondents came from urban and 24.5% from rural areas. At the moment of questioning, 40.9% lived at a student hostel or rented a flat; 59.1% resided in a privatised flat or private house. The average floor area per resident was 18±9.9 $m^2$. 4.6% of the subjects were married or cohabited, and 3.2% raised a child. The average size of household was 2.8±1.5 persons. The monthly income of 79.6% of the respondents was up to 2,000 Estonian kroons. 90.6% of the respondents considered their economic situation good or satisfactory.

32.8% of the respondents stated that they ate irregularly. 38.2% were still eating regularly three times a day. 69.1% had a hot meal at least once a day. 95.7% of the respondents had breakfast, 11.8% often or always ate late at night before going to bed. 39.2% ate sweets or suchlike between the meals, 41.9% did it occasionally. 32.5% had various complaints in connection with food.

**Table 1.** Weight, height and body mass index of 17–23-year-old women according to height-weight SD-classes

| Height-weight SD-classes | Statistics | Height (cm) | Weight (kg) | BMI (kg/m²) |
|---|---|---|---|---|
| 1. Small | Mean | 159.92 | 50.33 | 19.68 |
| n=131 | Minimum | 142.20 | 37.75 | 16.41 |
| | Maximum | 163.90 | 55.40 | 23.02 |
| | SD | 3.47 | 3.85 | 1.41 |
| 2. Medium | Mean | 166.85 | 59.19 | 21.27 |
| n=124 | Minimum | 164.00 | 55.60 | 19.38 |
| | Maximum | 169.70 | 63.95 | 23.52 |
| | SD | 1.66 | 2.47 | 0.97 |
| 3. Big | Mean | 174.36 | 71.23 | 23.44 |
| n=115 | Minimum | 170.00 | 64.10 | 20.38 |
| | Maximum | 185.30 | 98.85 | 32.35 |
| | SD | 3.43 | 6.71 | 2.20 |
| 4. Pycnic | Mean | 163.19 | 64.35 | 24.15 |
| n=158 | Minimum | 149.60 | 55.95 | 20.92 |
| | Maximum | 169.90 | 95.80 | 34.59 |
| | SD | 3.77 | 7.07 | 2.36 |
| 5. Leptosomic | Mean | 170.52 | 56.23 | 19.32 |
| n=196 | Minimum | 164.00 | 39.00 | 14.09 |
| | Maximum | 180.00 | 63.95 | 22.08 |
| | SD | 4.05 | 4.78 | 1.29 |

Estimates of consumption of various foodstuffs in different SD-classes are presented in Table 2. The subjects assessed the frequency of consumption of each foodstuff on a 5-grade scale, and the grades given in the Table have been obtained by adding the grades of the respective group of foodstuffs.

The distribution of energy obtained from food is presented in Figure 1. The daily energy intake of more than 75% of the subjects is between 750–2000 kcal. The average energy intake in the group was 1626 kcal which is below the norm recommended by Estonian nutrition experts.

The nutrient content of menus is presented in Table 3. In general, the amounts of nutrients obtained from food are close to those recommended; the differences are statistically insignificant.

Content of energy and the main nutrients in a 24-hour menu, compared by SD classes of height and weight, is presented in Table 4.

**Table 2.** Frequencies of consumption of main foodstuffs in SD-classes of height and weight (n=329)

| Groups of foodstuffs | 1. small n=57 | 2. medium n=51 | 3. big n=55 | 4. pycnic n=74 | 5. leptosomic n=92 | Statistical signifi-cance |
|---|---|---|---|---|---|---|
| Dairy prod-ucts | 28.16±6.62 | 30.23±7.38 | 28.48±6.66 | 29.27±6.42 | 30.01±5.43 | |
| Grain prod-ucts | 23.43±5.48 | 24.50±4.92 | 24.15±6.44 | 22.83±5.02 | 24.51±5.53 | |
| Meat | 27.22±7.21 | 27.06±7.73 | 26.69±6.10 | 25.55±7.42 | 27.52±7.21 | |
| Fish | 11.05±5.46 | 13.58±4.95 | 11.35±4.56 | 11.53±5.26 | 11.19±5.15 | |
| Vegetables | 42.07±12.73 | 48.17±11.98 | 45.26±11.88 | 46.00±12.64 | 43.29±11.39 | |
| Fruit | 44.40±12.48 | 43.24±11.07 | 43.43±11.01 | 43.39±11.17 | 45.20±10.71 | |
| Sweets | 24.23±7.45 | 23.59±7.89 | 22.65±6.63 | 20.52±5.35 | 24.18±5.95 | *** 1&4;4&5 |
| Juices | 11.11±3.87 | 11.14±3.40 | 9.65±3.75 | 9.73±3.21 | 11.20±3.26 | |
| Soft drinks | 6.75±3.23 | 6.62±3.53 | 6.76±2.55 | 6.78±3.28 | 6.91±3.13 | |
| Coffee, tea | 10.69±4.12 | 10.86±3.81 | 10.39±3.89 | 10.36±4.26 | 9.95±3.89 | |
| Alcohol | 5.19±2.90 | 4.90±3.35 | 4.75±2.77 | 5.49±2.87 | 5.05±3.31 | |

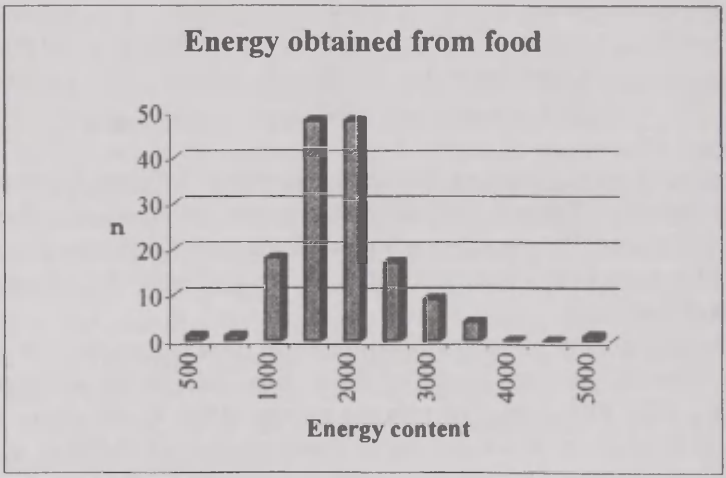


**Figure 1.** Distribution of energy obtained from food (n=147)

**Table 3.** Nutrient content of menus

| Nutrient | Norm | Min | Max | Mean | SD |
|---|---|---|---|---|---|
| Proteins, g | 51–75 | 12.4 | 131.5 | 53.66 | 21.56 |
| Fats, g | 68 | 9.2 | 160.2 | 55.57 | 30.6 |
| Carbohydrates, g | 280 | 73.3 | 647.9 | 221.91 | 85.01 |
| Saturated fatty acids, g | | 2.7 | 80.58 | 22.69 | 14.07 |
| Monounsaturated fatty acids, g | | 2.44 | 50.98 | 17.47 | 10.7 |
| Polyunsaturated fatty acids, g | | 1.87 | 55.19 | 10.5 | 6.8 |
| % of proteins in food energy | 10–15 | 5.16 | 24.95 | 13.66 | 3.29 |
| % of fats in food energy | 30–32 | 10.39 | 53.28 | 29.96 | 8.73 |
| % of carbohydrates in food energy | 52–60 | 35.76 | 78.34 | 56.36 | 9.02 |
| % of saturated fatty acids in food energy | 10–12 | 3.05 | 22.35 | 12.08 | 4.23 |
| % of monounsaturated fatty acids in food enery | 10 | 1.74 | 20.12 | 9.36 | 3.56 |
| % of polyunsaturated fatty acids in food energy | 10 | 1.73 | 18.2 | 5.84 | 2.84 |
| Cholesterol, mg | up to 300 | 22.19 | 638.97 | 181.02 | 139.33 |
| Fibres, g | 20–30 | 6.4 | 68.3 | 21.75 | 9.77 |
| Retinol, μg-equiv | 800 | 24.9 | 221 | 12 | 26 |
| Vitamin D, μg | 5 | 0.02 | 16.8 | 1.59 | 2.08 |
| Vitamin E | 8 | 2.12 | 39.44 | 7.8 | 4.57 |
| Tiamin (B1), mg | 1.1 | 0.29 | 2.58 | 0.9 | 0.4 |
| Riboflavin (B2), mg | 1.3 | 0.21 | 3.37 | 1.19 | 0.66 |
| Niacin, mg-equiv | 14 | 5.22 | 47.3 | 20.05 | 8.08 |
| Pyridoxine (B6), mg | 1.5–1.6 | 0.21 | 3.22 | 1.25 | 0.59 |
| Cyanocobalamin (B12), μg | 3 | 0.03 | 108.57 | 5.18 | 12.2 |
| Folic acid (B10), μg | 200 | 31.27 | 786.68 | 208.93 | 109.29 |
| Pantothenic acid (B3), mg | 4.7 | 0.56 | 10.6 | 3.93 | 1.66 |
| Biotin (H), μg | 100–200 | 3.1 | 68.04 | 22.28 | 12.56 |
| Vitamin C, mg | 60 | 0 | 385.8 | 65.55 | 61.39 |
| Sodium, mg | 1100–3300 | 446.1 | 44 | 21 | 894.94 |
| Potassium, mg | 1900 | 793.6 | 71 | 28 | 10 |
| Calcium, mg | 1000 | 91.8 | 22 | 677.92 | 388.37 |
| Magnesium, mg | 400 | 100.9 | 731.9 | 276.48 | 105.18 |
| Phosphorus, mg | 1000 | 288.8 | 27 | 11 | 433.2 |
| Iron, mg | 18 | 4.46 | 30.6 | 12.46 | 4.52 |
| Manganese, mg | 2.5–5 | 1.02 | 17.26 | 4.84 | 2.42 |
| Zinc, mg | 15 | 2.36 | 20.24 | 8.81 | 3.49 |
| Copper, μg | 2000–3000 | 291.24 | 86 | 12 | 965.54 |
| Molybdenum, μg | 150–500 | 11.9 | 226.54 | 73.34 | 30.21 |
| Chromium, μg | 50–200 | 3.96 | 53.17 | 19.2 | 8.35 |
| Fluorine, μg | 1500 | 117.08 | 947.22 | 407.33 | 159.15 |
| Iodine, μg | 150 | 2.94 | 455.16 | 184.88 | 91.31 |
| Selenium, μg | 30–60 | 1.57 | 117.36 | 50.48 | 22.03 |

| Nutrient | Norm | Min | Max | Mean | SD |
|---|---|---|---|---|---|
| Aluminium, µg | | 0.81 | 10.1 | 4.31 | 1.57 |
| Energy/body weight, kcal/kg | | 7.09 | 112.04 | 27.77 | 12.71 |
| Proteins/body weight, g/kg | | 0.17 | 2.86 | 0.91 | 0.41 |
| Fats/body weight, g/kg | | 0.16 | 3.91 | 0.95 | 0.58 |
| Carbohydrates/body weight, g/kg | | 1.08 | 15.95 | 3.79 | 1.76 |

**Table 4.** Comparison between energy and main nutrients content in SD-classes of height and weight (n=724)

| Variable | 1. small n=131 | 2. medium n=124 | 3. big n=115 | 4. pycnic n=158 | 5. leptosomic n=196 | Statistical sinifiance |
|---|---|---|---|---|---|---|
| Energy content, kcal | 1590±797 | 1752±707 | 1540±585 | 1469±523 | 1736±526 | |
| Proteins, g | 48.2±22.7 | 60.4±24.8 | 51.3±24.8 | 51.1±19.5 | 57.5±21.1 | |
| Fats, g | 54.3±33.7 | 56.0±27.8 | 51.8±32.2 | 47.2±27.0 | 63.3±29.1 | |
| Carbohydrates, g | 221.7±108.1 | 244.1±116.8 | 212.1±75.0 | 205.0±76.3 | 228.1±66.2 | |
| Proteins (% of food energy) | 12.69±2.86 | 14.36±3.55 | 13.53±3.85 | 14.38±3.84 | 13.62±3.04 | |
| Fats (% of food energy) | 29.65±7.70 | 28.95±9.59 | 29.33±9.73 | 28.15±8.57 | 32.15±8.15 | |
| Carbohydrates (% of food energy) | 57.67±7.27 | 56.68±10.95 | 57.14±10.83 | 57.47±8.99 | 54.23±7.72 | |
| Energy/body weight, kcal/kg | 32.2±19.6 | 29.7±12.3 | 21.4 ±8.2 | 23.7 ±10.0 | 30.2 ±10.0 | *** 1&3 |
| Proteins/body weight, g/kg | 0.98±0.54 | 1.02±0.43 | 0.71±0.34 | 0.82±0.37 | 1.00±0.39 | |
| Fats/body weight, g/kg | 1.10±0.78 | 0.95±0.49 | 0.72±0.44 | 0.77±0.48 | 1.10±0.54 | |
| Carbohydrates/body weight, g/kg | 4.49±2.71 | 4.13±1.99 | 2.97±1.11 | 3.30±1.45 | 3.97±1.25 | *** 1&3 |

Correlation analysis was carried out between nutrients and body measurements and indices calculated from them. The results are given

in Table 5. Statistically significant correlation coefficients have been marked by asterisks. The analysis revealed the measurements characterising body obesity yield statistically significant correlations with food energy and main nutrients.

**Table 5.** Correlations between body measurements and nutrients

| | Energy | Proteins | Fats | Carbohydrates |
|---|---|---|---|---|
| Weight | –0.20* | –0.12 | –0.14 | –0.21* |
| Upper chest circumference | –0.22* | –0.09 | –0.17 | –0.23* |
| Waist circumference | –0.17 | –0.07 | –0.10 | –0.21* |
| Pelvis circumference | –0.23* | –0.10 | –0.17 | –0.25* |
| Hips circumference | –0.25* | –0.14 | –0.18 | –0.25* |
| Waist skinfold | –0.25* | –0.16 | –0.18 | –0.27* |
| Suprailiac skinfold | –0.28* | –0.15 | –0.22* | –0.28* |
| Umbilical skinfold | –0.30* | –0.22 | –0.22* | –0.30* |
| Subscapular skinfold | –0.30* | –0.17 | –0.21* | –0.32* |
| Thigh skinfold | –0.27* | –0.15 | –0.20* | –0.28* |
| BMI | –0.23* | –0.15* | –0.17* | –0.23* |
| Rohrer index | –0.23* | –0.16* | –0.17* | –0.23* |
| Body surface area | –0.17* | –0.09 | –0.11 | –0.18 |
| Total body fat | –0.30* | –0.17* | –0.21* | –0.32* |
| Mean skinfold | –0.29* | –0.17* | –0.20* | –0.31* |
| Mass of subcutaneous adipose tissue | –0.26* | –0.16* | –0.17* | –0.28* |
| Body density | 0.22* | 0.08 | 0.17* | 0.23* |

On the basis of what has been said above, regression analysis was carried out. An attempt was made to predict energy content and the main nutrients according to anthropometric characteristics. The significance level was placed at 0.1. The results are presented in Table 6.

Stepwise regression showed that the mean skinfold was a significant independent variable, and the formulae obtained describe 3–12% of the variability of the dependent variables.

**Table 6.** Prediction of nutrient content by anthropometric variables

| Regression formula | $R^2$ |
|---|---|
| *ENERGY = 2245.444 – 50.274(mean skinfold)* | 0.085 |
| *PROTEINS = 66.101 – 1.029(mean skinfold)* | 0.03 |
| *FATS = 76.867 – 1.724(mean skinfold)* | 0.041 |
| *CARBOHYDRATES = 464.268 – 6.84(age) – 8.266(mean skinfold)* | 0.12 |

## DISCUSSION

The socio-economic situation of the young women participating in the present study can be estimated as good. The study of their eating habits revealed, in concordance with earlier investigations, a considerable amount of respondents ate irregularly, had snacks (sweets) between meals, etc. Still, only less than 5% of the subjects omitted breakfast. The energy content of the food remained lower than recommended, particularly in the group of pycnics. It is possible that this group underestimated their daily menu. Nonetheless, the nutrient content of the menus was more or less within the norms. A limitation of the present study was that factual nutrition was observed during one day only. A 24-hour questionnaire probably is insufficient for more precise assessment of the daily energy intake and nutrient content of the menu.

The comparison of eating habits of young women with different body builds did not reveal any significant differences between the SD-classes. Statistically significant differences were noticed only in consumption of sweets in the extreme classes. Namely, differences were revealed between the classes of small and pycnic subjects, and pycnics and leptosomes. While comparing the daily energy intake and consumption of main nutrients in height-weight classes, certain differences could be noticed both in energy intake and main nutrients. Statistically significant differences between the small and big classes were revealed when comparing the amount of energy and carbohydrates per one kilogram of body weight. This shows that, in the case of relatively similar nutrition, in the case of different body build the intake of energy and nutrients per one kilogram is different.

Correlation analysis showed a statistically significant correlation between the food energy and main nutrients content, and the measurements and indices characterising body obesity. The length measurements were connected with nutrition mainly by indices characterising body build. While predicting the consumption of nutrients by body measurements, the significant arguments were skinfold and age which described up to 12% of the dispersion of energy and main nutrients amount. Thus, although in the age bracket under discussion no essential differences were revealed between different age groups in anthropometric measurements or nutrition, age still has a certain influence on eating behaviour. Nutrition is influenced both by external factors and the individual peculiarities of metabolism. The latter obviously causes differences in eating habits and nutrients intake in persons with different body builds.

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# RELATIONSHIP BETWEEN CONSTITUTION AND INDIVIDUAL PSYCHOLOGICAL PECULIARITIES IN PATIENTS WITH ACUTE MYOCARDIAL INFARCTION

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ABSTRACT

337 males who had had myocardial infarction were studied by the anthropometric method and following somatotype determination. The age of patients ranged from 21 to 69 years. Somatometric study was carried out by the method of V. V. Bunak in the modification of V. P. Chtetsov. In comparison with the others, accompanying arterial hypertension was revealed more rarely in patients of the thoracal somatotype. Myocardial infarction with front localisation was recorded more often in patients of the muscular somatotype. Myocardial infarction with the Q-wave was observed more frequently in patients of the abdominal somatotype. As to the structure of complications, patients of the thoracal somatotype suffered more often from circulatory insufficiency and patients of the muscular type — from rhythm and conduction disorders. In patients of the abdominal somatotype the percentage of several complications was high. Myocardial infarction with an uncomplicated course predominated in patients of an indefinite somatotype. Psychological peculiarities distinguishing the patients of the thoracal somatotype from the others were determined. The predictors of myocardial infarction (MI) development were revealed in patients of the thoracal somatotype.

**Key words:** myocardial infarction, somatotype, psychological testing

## INTRODUCTION

In spite of many published works about the decrease of mortality rate from coronary disease, it is the main cause of morbidity and mortality in our time. Despite the abundance of information, comparative data of

investigations reveal that the role of excessive mass for etiology of coronary disease is unclear. Among early investigations of the relationship between coronary heart disease and body mass and growth we can note the classical studies on students of Harvard and Pennsylvania Universities [1, 2]. Paffenberger *et al.* revealed that the patients who died from coronary heart disease had a higher body mass at primary study than in the control group. It was also determined that most patients who died from coronary heart disease were shorter than 172 cm.

M. M. Gertler [3] *et al.* observed that the males hospitalised with myocardial infarction were about 5 cm and 3 kg heavier than in the control group. The analysis carried out lately showed that body mass had the second place after general cholesterol level as a factor predicting coronary heart disease development (although smoking was not taken in consideration).

Dyer *et al.* [4] revealed that the relationship between the body mass index and mortality from coronary heart disease could not be showed as a U-shaped curve. In South Africa coronary heart disease rate [5] was spread both in the group with the smallest Kettle's index — body mass index (<20) and in group with the greatest one (30–35 and more).

At the same time many investigations (length of study from 5 to 26 years) have showed a slight relationship or its absence between coronary heart disease and body mass index [6, 7, 8, 9]. We supposed that the relationship between body mass index and coronary heart disease was characteristic of only some groups of patients and made an attempt to study the relationship between somatotypes and acute myocardial infarction.

## MATERIAL AND METHODS

To solve this problem we studied 337 males with myocardial infarction in the Department of Emergent Cardiology of Krasnoyarsk Ambulance Hospital. A composite examination including anthropometric measuring with following somatotype determination was carried out. The somatometric study was carried out by the method of Bunak [10] in the modification of V. V. Chtetsov [11]. The psychological profile of the patients was studied with the help of the Mini-Multi-Test [12]. Among the examined patients 41 males (12.16%) had a thoracal somatotype (average age 52.829±1.342), 89 males (26.40%) — a mus-

cular somatotype (average age 50.843±0.835), 96 (28.49%) — an abdominal somatotype (average age 53.760±0.686) and 111 (32.95%) — an indefinite somatotype (average age 54.721±0.790). Among the patients of the thoracal somatotype males with incomplete secondary and secondary education (80.49%) predominated, while 39.58% of patients of the abdominal somatotype had higher education ($p<0.05$). Among the patients of the muscular and abdominal somatotypes the percentage of employees was statistically significant ($p<0.02$) in comparison with the group of thoracal somatotype where workers predominated (58.54% versus 32.58 and 31.25% respectively).

## RESULTS

There were no statistically significant differences between the observed groups in the frequency of primary and secondary myocardial infarction. Accompanying arterial hypertension was revealed significantly more often in the patients of the muscular, abdominal and indefinite somatotypes in comparison with the patients having a thoracal somatotype (Figure 1). As our studies showed, this group of patients had the greatest duration of arterial hypertension (14.25±4.246 years). Arterial hypertension of significantly lesser duration was revealed in patients of the abdominal somatotype (8.560±0.914 years), the indefinite somatotype (8.880±1.184 years) and the muscular somatotype (9.122±0.923 years). Our study showed different frequency of hypertrophy of the left ventricle (HLV) in patients of different somatotypes. HLV without accompanying arterial hypertension was revealed in 10.98% of patients of the indefinite somatotype, in 12.44% of patients of the abdominal somatotype, in 16.35% of patients of the thoracal and in every fourth patient (in 28.79% of cases) of the muscular type of constitution.

Lower localisation of myocardial infarction was observed more often in patients of the thoracal somatotype (36.59%) in comparison with patients of the muscular somatotype (26.97%). For this group of patients myocardial infarction with front localisation was characteristic (58.43%). Myocardial infarction of posterior basal part was revealed more often in patients of the indefinite somatotype (6.31%) in comparison with patients of other somatotypes (from 2.44 to 3.37%). Circular MI was observed slightly more often in the group of the ab-

dominal somatotype (5.21%) in comparison with the indefinite (0.90%) and the thoracal (2.44%) somatotypes. No patients of the muscular somatotype had circular MI.

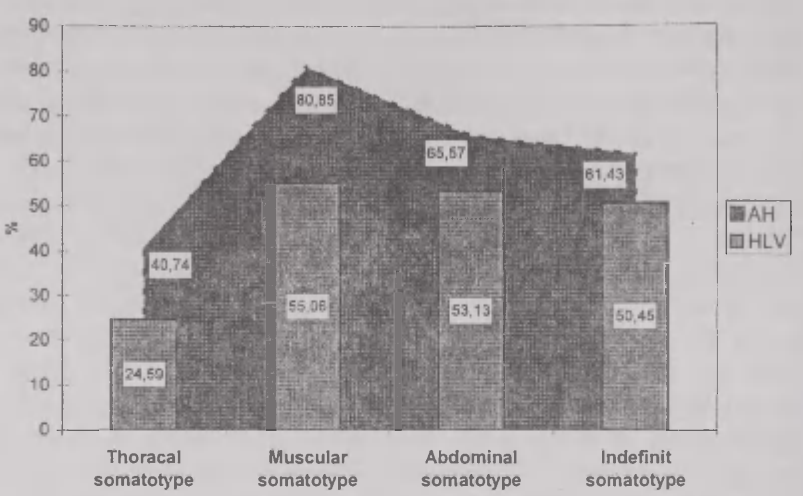


**Figure 1.** Frequency of arterial hypertension (AH) and hypertrophy of left ventricle in patients of different somatotypes with myocardial infarction

Concerning the frequency of MI development with the Q-wave, the abdominal somatotype was the most unfavourable (58.33%), whereas this disease was revealed more seldom in patients of the thoracal somatotype (39.02% of cases — $p<0.05$) (Figure 2). The analysis of MI complications (Figure 3) showed that circulatory insufficiency predominated in patients of the thoracal somatotype (41.47%). The difference ($p<0.05$) was statistically significant in comparison with the group of the muscular somatotype (23.60%). The muscular somatotype was in the lead in the frequency of uncomplicated MI (43.82%) and cardiogenic shock (10.1%), but the differences were statistically insignificant. The structure of complications was similar in patients with excess fat mass (the abdominal and indefinite somatotypes). There was only a difference in the frequency of multiple complications (25.01 and 16.21% respectively but $p<0.05$).

As compared to the indices of the Mini-Multi-Test (Figure 4), we observed statistically significant differences according to scale 1 (hypochondria), 6 (paranoia) and 9 (activity) between patients of the thoracal somatotype and other groups. In patients of the muscular, ab-

dominal and indefinite somatotypes the leading profile was the first one (hypochondria) and in patients of the thoracal somatotype — the sixth (paranoia).

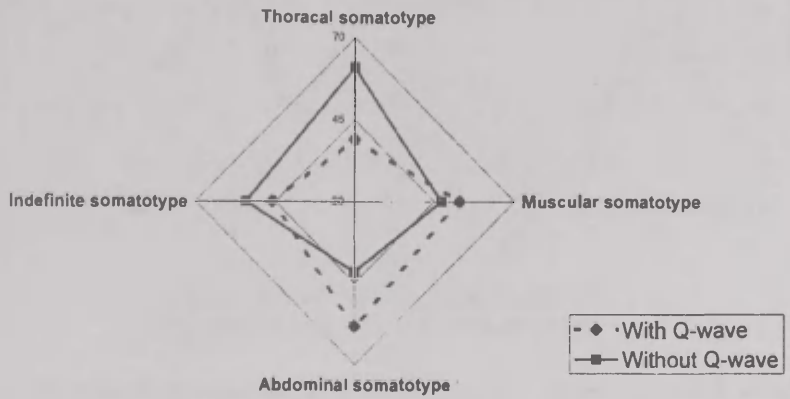


**Figure 2.** Death of myocardial infarction depending on somatotype
• $p < 0,05$ — reliability of differences in thoracal somatotype

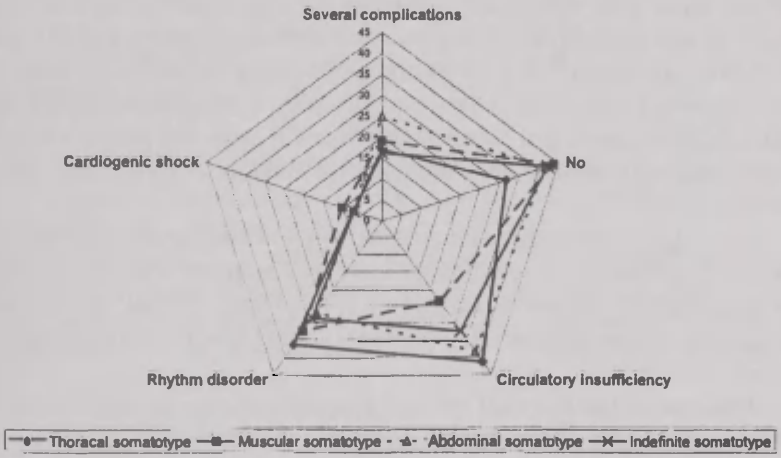


**Figure 3.** Complications of myocardial infarction in patients with different somatotypes

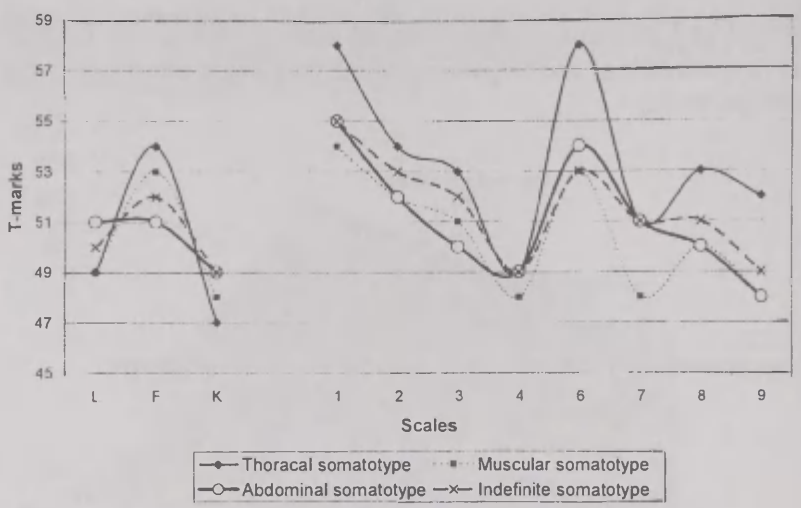


**Figure 4.** Average profile of Mini-Multi-Test in patients with myocardial infarction having different somatotypes

The patients of all groups were very attentive to themselves and their sensations, had no outward sign of alarm. These patients were anxious about the state of their health. Patients of the abdominal and indefinite somatotypes with myocardial infarction were too selfish and exacting, inactive and dissatisfied. Pedantry, persistence obstinacy, rigidity and difficulty in change of work forms were characteristic of patients of the thoracal somatotype. These patients were remarkable for their diffidence, touchiness and strained relationship with the people of their circle, although these traits were not expressed in the behaviour of the patients.

The analysis of individual profiles (Figure 5) showed that the patients of the muscular somatotype were best adapted socially (43.04% of them had no sings of disadaptation). 66.28% of the patients with the abdominal somatotype needed the consultation of a psychologist and a psychotherapist.

Patients of the thoracal somatotype were the most unfortunate in the frequency of psychological disorders (27.27%). The differences were statistically significant in comparison with the abdominal somatotype (6.98%, $p<0.01$).

In conclusion it should be noted that the predictors of MI development in patients of thoracal somatotype are: a low level of education and low social status, duration of arterial hypertension in the

course of 10 years and high indices of Mini-Multi-Test according to the 6th scale. Among patients with MI in this group the development of heart failure can be expected in every second person.

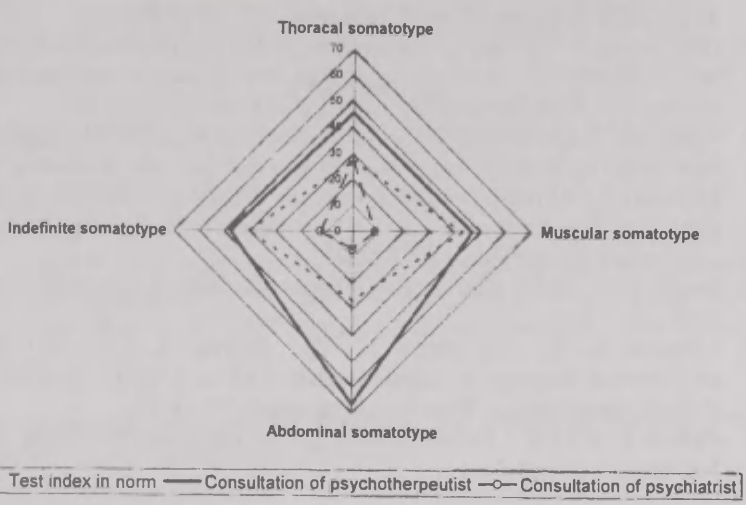


**Figure 5.** Frequency of signs of social and psychological disadaptation in patients with myocardial infarction having different somatotypes

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# PREDICTION OF THE WEIGHT OF THE FOETUS AND THE NEWBORN BY ULTRASOUND MEASUREMENTS

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**Key words:** Weight of the foetus, weight of the newborn, biparietal diameter of the foetus' head, breadth and depth of the foetus' abdomen, femur length of the foetus, ultrasound age of the foetus

The article deals with the prediction of the weight of the foetus and the newborn by ultrasound measurements.

Estimation of the child's birthweight has caused problems for a long time, and attempts have been made to find solutions by several methods. One possibility is to use anthropometric measuring of the mother. In practice Prof. I. Zordania's formula [1] has been used, according to which the weight of the newborn is expressed as the height of the uterus multiplied by the circumference of the abdomen. In cooperation between the Women's Hospital of Tartu University and the Centre for Physical Anthropology [2] the actual weight of the newborns of Tartu was found to be systematically different from that calculated by Zordania's formula, and the difference was connected with mother's height and weight.

The precision of prediction improves considerably if we can use ultrasound measurements.

These broadened opportunities also bring along new tasks:

a) monitoring the development of the foetus (in order to discover irregularities in growth rate);
b) prediction of birth weight and size in order to predict and prevent possible traumas and aggravations at parturition.

Ultrasound measurements have been practised at the Women's Hospital of Tartu University since the 1980s. Until now, the weight of the foetus has been assessed by a formula empirically derived at the Karolinska Hospital in Sweden. This does not include the gestational

age as the formula is used to assess the weight of the foetus on the basis of measurements obtained by ultrasound measurements. The formula runs as follows:

$$(\text{Weight of foetus}) \times 100 = BIP \times 0.86 + ABD \times 1.59 + FEM \times 0.91 - 0.11$$

where BIP is the biparietal diameter of the foetus' head; ABD the arithmetic means of the abdominal breadth and depth of the foetus; and FEM is the femur length of the foetus. Unfortunately, the author has no data about investigations and publications concerning this formula. Until now no systematic statistical analysis of the results of ultrasound measuring and the concordance of the formula with the data of Tartu Women's Hospital has been made. Therefore we have no clear idea about the precision of the formula and its appropriateness to Estonian data. Neither has the precision of anthropometric measurements performed by ultrasound been evaluated and the dynamics of measures investigated.

In the present study our aim is:

1. To assess the growth curves of ultrasound measurements (biparietal diameter of the head, femur length, abdominal breadth and depth), considering the mother's size (height and weight) as well.
2. To check the appropriateness of some methods used in literature for assessing the weight of the foetus and the newborn in Estonian conditions.

## MATERIAL AND METHODS

Data of the Women's Hospital of Tartu University were use
investigation. We studied 772 live-born neonates and their
Three groups of empirically measured variables were used:
urements of the foetus obtained by ultrasound measurements
tal diameter of the head, femur length, abdominal breadth and depth),
the mother's measurements (body height and circumference of the abdomen) at the end of pregnancy, and the newborn's weight on its first day of life. From the results of ultrasound measurements, the ultrasound age of the foetus was determined, which shows how old the foetus should be according to the data measured. The ultrasound age can differ from gestational age (the actual age of the foetus) during the ultrasound measuring. An overview of the results of the measurements is provided in Table 1.

**Table 1.** Basic statistics

| Variable | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Mother's age | 764 | 24.75 | 5.08 | 14 | 44.0 |
| Duration of pregnancy, weeks | 768 | 39.7 | 1.8 | 25.3 | 44.6 |
| Mother's height at parturition | 769 | 166.15 | 6.13 | 147.0 | 183.0 |
| Mother's weight at parturition | 759 | 75.4 | 11.6 | 49.0 | 137.0 |
| Circumference of mother's abdomen at parturition | 761 | 100.5 | 8.3 | 70.0 | 155.0 |
| Newborn's weight | 772 | 3578.5 | 534.4 | 870.0 | 5216.0 |
| Biparietal diameter of foetus' head | 770 | 7.3 | 2.1 | 2.0 | 10.8 |
| Foetus' abdominal breadth | 769 | 8.0 | 2.8 | 1.6 | 13.3 |
| Foetus' abdominal depth | 768 | 7.9 | 2.8 | 2.0 | 13.3 |
| Foetus' femur length | 763 | 5.5 | 2.0 | 1.0 | 9.8 |
| Foetus' ultrasound age | 768 | 30.1 | 8.2 | 12.5 | 44.0 |

In order to predict the growth curves and weights we used nonlinear regression analysis with the ultrasound age of the foetus as an independent variable. The use of nonlinear regression analysis is well grounded because of different growth rates at different stages of pregnancy.

## INVESTIGATION OF THE ANTHROPOMETRY OF THE FOETUS. GROWTH CURVES DURING PREGNANCY

We compiled several linear models of changes in the foetus' measurements. As for the mother's measurements, her weight was statistically significant for predicting the abdominal measurements of the foetus. For predicting the femur length and the head diameter of the foetus, however, the mother's height was significant. A mother 1 cm taller than the average added on the average 1 mm to the abdominal measurements of the foetus, and a mother 1 kg heavier than the average added 0.8 mm to the diameter of the foetus' head and 1 mm to its femur length.

As the growth rates of the foetus were different during different stages of pregnancy, the best model of each measurement of the foetus was obtained by the multiplicative model.

The models together with the determination coefficient $R^2$ are presented in Table 2, where BIP is the biparietal diameter of the foetus' head; ABL — abdominal breadth of the foetus; ABS — ab-

dominal depth of the foetus; FEM — femur length of the foetus; UHVAN — ultrasound age of the foetus.

**Table 2**

| Growth curve model (weeks 12–42) | $R^2$ |
|---|---|
| $BIP = 0.6253 \cdot e^{0.1316 UHVAN - 0.0016 UHVAN^2}$ | 0.98 |
| $ABL = 0.6033 \cdot e^{0.128 UHVAN - 0.0014 UHVAN^2}$ | 0.95 |
| $ABS = 0.7426 \cdot e^{0.114 UHVAN - 0.0012 UHVAN^2}$ | 0.95 |
| $FEM = 0.2372 \cdot e^{0.1666 UHVAN - 0.002 UHVAN^2}$ | 0.97 |

Graphically the changes in the foetus' measurements are presented on Figures 1 and 2.

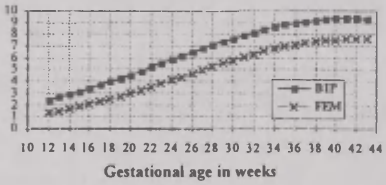


**Figure 1.** Growth curve of foetus' head diameter and femur length during pregnancy.

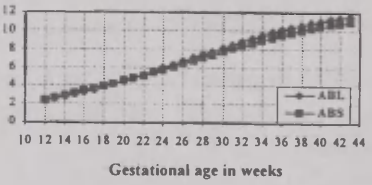


**Figure 2.** Growth curve of foetus' abdominal breadth and depth during pregnancy.

We found that the diameter of the head and the femur length change in a similar way, and so do the abdominal measurements. It can be said that the foetus shows a relatively quicker growth rate during the 15th–32nd weeks of pregnancy. The growth of linear measurements slows down at the end of pregnancy, so they do not change significantly if pregnancy lasts longer from the average. If the duration of pregnancy is less than 38 weeks, then all the linear measurements of the newborn differ considerably from the average.

## CHANGES IN THE FOETUS' WEIGHT DURING PREGNANCY

In order to describe the changes in the foetus' weight, we use the formula elaborated at Karolinska Hospital in Sweden. Using this formula, we calculate the weight of the foetus at the moment of

ultrasound measuring. Thereafter, using simple regression analysis, we find the weight gain per week. We found that the foetus' weight during the 12th week of pregnancy was approximately 500 grams. Until the 23rd week the weight grows on the average by 116.7 grams a week, and from the 23rd week to the end of pregnancy by 87.6 g a week. As the increase of weight is different during different stages of pregnancy, we use the multiplicative model:

$$F(WEIGHT) = 174.985 \cdot e^{0.1335 UHVAN - 0.0015 UHVAN^2} \qquad (R^2 = 0.98),$$

where F(WEIGHT) is the weight of the foetus and UHVAN is the ultrasound age.

We also compiled a graph showing the changes in the foetus' weight (Figure 3).

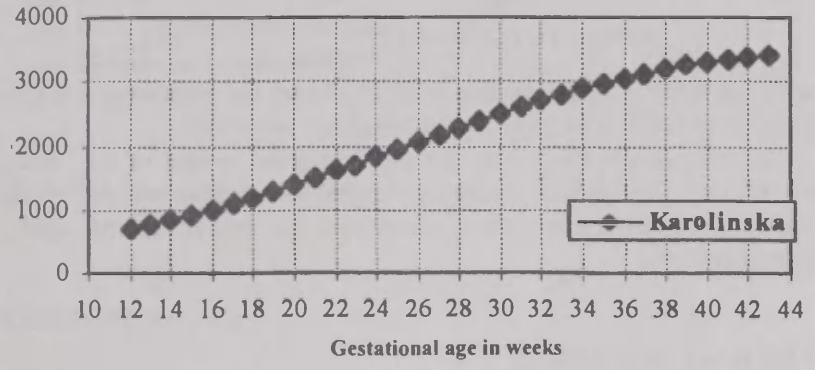


**Figure 3.** Changes in foetus' weight during pregnancy.

As the graph shows, by the 12th week of pregnancy the foetus weighs approximately 700 g. Next, we are going to describe the average growth of the fetus during pregnancy. During the following ten weeks, the foetus grows by 897 g, weighing 1596.71 g by the 22nd week of pregnancy. The following ten weeks are the period of fastest growth during the whole pregnancy — the foetus gains 1102 g, weighing 2699.17 g by the 32nd week. During the last weeks of pregnancy the growth slows down; the weight increases by 701.41 g by the 43rd week, achieving 3400.58 g by the end of pregnancy. During weeks 38–43 the weight of the foetus increases by only 200 g, which shows that in the case of belated delivery the weight of the foetus does not change essentially.

## TWO MODELS FOR ASSESSING THE FOETUS' WEIGHT
## THE MONGELLI-GARDOSI MODEL

The Mongelli-Gardosi model of proportional growth [3] is based on the assumption that if the foetus, at some moment of pregnancy (generally, from the 24th week onwards), is bigger than the average, then it is proportionally as much bigger than the average at the moment of birth as well. For assessing the average Mongelli and Gardosi used the *median*.

We find the medians of the foetus' weight for each week of pregnancy and the medians of birth weight according to the duration of pregnancy. As the graph of birth weight medians is very unsmooth because of insufficient data on small durations of pregnancy (30 weeks and below), we approximate it with the help of the multiplicative model:

$$BWMED = 0.464 \cdot e^{0.4086 RASKEST - 0.0046 RASKEST^2},$$

where BWMED is the median birthweight on the respective week of pregnancy and RASKEST is gestational age at parturition.

In order to use this model for predicting the weight of the foetus, we replace the median birthweight with the median weight of the foetus at the respective week of ultrasound age, and gestational age by ultrasound age.

## THE HADLOCK MODEL

Hadlock [4] estimates the weight of the foetus on the basis of ultrasound measurements and thereafter attempts to describe the weight estimates as a function of gestational age.

The optimum model was obtained as a logarithmic model of weight (coefficients found using the data of the Women's Hospital of Tartu University):

$$ln(WEIGHT) = 0.578 + 0.332\ UHVAN - 0.00354\ UHVAN^2,$$

where ln (WEIGHT) is the logarithm of the age of the foetus.

The formulas with parameters estimated by us, using the data of the Women's Hospital of Tartu University, are, in general, as precise as the formula presented in literature.

In Figure 4 we present the growth curve based on the Karolinska formula together with Mognelli-Gardosi's and Hadlock's growth curves. The Karolinska formula for calculating the weight of the foetus raises certain doubts, as the growth curve calculated by it differs considerably from the growth curves calculated according to the other models.

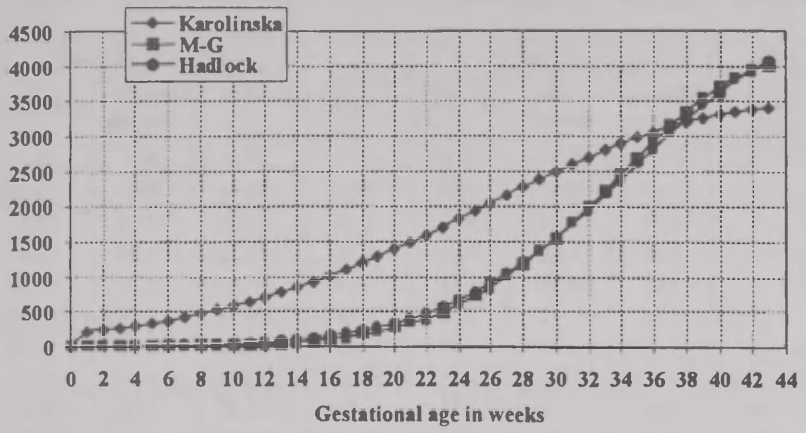


**Figure 4.** Growth curve of foetus' weight.

## DISCUSSION

The linear measurements of the foetus obtained by ultrasound measurments change in a rather regular manner, whereas their growth can be successfully described by the linear, quadratic as well as multiplicative model. The linear measurements appeared to increase most quickly during the 12th–32nd weeks of pregnancy, when the measurements observed by us increased up to 3 mm a week. At the end of pregnancy the growth of linear measurements slows down.

A certain problem about the predictions of this kind is that usually the duration of pregnancy has been determined by ultrasound measurements. This also explains the high rate of determination (up to 95–98%).

In order to assess the weight of the foetus by linear measurements, several formulas are applied; one of them is used at the Women's Hospital of Tartu University as well.

The estimates achieved can be quite well approximated by functions depending on time only. At that, different models that work well at the end of pregnancy can give radically different weight estimates for the earlier period of pregnancy. The estimates of the weight and other measurements of the foetus are given in Table 3.

**Table 3.** The models for prediction of the foetus' measurements and weight

| Gestational age in weeks | Head's biparietal diam. | Abdominal breadth | Abdominal depth | Fermur length | Predictions of weight | | |
|---|---|---|---|---|---|---|---|
| | | | | | Karolinska | Mongelli-Gardos' | Hadlock' |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0.71 | 0.69 | 0.83 | 0.28 | 199.68 | 0.69 | 2.48 |
| 2 | 0.81 | 0.78 | 0.93 | 0.33 | 227.17 | 1.03 | 3.41 |
| 3 | 0.91 | 0.88 | 1.03 | 0.38 | 257.68 | 1.52 | 4.67 |
| 4 | 1.03 | 0.99 | 1.15 | 0.45 | 291.40 | 2.21 | 6.36 |
| 5 | 1.16 | 1.11 | 1.27 | 0.52 | 328.55 | 3.19 | 8.58 |
| 6 | 1.30 | 1.24 | 1.41 | 0.60 | 369.33 | 4.56 | 11.50 |
| 7 | 1.45 | 1.39 | 1.56 | 0.69 | 413.93 | 6.47 | 15.31 |
| 8 | 1.62 | 1.54 | 1.71 | 0.79 | 462.52 | 9.08 | 20.24 |
| 9 | 1.80 | 1.72 | 1.88 | 0.90 | 515.27 | 12.64 | 26.56 |
| 10 | 1.99 | 1.90 | 2.06 | 1.03 | 572.32 | 17.43 | 34.61 |
| 11 | 2.19 | 2.10 | 2.25 | 1.16 | 633.78 | 23.81 | 44.78 |
| 12 | 2.41 | 2.31 | 2.45 | 1.31 | 699.73 | 32.23 | 57.53 |
| 13 | 2.64 | 2.54 | 2.67 | 1.48 | 770.24 | 43.23 | 73.39 |
| 14 | 2.88 | 2.78 | 2.90 | 1.65 | 845.31 | 57.45 | 92.96 |
| 15 | 3.14 | 3.03 | 3.13 | 1.84 | 924.91 | 75.65 | 116.92 |
| 16 | 3.41 | 3.31 | 3.38 | 2.04 | 1008.99 | 98.70 | 146.02 |
| 17 | 3.69 | 3.59 | 3.65 | 2.26 | 1097.40 | 127.60 | 181.08 |
| 18 | 3.98 | 3.89 | 3.92 | 2.49 | 1189.99 | 163.45 | 222.97 |
| 19 | 4.28 | 4.20 | 4.20 | 2.73 | 1286.53 | 207.46 | 272.62 |
| 20 | 4.58 | 4.52 | 4.49 | 2.98 | 1386.73 | 260.90 | 330.97 |
| 21 | 4.90 | 4.85 | 4.79 | 3.25 | 1490.25 | 325.10 | 398.97 |
| 22 | 5.21 | 5.20 | 5.10 | 3.52 | 1596.71 | 401.39 | 477.54 |
| 23 | 5.53 | 5.55 | 5.42 | 3.80 | 1705.65 | 491.04 | 567.57 |
| 24 | 5.85 | 5.91 | 5.74 | 4.09 | 1816.56 | 595.22 | 669.80 |
| 25 | 6.17 | 6.28 | 6.06 | 4.38 | 1928.89 | 714.89 | 784.87 |
| 26 | 6.49 | 6.65 | 6.39 | 4.67 | 2042.03 | 850.76 | 913.22 |
| 27 | 6.80 | 7.02 | 6.72 | 4.96 | 2155.33 | 1003.18 | 1055.06 |
| 28 | 7.11 | 7.39 | 7.05 | 5.25 | 2268.11 | 1172.07 | 1210.34 |
| 29 | 7.40 | 7.76 | 7.38 | 5.53 | 2379.63 | 1356.86 | 1378.67 |
| 30 | 7.68 | 8.13 | 7.71 | 5.81 | 2489.16 | 1556.40 | 1559.34 |
| 31 | 7.94 | 8.49 | 8.03 | 6.07 | 2595.93 | 1768.93 | 1751.24 |

| Gestational age in weeks | Head's biparietal diam. | Abdominal breadth | Abdominal depth | Fermur length | Predictions of weight | | |
|---|---|---|---|---|---|---|---|
| | | | | | Karolinska | Mongelli-Gardos' | Hadlock' |
| 32 | 8.19 | 8.84 | 8.34 | 6.32 | 2699.17 | 1992.07 | 1952.87 |
| 33 | 8.42 | 9.18 | 8.65 | 6.56 | 2798.11 | 2222.81 | 2162.36 |
| 34 | 8.63 | 9.51 | 8.95 | 6.78 | 2891.99 | 2457.57 | 2377.43 |
| 35 | 8.82 | 9.82 | 9.23 | 6.97 | 2980.06 | 2692.24 | 2595.45 |
| 36 | 8.98 | 10.11 | 9.50 | 7.15 | 3061.62 | 2922.31 | 2813.48 |
| 37 | 9.11 | 10.38 | 9.75 | 7.30 | 3135.99 | 3142.99 | 3028.30 |
| 38 | 9.22 | 10.63 | 9.99 | 7.42 | 3202.54 | 3349.38 | 3236.53 |
| 39 | 9.29 | 10.85 | 10.21 | 7.51 | 3260.71 | 3536.63 | 3434.67 |
| 40 | 9.34 | 11.05 | 10.41 | 7.58 | 3309.99 | 3700.15 | 3619.23 |
| 41 | 9.36 | 11.22 | 10.58 | 7.61 | 3349.95 | 3835.78 | 3786.80 |
| 42 | 9.35 | 11.36 | 10.74 | 7.62 | 3380.23 | 3939.97 | 3934.18 |

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# ANTHROPOMETRIC EVALUATION OF BODY FAT DISTRIBUTION

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## INTRODUCTION

Adiposity and distribution of subcutaneous fat is often studied by human biologists. Indeed, adiposity can have different influences, such as on physical activity [63, 65], on feminine fertility [32], on biological adaptation to climate [90, 40], and, of course, it is also related to the nutritional status and to the health situation.

Many anthropological researches have shown ontogenic, sexual, interpopulational and intrapopulational differences in the quantity and distribution of the body fat. It is also well known that changes in human ecosystems, produced by the processes of industrialisation and urbanisation, can cause important changes in the biology of populations [9], such as the positive secular changes of stature in European populations but also the increase of the frequency of obesity, of hypertension and of coronary diseases [109]. In industrialised societies, excess of weight constitutes an important factor in terms of preventive medicine, increasing the risk of the various diseases, such as, for instance, cardiovascular diseases and type II of diabetes mellitus [35, 46].

In the 1950s, it was suggested that not only the quantity of fat but also its distribution are conditioning the susceptibility to diseases as well as the mortality rate [102]. For instance, the way fat is distributed allows to identify groups of risk for cardiovascular diseases [54], for coronary arteriosclerosis [98] and for diabetes mellitus non-dependent on insulin [33]. These diseases are associated with centralised distribution of fat [11]: epidemiological studies have demonstrated indeed that centripetal distribution of fat (trunk and higher level of the body) is associated with a higher incidence of coronary diseases, of diabetes, and a higher concentration of triglycerides in the serum [31]. Trunk

and abdominal distribution is more frequent (but not exclusive) in men than in women, where the fat is more frequently present at buttock, thigh and hip level [57].

## FAT DISTRIBUTION AND GROWTH. GENETIC AND ENVIRONMENTAL FACTORS

During the growth period, changes occur both in the quantity of body fat and its anatomical distribution. Adolescence is, without doubt, a period of large morphological and physiological changes, when a real endocrine "revolution" occurs. Although an excess of weight during the infancy period is not totally related to obesity in adulthood, the relative risk of an obese child to become an obese adult is about 2, for an obese adolescent, the relative risk to become an obese adult is higher, 5 or 6 [56]. These obese children and adolescents constitute a group at risk, whose identification during growth is an important tool of primary prevention. Auxological studies of fat distribution are important at the peripubertal period, when changes in terms of subcutaneous fat in skinfolds are pronounced [22, 23].

Quantity and distribution of fat are also related to the maturational level: children with higher quantity of fat tend to maturate earlier than thinner children of the same chronological age; earlier maturation is also related to higher centripetal distribution of subcutaneous fat [30]. Sexual differences in fat distribution during growth are characterised by redistribution during infancy and adolescence of the fat tissue from the extremities to the trunk in boys but not in girls [5]. Moreover, the changes in distribution of subcutaneous fat seem to be independent of changes of adiposity itself and are therefore probably basically physiological.

During childhood, and surely during adolescence, genetic factors influence the distribution of fat [63] as well as environmental factors, particularly socio-economic status and adequacy of nutrition [9]. With a decrease of socio-economical level, subcutaneous fat becomes more centripetal, decreasing at arm level and increasing at trunk level. Sexual differences are also influenced by socio-economic factors. However, different studies of genetic and environmental influences on the distribution of fat have not been able to separate both kinds of influences with precision [26, 9, 64], even if it is clear that both factors influence the distribution of fat indeed.

On the other hand, in studies about genetic and environmental influences, which take into account the maturational status, the same environmental factors accelerating maturation (the age of menarche, for instance) are also influencing the distribution of fat at trunk level (centripetal) [30]. Depending on their sex and age, children can react differently to the same environmental conditions, such as familial factors. Siniarska [90] mentioned that the somatic growth of girls would be more influenced by economic factors, whereas the growth of boys would be influenced also by genetic factors. As for the fat tissue, sensitivity to the factors associated with the parents' education is particularly high during the prepubertal and pubertal periods.

## SOMATOTYPE AND DISTRIBUTION OF FAT

The body shape can be evaluated through the calculation of the somatotype. Its study during growth, using adequate anthropometric techniques [41, 19], allows us to quantify the plasticity of the human body, to give a global image of the body proportions, and to consider a relation with body composition [3]. Calculation of somatotype is included in growth study [18] as well as in epidemiological studies [1, 2, 65], but also in the analysis of associations with the distribution of fat [4]. In a recent study of children of the Vizcaya province (Basque Country), Rosique *et al.* [84] showed that a centralised type of fat distribution is associated with obesity: 16.3% of boys and 21.8% of girls showing a centralised distribution of fat are also classified as obese. Moreover, individuals determined as obese through the relative BMI [74] have high values of endomorphy and mesomorphy, and low values of ectomorphy.

## ENERGY INTAKE AND HUMAN ADIPOSITY

Overweight is usually more prevalent in populations with higher energy intake [81]. Nutritionists agree that dietary fat intake should contribute to approximately 30% to the daily energy intake. The dietary fat intake is known to be too high in many situations; it amounts to about 32–37% of the total daily energy intake for adults of all ethnic groups in the United States [69] and even about 40% in children of 6

to 12 years of the Belgian Luxembourg [35]. The total energy intake is not related to obesity [81, 6, 35], but this is well the case for lipid intake, particularly the saturated fats. Population studies show a positive association between fat intake and adiposity [48, 98]. The dietary proportion of saturated to unsaturated fat affects probably adiposity: Jones and Schockler [47], Jones *et al.* [46], Doucet *et al.* [27] have showed, for instance, that the diet inducing thermogenesis was greater for the high polyunsaturated to saturated fat ratio diets than for diets with lower ratio.

## ANTHROPOMETRIC TECHNIQUES. INTEREST IN ESTIMATION OF OBESITY AND DISTRIBUTION OF FAT

Anthropometry, a way to measure human morphology [100], is of use in different areas of basic or of applied research, such as the anthropometric techniques used in health sciences (nutritional status, growth and development, epidemiology, etc.). Indeed, anthropometric determination of the nutritional status — of course with clinical observations — is actually the most accessible way of nutritional observations in children, adults and older people. Anthropometry is used by physiologists, nutritionists and clinicians, and the techniques well known from anthropologists and human biologists are also more and more often applied in sport medicine, ergonomy, orthopedics and pediatrics. Compared to other techniques, the anthropometrical methodology is not expensive, not invasive, recognised by the scientific community, can be easily used in field studies and has no ethical implications even in children [28, 34, 99]. Still it has some inconveniences we have to take into account, such as its low sensibility to variations of body composition and to high measurement errors especially in obese individuals [111].

Obesity is, most often, defined as an excess of fat tissue resulting in an increase of body weight. Overweight, on the contrary, consists in an increase of weight due to a higher amount of muscles and/or of bones but not of fat. To define obesity, not only weight but body composition must be analysed. Obesity is one of the most frequent and serious health problems in the western society, leading to locomotory difficulties, endocrine diseases such as diabetes, digestive or circulatory problems [104, 103]. The association between body fat and cardiovascular risk factors is not the same in adults and children [86]. In

children, general fatness would be a more important factor than body fat distribution. Postpubertal children show, however, a risk factor related to body fat distribution, the more centripetal distribution is developing about the puberty age, too [4, 84].

Nutritional anthropometry can even be used in the epidemiology of cancer [59]. Hems [42] demonstrated secular trends of dietary factors and cancer mortality from 1911 to 1971. The trend for breast cancer mortality was particularly related to dietary fat, animal protein and sugar intake over time.

Obesity has a multifactorial ethology [105]. Only one percent is secondary and of endocrine origin but most cases are of alimentary origin. Genetic factors or familial tendencies have been observed; psychological factors and influences of physical exercise can be present too.

Obesity is a complex morphological alteration accompanied by somatic diseases but also by psychological effects causing changes in the perception of the body image and in emotional stability. If theoretically obesity can be defined as an increase of body fat, the concept remains very imprecise and has some arbitrary limits: obesity is not overweight, even if the difference is not always precise. Indeed, the problem is to decide which weight or overweight (due to a higher amount of fat) will be considered as excessive. The relationship between weight and excess of fat is directly influenced by other parameters such as age, stature, sex and body structure. Weight measurement is the most generalised way to determine obesity, which could than be defined as a weight above some chosen percentile (90, 95, 97, ...). For instance, the obesity can be quantified in function of the ideal weight calculated in function of sex, age and stature ((RW/IW)×100 with RW the real weight and IW the ideal weight). Obesity is considered as discrete (with a weight 15% higher than the ideal weight), moderate (between 15–25%), serious (25–50%) and morbid (more than 50%).

In the NHANES III [50], obesity is defined as a body mass index greater than or equal to 27.8 $kg/m^2$ for men and 27.3 $kg/m^2$ for women, which represents approximately 124% of the ideal body weight for men and 120% of ideal weight for women. The use of height and weight tables enforces the misconception that body weight is more important than body fatness. Obesity is better defined as an excessive amount of total body fat for a given body weight. Other anthropometric parameters must be added to have a better definition, such as measurement of skinfolds, which can adequately characterise

the distribution of subcutaneous fat, and can be considered as a general factor of fat related to body weight and the percentage of total body fat [25].

Anthropometric parameters, including weight, height and skinfolds (biceps, triceps, subscapular, suprailiac, for instance), are related to factors of cardiovascular risks and are used in public health such as the waist/hip and waist/thigh relationship in adults [101]. The relationship weight (kg)/height$^2$ (m), known as body mass index (BMI), is largely used to measure malnutrition or overweight and obesity, due to the high correlation between body fat and weight but the low correlation between body fat and stature [70]. It has also been shown that BMI, in children as well as in adults, is correlated with body composition and is as such very useful, not only to analyse nutritional conditions, but also in different applications such as the prognosis of anorexia nervosa and the diagnosis of cardiovascular risks [57]. The regional office of the WHO for Europe [109] proposed ponderal classifications in function of BMI, in terms of slim and normal weight, overweight and obesity. Even, if it is obvious that anthropometry cannot substitute for classical risk factors of chronic diseases (tabagism, high blood pressure, etc.), the necessity to include morphological data in epidemiological studies is also evident.

## METHODOLOGY

Clinical techniques of diagnosis exist, such as captation of inert gasses by fat tissue, measurement of body potassium, percentage of body fat derived from underwater weighing, dual photon absorptimetry, X-ray computed tomography, magnetic resonance imaging, B-mode ultrasonography, but they are not useful in terms of public health. At the epidemiological level, distribution of fat must be described in a relatively simple and valid way for all populations. This can be based on anthropometry and on principal components analysis (PCA).

### a) Estimation of subcutaneous fat and relative weight

Before studying the distribution of fat, the quantity of fat must be estimated. One of the techniques used most often is the measurement of skinfolds, as they are relatively easy to measure by calibrated instruments of constant pressure, such as the Lange or the GPM skinfold

calliper. Skinfolds are most often measured at triceps, subscapular, suprailiac and calf levels, more recently also at the abdominal level [80]. Mueller and Wohlleb [68] have suggested that the information gathered from the four skinfolds already mentioned is rather equivalent to the multivariate analysis (PCA) of a larger number of skinfolds.

Of course, skinfolds are soft-tissue measurements; their standardisation is more difficult than in the case of anthropometric measurements of bony sites. Skinfolds must always involve location in relation to unambiguous landmarks. The compressibility of both skin and adipose tissue varies with the state of hydration, age, size and other individual factors [38]. Recommendations for measuring has been described in detail by IBP [107] and by Lohman *et al.* [55]. As skinfolds have a larger technical error than other anthropometric measurements, it is recommended that in a study skinfolds were taken by the same person and that the intra-observer error were calculated [16], as $(d^2 12)/2N$ with d12 being the difference between duplicated measurements and N the number of measured individuals.

Relative weight subgroups of the studied population can be defined through the analysis BMI (Body Mass Index); this is an operative way to do it, even if not strictly clinical, and to recognise the complex multifactorial aetiology. The use of BMI allows us, for instance, to divide the sample into three subgroups (normal weight, overweight, obesity) and to obtain in these subsamples the way of fat distribution (centripetal or peripheral); this kind of analysis can confirm the incidence of obesity in individuals with extreme fat distribution.

In the particular case of children, the detection of individuals, where obesity and central distribution of fat are associated, is a way to prevent possible pathologies in adulthood. These children, and particularly these adolescents, are considered as a population at risk, because maintaining this morphology in adulthood brings the susceptibility to chronic diseases linked to the centripetal position of fat. We have, however, to mention that the use of BMI to identify overweight and obesity in children has been criticised due to the different significance of BMI in children and adults. Indeed, the velocity of growth of height and weight is proportionally different, the result being a variable relationship between weight and height during the different growth periods. Therefore, Poskitt [74] proposed to use the relative body mass index (relative BMI=(actual BMI/BMI at the 50th percentile age and sex-specific)×100) to identify deviations from normality in children's samples. However, the used limit will remain arbitrary.

For instance, Marshall *et al.* [58], using the relative BMI in adolescents, put 120% as the cut-off point to classify obese children.

b) Distribution of fat through PCA (Principal Component Analysis)

Although a variety of methods can be used to obtain the patterns of body fat distribution, such as photoscopic [15] or indices [87], for instance the CFR index [44] (Centripetal Fat Ratio=subscapular skinfold/ subscapular+triceps skinfolds), the PCA can better analyse the differences related to specific skinfolds [67, 76]. PCA allows us to summarise the whole data corresponding to "n" observations of "p" variables. As for the methods of extraction and the way of interpretation, we would like to refer to Cuadras [24] and Lebart *et al.* [54]. Authors are using absolute measurements (mm) of different skinfolds as well as indices of fat, preferably indices maximising the trunk-extremities opposition. Using indices in the PCA allowed Hattori *et al.* [40] to identify individuals with a centripetal distribution of fat. Indices nominated following the skinfold of the numerator were also used by Baumgartner *et al.* [5] and Rosique *et al.* [84]:

* triceps=(triceps sk./(subscapular+suprailiac))
* calf=(calf sk./ (subscapular+suprailiac))
* subscapular=(subscapular sk./(triceps+calf))
* suprailiac=(suprailiac sk./(triceps+calf))

To correct for body fat, ratios can be obtained by dividing each skinfold by the total sum of skinfolds [40]. The ratios can also be log transformed as follows (x skinfold=lg (skinfold x/total sum of skinfolds)) and, when used in PCA, can maximise the contrast between the trunk and the extremities [80].

Applying PCA, new variables are obtained by summarising the fat indices (or the skinfolds when used in absolute values); these new variables are called factors or, rather, components. Generally, the first component is related to the global value of fat distribution of each individual and it situates each person in terms of centripetal or peripheral way of distribution. The second component is less informative, and its biological signification depends on how the variables (indices or skinfolds) were introduced in the PCA; the addition of a skinfold (biceps or calf for instance) can change the signification of this second component. However, in most of the cases, this second component gives an idea of the distribution of fat in the superior or inferior parts of the body. This bidimensional representation has been used by Rosique *et al.* [84], Rebato and Rosique [79], and Rebato *et al.* [80].

In a sample of children from the Basque Country, Rosique *et al.* [84] performed a PCA on four skinfold indices (triceps, calf, subscapular, suprailiac), and two components were extracted (accounting respectively for 81.4% and for 10%). The first principal component reflects the trunk-limb pattern of fat distribution (viewed as centripetal) and the second — the contrast between upper and lower trunk (upper-lower trunk pattern) (Figure 1). For both sexes, the curve of the transformed score of the first principal component (1-F) follows the pattern of mean endomorphy (Figure 2). Endomorphy is highly and significantly correlated with the sum of the four skinfolds, mesomorphy is less correlated [20].

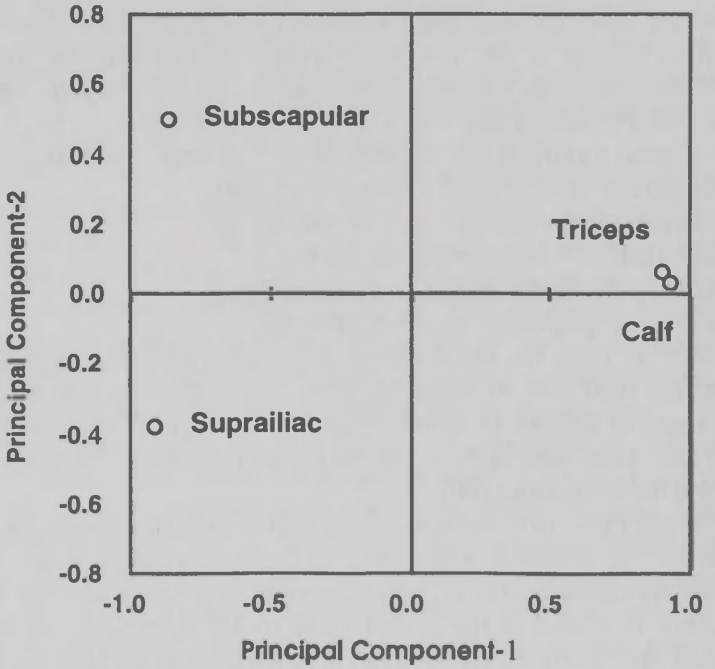


**Figure 1.** Relationship between first and second principal component of a PCA performed on four skinfolds (triceps, calf, subscapular and suprailiac) (following Rosique *et al.*, 1994)

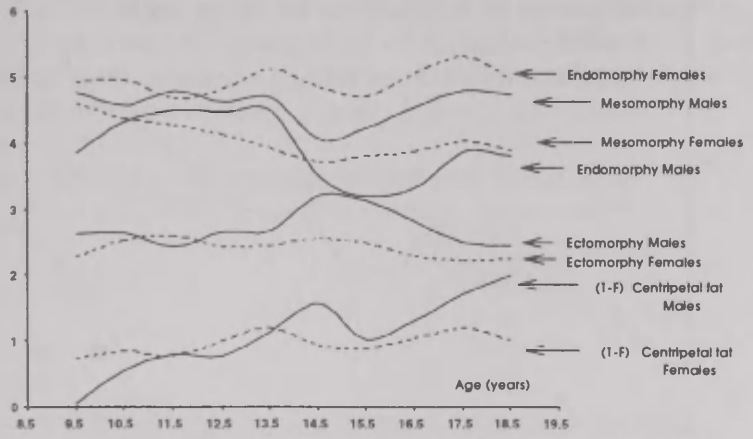


**Figure 2.** Evolution with age of the somatotype components as well as of the transformed score of the first principal component (following Rosique *et al.*, 1994)

In another sample from the Basque Country, Rebato *et al.* [80], also found, using PCA on five skinfolds (triceps, medial calf, subscapular, suprailiac and abdominal), that the first principal component was stable across age and sex-related as an indicator of a centripetal/peripheral body fat distribution. The variation in this fat pattern by age is characteristic: factor scores start being negative (from 4 to 12 in girls and from 4 to 14 in boys) and become positive increasing steadily in value with age (Figure 3: older children have a more central pattern of body fat). The same observation was also made on South African Black children [17].

At the end of the growth period, centralisation of fat is higher in boys than in girls because boys require relatively more subcutaneous trunk fat than extremity fat as was also demonstrated by a mixed-longitudinal French study [82]. This trend corresponds to the hormon-induced masculinising process [62] of redistribution of subcutaneous fat from the extremities to the trunk during adolescence [56, 82, 85].

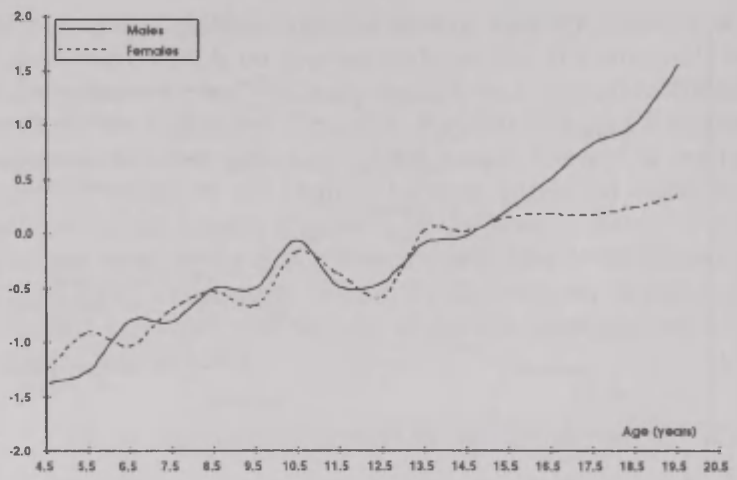


**Figure 3.** Variation in function of age of the first principal component of a PCA on five skinfolds (triceps, calf, subscapular, suprailiac and abdominal) (following Rebato *et al.*, 1998)

## METHODOLOGY IN GENETIC RESEARCH

Methodological problems in the study of quantitative genetics are related to the fact that genetic and environmental factors interact almost invariably and are rarely independent.

Familial studies and twin studies allow us to approach the quantitative nature of the genetic effects and to estimate heritability [91, 92, 93, 94, 95]. Classical approaches to multifactorial or polygenic traits are based on the degree of familial resemblance which provides the means of estimating the amount of additive variances. In the Hardy-Weinberg equilibrium, neglecting all non-genetic causes and epistatic factors, the covariance between relatives is composed of the additive and dominant components and thus can be used to estimate these causal components (Table 1). Theoretically, the most reliable data are the regression of offspring on mid parent (if the variance of the two sexes is equal) and the regression of offspring on one parent (only on the father, if an important maternal effect is suspected). The full-sib correlation (and even the half-sib correlation, if they are reared together for a long period) is the least reliable, since the contribution of the common environment is large. Twin studies have often been used

also, but for many traits, the environment of monozygotic twins is more similar than the environment of dizygotes. Using these coefficients, or even correlation coefficients between relatives, helps in any way to determine a decreasing order of genetic influences.

**Table 1.** Coefficients of heritability ($h^2$) and some estimates

| | |
|---|---|
| Twin | $h^2$ = rmz |
| | $h^2$ = (rmz-rdz)/(1-rdz) |
| Parent-child | $h^2$ = bmp-c |
| | $h^2$ =2bp-c |
| Sibling | $h^2$ =2rsibs |
| rth degree | $h^2$ = 2rbr |

r = correlation coefficients, b = regression coefficients, mz=monozygotic, dz = dizygotic, mp = mid parent, p = parent, c = child

To allow to take into account cultural inheritance, Wright [112] and Rao *et al.* [78] developed path analysis, a linear model explaining the interrelationship between the genetic and environmental variables by a causal scheme. Its advantage is that it can evaluate genetic determination and socio-cultural inheritance and test the hypothesis about these factors of inheritance.

During growth, the relative influence of genotype and environment is changing, and thus the coefficients of heritability will not be constant during different growth periods. Parent-offspring correlation coefficients, for instance, where the correlations are calculated for the height between the value of the adult parents and the value of the growing children, increase from birth to maturity, reflecting an increase of the children's own genes [94]. Longitudinal studies on twins [102, 110] have also shown a gradual increase of the genetic factors. For correlation between sibs, a decrease is observed when age differences increase [77, 60, 61].

More recently efforts have been made to identify genes relevant to a multifactorial phenotype and to localise them on the genomic map. This is known as the quantitative trait loci approach [52, 71].

Genetics of obesity has been reviewed by Mueller [63] and Bouchard and Pérusse [11, 12]. Although the familial nature of obesity is well established [36, 37], the amount of genetic factors in this familial resemblance is unclear. High influence of genetic factors in twins has been suggested by Silby *et al.* [88]. Many other studies, however, have identified an important factor of cultural inheritance. Bouchard *et al.* [11], in the path analysis of a Quebec sample, showed that the total

transmission effect reached 35% for BMI and amount of subcutaneous fat and 55% for the percentage of body fat and total fat mass, but respectively only 5% and 25% of it was caused by genetic effects (heritability), most of the transmission being cultural. In a large Norwegian sample, Tambs *et al.* [96] estimated the heritability level for BMI to be 40%, although cultural transmission is also significant.

For a given level of fatness, some individuals will store more fat on the trunk or abdominal level, while others store it primarily on the lower extremities [11]. Genetic influences, however, can be different in children and adults; influences of genes can change during the growth period. Province and Rao [75] and Fabsitz *et al.* [29] observed changes with time or the transmissibility of BMI; it may put some individuals at increased risk of developing obesity with age.

Familial resemblance in nutrient intake has also often been reported [33, 7], in twin studies as well [106, 21]. However, a familial aggregation can be determined by genetic and non-genetic effects of cultural inheritance including home environmental effects: the method of path analysis has proven to be useful for quantifying these genetic and cultural inheritances [113]. In a Canadian population of French descent, Pérusse *et al.* [73] did not find a significant genetic influence on intake of nutrients, and cultural inheritance was more important, non-transmitted environmental factors accounted for more than 50% of the variation observed in energy intake.

Other factors are probably also under partial genetic control, such as the energy expenditure phenotype, a complex factor implying basal and resting metabolic rates, energy expenditure of activities and physical activity level, for instance. Genetic control has been supported by the studies of Hewitt *et al.* [43] on the metabolic rate to environmental stimulus, Bouchard *et al.* [14] on the thermic effect of food, Pérusse *et al.* [72] on leisure-time energy expenditure.

Like many polygenic traits, fat distribution is influenced by a mixture of genetic and environmental factors. The latter are, for instance, identified in the socio-economic status (SES) differences of body fat distribution [9, 83] as well as in the related metabolic and endocrine risks [51]. These SES differences are more related to fatness and skinfold thickness than to fat patterns [67].

## CONCLUSION

Many anthropological researches have shown ontogenic, sexual, interpopulational and intrapopulational differences in the quantity and in the distribution of body fat. In industrialised societies, excess of weight constitutes an important factor in terms of preventive medicine, the risk of the various diseases being increased such as for instance cardio-vascular diseases.

Quantity and distribution of fat is also related to the maturational level: children with higher quantity of fat tend to maturate earlier than thinner children of the same chronological age; earlier maturation is also related to a higher centripetal distribution of subcutaneous fat. Sexual differences of fat distribution during growth are characterised by a redistribution during infancy and adolescence of the fat tissue from extremities to the trunk in boys but not in girls.

In a sample from the Basque Country, Rebato *et al.* [80] found, using PCA on five skinfolds (triceps, medial calf, subscapular, suprailiac and abdominal), that the first principal component was stable across age and sex-related as an indicator of a centripetal/peripheral body fat distribution. The variation in this fat pattern by age is characteristic: factor scores start being negative (from 4 to 12 in girls and from 4 to 14 in boys) and become positive increasing steadily in value with age.

Like many polygenic traits, fat distribution is influenced by a mixture of genetic and environmental factors. The latter are, for instance, identified in the socio-economic status (SES) differences of body fat distribution.

## ACKNOWLEDGEMENTS

This study was partly supported by the UPV 154.310-EA 006/97 research project from the Universidad del Pais Vasco-Euskal Herriko Unibertsitatea (University of the Basque Country) and by the Basque Government (Department of Education, Universities and Research) through a pre-Doctoral grant.

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# CORRELATION OF AGE AND BODY BUILD OF 12-17-YEAR-OLD GIRL VOLLEYBALLERS WITH THEIR PHYSICAL FITNESS AND RESULTS OF VOLLEYBALL TECHNICAL TESTS AND PSYCHO-PHYSIOLOGICAL COMPUTER TESTS

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ABSTRACT

The significance of body build, physical fitness and results of psycho-physiological tests for assessing volleyball skills was studied.

The sample studied consisted of 49 girls aged 12–17 (average age 14.45 years) who practised regularly in volleyball training groups. All of them were investigated anthropometrically (36 basic measurements, 12 skinfolds, 65 indices and characteristics of body composition). Their physical fitness was assessed by 10 tests and mastery of volleyball skills by 9 tests. The girls' ability of anticipation and their reaction speed was measured by 4 psycho-physiological computer tests. It was proved that efficiency in volleyball technical tests is determined by body build, physical fitness and psycho-physiological peculiarities within the range of 17–58%.

As a result, it was proved that body build as well as all the tests were significant. A system based on build types in a 5 SD classification was elaborated for comparative assessment of all the data.

**Key words:** girl volleyballers' body build, volleyball technical tests, psycho-physiological tests

## INTRODUCTION

Volleyball like all the other team sports requires a number of very different skills from the players [1, 2, 4, 5, 15, 17, 21]. The players also differ from each other in their individual body build, physical abilities, scope and speed of acquiring the technical skills of the game.

Therefore, coaches and sports managers need a system of evaluation that would enable them to assess in an integrated and objective way the correlation between the technical skills of the game acquired by practice and various individual abilities. This way they could change and improve their training methods if necessary. The Development Council of the Estonian Volleyball Federation is planning in the near future to improve young people's coaching in volleyball. Therefore, a respective system of evaluation should be created.

The aim of the present study was to find, in Estonian circumstances, which tests and anthropometric characteristics would be most closely correlated with the technical skills of volleyball and, therefore, should be included into the system of evaluation that is being created.

## MATERIAL AND METHODS

The sample under investigation consisted of Estonian girl volleyballers (n=49) from six regularly practising training groups. All of them were practically healthy and their sexual development was in concordance with their age.

Two of the girls were 12 years old, and one was 17. Thus, the age of most of them ranged from 13 to 16 years, the average being 14.43 years. All of them underwent detailed anthropometric measurements according to Martin [16] (36 principal measurements and 12 skinfolds). From these data we calculated 65 indices and characteristics of body composition. The aim of processing the anthropometric data was to develop a methodology for universal application of anthropometric data in order to create an integrated system of evaluation. At that we relied on the long-term experience of the Centre for Physical Anthropology at the University of Tartu whose studies on body structure, and classification and typification of data have won international recognition [8–11].

All the subjects went through a number of tests which were meant to measure their playing skills and general physical fitness. They took

ten generally recognised tests of physical ability — tests of standing vertical jump and reach and running vertical jump and reach (on the basis of these standing vertical jump height and running vertical jump height were calculated), an endurance test (Eurofit), a test of flexibility, a strength test of arm and back muscles, and a strength test of stomach muscles.

Their mastery of volleyball skills was evaluated by nine tests compiled by the authors of the paper. The tests included all the main elements of the game. There were two overhead pass tests, a forearm pass test, two serve tests, a reception test, two spike tests and a feint test.

The girls' psychophysiological abilities were evaluated by three computerised tests. These were tests on perception of speed, colour and light. The tests on perception of colour and light were evaluated as simple reactions. The test on speed perception, during which the subjects were first required to assess objects moving at different speeds and to adopt a decision, and only then to react, was evaluated as a complex reaction. In order to compare individually the speed of processing different information, we calculated the difference in seconds between the results of the test of speed perception as a complex reaction and perception of colour as a simple reaction and called the respective test anticipatory reflection of reality.

The computer program necessary for administering these tests was compiled by one of the authors of the article, K. Thomson. It was based on his earlier extensive studies for evaluation of the perception of speed or anticipation at the laboratory of cognitive neuroscience and experimental psychology at Tallinn University of Pedagogical Science [23, 24].

The data were processed statistically, using the methods of multivariate statistical analysis, by one of the authors of the paper, Säde Koskel M.Sc. from the Institute of Mathematical Statistics at the University of Tartu.

## RESULTS

We began our analysis with the girls' anthropometric data (see Tables 1 and 2). The following variables proved to be in correlation with age: height, weight, head-neck length, sternum length, upper limb length, spread of arms, biacromial and pelvis breadth, circumferences of arm, forearm, middle thigh and pelvis. Five different indices also showed

correlation with age. On the other hand, the main characteristics of body composition, such as body density, the mean skinfold, mass of subcutaneous adipose tissue, total mass of body fat and body mass index were not in statistically significant correlation with age.

**Table 1.** Basic statistics of anthropometic measurements of girl volleyballers aged 12–17 (n=49)

| No | Variable | $\bar{x}$ | SD | min | max | Statistically significant correlations with age (r) |
|---|---|---|---|---|---|---|
| 1. | Age | 14.43 | 1.21 | 12.00 | 17.00 | 1.0 |
| 2. | Weight (kg) | 55.766 | 9.016 | 37.950 | 80.250 | 0.308 |
| 3. | Height (cm) | 166.16 | 5.94 | 153.50 | 181.40 | 0.418 |
| 4. | Head-neck length (cm) | 30.86 | 1.12 | 27.10 | 33.20 | 0.427 |
| 5. | Sternum length | 14.77 | 1.84 | 10.50 | 17.80 | 0.397 |
| 6. | Abdomen length | 35.31 | 5.23 | 25.90 | 53.60 | – |
| 7. | Trunk length | 50.08 | 5.40 | 43.60 | 69.00 | – |
| 8. | Upper body length | 66.77 | 5.32 | 58.90 | 93.20 | – |
| 9. | Lower body length | 99.39 | 7.05 | 63.20 | 111.80 | – |
| 10. | Upper limb length | 72.57 | 14.00 | 62.30 | 81.60 | 0.354 |
| 11. | Lower limb length | 87.79 | 5.53 | 73.10 | 100.20 | – |
| 12. | Horizontal spread of arms | 167.29 | 8.20 | 148.00 | 187.80 | 0.440 |
| 13. | Biacromial breadth | 35.19 | 1.69 | 31.00 | 39.00 | 0.398 |
| 14. | Chest breadth | 23.79 | 1.52 | 20.00 | 26.50 | – |
| 15. | Waist breadth | 21.86 | 1.70 | 18.50 | 26.00 | – |
| 16. | Pelvis breadth | 25.61 | 1.52 | 21.00 | 30.50 | 0.355 |
| 17. | Chest depth | 16.29 | 1.26 | 14.00 | 20.50 | – |
| 18. | Abdomen depth | 15.48 | 1.30 | 11.00 | 19.00 | – |
| 19. | Femur breadth | 8.69 | 0.55 | 7.50 | 9.90 | – |
| 20. | Ankle breadth | 6.48 | 0.48 | 5.80 | 7.60 | – |
| 21. | Humerus breadth | 6.18 | 0.39 | 5.50 | 6.90 | – |
| 22. | Wrist breadth | 5.06 | 0.29 | 4.30 | 5.60 | – |
| 23. | Head circumference | 54.94 | 1.47 | 51.70 | 57.70 | – |
| 24. | Neck circumference | 31.42 | 1.72 | 28.20 | 36.00 | – |
| 25. | Upper chest circumference | 81.07 | 4.93 | 72.00 | 95.30 | – |
| 26. | Lower chest circumference | 73.82 | 5.28 | 62.60 | 87.80 | – |
| 27. | Waist circumference | 67.53 | 5.50 | 57.70 | 87.10 | – |

| No | Variable | $\bar{x}$ | SD | min | max | Statistically significant correlations with age (r) |
|---|---|---|---|---|---|---|
| 28. | Pelvis circumference | 79.34 | 6.20 | 65.70 | 92.20 | 0.361 |
| 29. | Hip circumference | 84.99 | 9.10 | 50.40 | 100.30 | |
| 30. | Upper thigh circumference | 54.86 | 5.83 | 39.80 | 68.40 | |
| 31. | Middle thigh circumference | 46.17 | 4.81 | 36.30 | 59.00 | 0.297 |
| 32. | Upper leg circumference | 34.04 | 2.72 | 29.20 | 38.80 | – |
| 33. | Lower leg circumference | 22.02 | 1.59 | 18.40 | 24.70 | – |
| 34. | Arm circumference | 24.77 | 2.39 | 18.70 | 29.50 | 0.285 |
| 35. | Strained arm circumference | 26.70 | 2.58 | 20.60 | 32.40 | – |
| 36. | Forearm circumference | 22.34 | 1.63 | 18.70 | 26.10 | 0.341 |
| 37. | Wrist circumference | 15.68 | 0.95 | 13.50 | 18.30 | – |
| 38. | Chin skinfold (cm) | 0.63 | 0.22 | 0.30 | 1.30 | – |
| 39. | Chest skinfold | 0.68 | 0.27 | 0.30 | 1.40 | – |
| 40. | Side skinfold | 0.81 | 0.39 | 0.40 | 2.00 | – |
| 41. | Waist skinfold | 1.25 | 0.50 | 0.40 | 2.80 | – |
| 42. | Suprailiacal skinfold | 0.82 | 0.38 | 0.30 | 2.00 | – |
| 43. | Umbilical skinfold | 1.02 | 0.40 | 0.30 | 2.20 | – |
| 44. | Subscapular skinfold | 1.02 | 0.41 | 0.50 | 2.50 | – |
| 45. | Biceps skinfold | 0.80 | 0.30 | 0.30 | 1.70 | – |
| 46. | Triceps skinfold | 1.26 | 0.39 | 0.50 | 2.30 | – |
| 47. | Thigh skinfold | 2.11 | 0.56 | 0.90 | 3.30 | – |
| 48. | Calf skinfold | 1.34 | 0.33 | 0.60 | 2.00 | – |
| 49. | Back of hand | 0.23 | 0.06 | 0.15 | 0.40 | – |

In order to systematise anthropometric data in their correlation with age, we first studied the anthropometric structure of the body. We correlated all the variables between themselves and found that we had to do with a system of statistically significantly correlated variables where the leading characteristics were height and weight [8, 9]. Predicting each single variable on the basis of height, weight and age, we found that each variable was determined by these arguments within the range of 19–90%, the rest being determined by the individual variability of each characteristic. Consequently, body build as a whole can be represented by weight and height as well as by each single variable or by combinations of single variables as parts of the body as a whole. Relying on what has been said above, we used for the

classification of anthropometric data a system of five SD classes evolved by the Centre for Physical Anthropology at the University of Tartu [11, 18]. This classification differentiates between the subjects according to the degrees of size and classical somatotypes. We formed three classes according to the relative correspondence between height and weight: (1) short and light girls, (2) girls of medium height and weight, (3) tall and heavy girls. Two classes were characterised by the greatest non-correspondence/discord between height and weight: (4) pycnics and (5) leptosomes. As a result, the length, breadth and depth measurements, circumferences and body proportions fell into a system. The average age differed only in classes 1 and 2.

**Table 2.** Basic statistics of anthropometric measurements of girl volleyballers (n=49)

| No. | Variable | $\bar{x}$ | SD | Mini-mum | Maxi-mum | Statisti-cally significant correla-tion with age (r) |
|---|---|---|---|---|---|---|
| 50 | Rohrer index | 1.211 | 0.148 | 0.989 | 1.701 | – |
| 51 | Body mass index | 20.122 | 2.552 | 15.898 | 28.017 | – |
| 52 | Body surface area ($m^2$) | 1.613 | 0.141 | 1.302 | 2.010 | 0.375 |
| 53 | Relat. trunk length(%) | 30.137 | 3.077 | 26.847 | 42.079 | – |
| 54 | Relat abdomen length | 21.255 | 3.099 | 15.948 | 32.717 | – |
| 55 | Relat. upper body length | 40.207 | 3.337 | 35.681 | 59.591 | – |
| 56 | Relat. lower body length | 59.793 | 3.337 | 40.409 | 64.319 | – |
| 57 | Relat. upper limb length | 43.666 | 1.557 | 39.977 | 47.113 | – |
| 58 | Relat lower limb length | 52.812 | 2.314 | 46. 411 | 56. 105 | – |
| 59 | Relat. arms spread | 100.673 | 3.142 | 95. 173 | 115.640 | – |
| 60 | Relat. biacromial breadth | 21.189 | 0.898 | 19.275 | 23.091 | – |
| 61 | Relat. chest breadth | 14.319 | 0.835 | 12.945 | 16.119 | – |
| 62 | Relat. waist breadth | 13.156 | 0.932 | 11.675 | 15.576 | – |
| 63 | Relat. pelvis breadth | 15.413 | 0.714 | 13.592 | 17.134 | – |
| 64 | Relat chest depth | 9.802 | 0.693 | 8.631 | 12.447 | – |
| 65 | Relat. abdomen depth | 9.318 | 0.746 | 6.866 | 11.536 | – |
| 66 | Relat. femur breadth | 5.229 | 0.305 | 4.654 | 6.048 | – |
| 67 | Relat. ankle breadth | 4.119 | 0.263 | 3.384 | 4.554 | – |
| 68 | Relat. humerus breadth | 3.722 | 0.207 | 3.366 | 4.211 | –0.372 |
| 69 | Relat. wrist breadth | 3.047 | 0.158 | 2.720 | 3.415 | – |
| 70 | Relat. head circumference | 33.092 | 1.200 | 30.552 | 35.786 | –0.401 |
| 71 | Relat. upper chest circumfer-ence | 48.810 | 2.744 | 43.493 | 57.863 | – |

| No. | Variable | $\bar{x}$ | SD | Minimum | Maximum | Statistically significant correlation with age (r) |
|---|---|---|---|---|---|---|
| 72 | Relat. lower chest circumference | 44.470 | 2.999 | 39.933 | 53.005 | – |
| 73 | Relat. waist circumference | 40.647 | 3.042 | 35.984 | 50.817 | – |
| 74 | Relat. pelvis circumference | 47.741 | 3.182 | 41.448 | 55.616 | – |
| 75 | Relat. hip circumference | 51.141 | 5.136 | 31.188 | 60.899 | – |
| 76 | Relat. upper thigh circumference | 32.992 | 3.101 | 24.629 | 39.587 | – |
| 77 | Relat. upper leg circumference | 20.480 | 1.396 | 18. 353 | 23.614 | – |
| 78 | Relat. arm circumference | 14.901 | 1.300 | 12.104 | 17.790 | – |
| 79 | Relat. forearm circumference | 13.440 | 0.842 | 12.068 | 15.455 | – |
| 80 | Relat. wrist circumference | 9.438 | 0.492 | 8. 677 | 11.111 | – |
| 81 | Arm circumference/upper limb length (%) | 34.157 | 3.092 | 29.265 | 40865 | – |
| 82 | Forearm circumference/upper limb length | 30.818 | 2.218 | 27.574 | 35.901 | – |
| 83 | Wrist circumference/upper limb length | 21.637 | 1.310 | 18.995 | 25.523 | – |
| 84 | Humerus breadth/upper limb length | 8.531 | 0.501 | 7.349 | 9.682 | –0.435 |
| 85 | Wrist breadth/upper limb length | 6.986 | 0.422 | 6.127 | 8.140 | – |
| 86 | Upper thigh circumference/lower limb length | 62.635 | 7.042 | 45.695 | 75.034 | – |
| 87 | Middle thigh circumference/lower limb length | 52.736 | 5.829 | 43.369 | 65.265 | – |
| 88 | Upper leg circumference/lower limb length | 38.872 | 3.371 | 33.257 | 47.897 | – |
| 89 | Lower leg circumference/lower limb length | 25.146 | 1.978 | 21.495 | 31.208 | – |
| 90 | Femur breadth/lower limb length | 9.925 | 0.809 | 8.597 | 12.212 | – |
| 91 | Ankle breadth/lower limb length | 7.815 | 0.616 | 6.263 | 9.634 | – |
| 92 | Chest breadth/ chest depth | 146.525 | 10.278 | 126.829 | 171.429 | – |
| 93 | Chest depth/chest breadth | 68.574 | 4.771 | 58.333 | 78.846 | – |
| 94 | Waist breadth/abdomen depth | 141.700 | 11.074 | 120.588 | 181.818 | – |
| 95 | Abdomen depth/waist breadth | 70.967 | 5.203 | 55.000 | 82.927 | – |
| 96 | Biacromial breadth/pelvis breadth | 137.645 | 6.564 | 125.455 | 154.348 | – |
| 97 | Waist circumference/pelvis circumference | 85.168 | 3.357 | 76.952 | 94.674 | –0.310 |

| No. | Variable | $\bar{x}$ | SD | Minimum | Maximum | Statistically significant correlation with age (r) |
|---|---|---|---|---|---|---|
| 98 | Biacromial breadth/upper chest circumference | 43.497 | 2.2246 | 36.726 | 47.771 | – |
| 99 | Trunk length/upper chest circumference | 61.853 | 6.328 | 53.410 | 84.788 | – |
| 100 | Body density ($g/cm^3$) | 1.057 | 0.008 | 1.040 | 1.082 | – |
| 101 | Relat. mass of fat by Siri (%) | 18.390 | 3.737 | 7.485 | 25.804 | – |
| 102 | Mean skinfold (cm) | 1.065 | 0.319 | 0.500 | 1.982 | – |
| 103 | Mass of subcutaneous adipose tissue (kg) | 0.787 | 0.291 | 0.327 | 1.633 | – |
| 104 | Relat. mass of subcutaneous adipose tissue (%) | 0.257 | 0.061 | 0.142 | 0.438 | – |
| 105 | Total cross-sectional area of thigh ($cm^2$) | 49.261 | 9.500 | 27.827 | 69.252 | – |
| 106 | Total cross-sectional area of thigh ($cm^2$) | 242.108 | 50.362 | 126.054 | 372.308 | – |
| 107 | Bone-muscle rate of the cross-sectional area of arm ($cm^2$) | 37.157 | 5.827 | 21.667 | 51.231 | – |
| 108 | Fat rate of the cross-sectional area of arm ($cm^2$) | 12.104 | 4.623 | 4.194 | 23.825 | – |
| 109 | Bone-muscle rate of the cross sectional area of thigh ($cm^2$) | 187.195 | 38.436 | 97.971 | 285.694 | – |
| 110 | Fat rate of the cross-sectional area of thigh ($cm^2$) | 54.913 | 17.633 | 20.019 | 94.902 | – |
| 111 | Bone muscle rate of the cross-sectional area of arm/total cross-sectional area of arm | 0.761 | 0.056 | 0.635 | 0.887 | – |
| 112 | Fat rate of the cross sectional area of arm/total cross-sectional area of arm (%) | 0.239 | 0.056 | 0.113 | 0.365 | – |
| 113 | Bone-muscle rate of the cross-sectional area of thigh/total cross-sectional area of thigh (%) | 0.775 | 0.049 | 0.638 | 0.881 | – |
| 114 | Fat rate of the cross-sectional area of thigh/total cross-sectional area of thigh (%) | 0.225 | 0.049 | 0.119 | 0.362 | – |

Next we present basic statistics of all the test results and their correlation with age (Table 3). The tests of general physical fitness correlated strongly with age, whereas the other tests did not show any correlation with age. Thereafter we correlated the results of each test

**Table 3.** Basic statistics of tests administered to girl volleyballers and their correlation with age

| No | Variable | N | $\bar{x}$ | SD | Min | Max | Statistically significant correlation with age |
|---|---|---|---|---|---|---|---|
| | **Test of physical abilities** | | | | | | |
| 1 | Highest reach of outstretched hand $PA_1$ | 47 | 217.298 | 8.262 | 201.000 | 236.000 | 0.33 |
| 2 | Standing vertical jump and reach PA2 | 47 | 253.064 | 10.079 | 237.000 | 275.000 | 0.336 |
| 3 | Running vertical jump and reach PA3 | 47 | 257.021 | 10.126 | 243.000 | 284.000 | 0.315 |
| 4 | Endurance test PA4 | 47 | 382.532 | 83.740 | 135.000 | 545.000 | – |
| 5 | Strength test of stomach muscles PA5 | 47 | 167.298 | 58.773 | 85.000 | 300.000 | 0.325 |
| 6 | Test of flexibility PA6 | 47 | 16.202 | 6.302 | 4.000 | 32.500 | – |
| 7 | Test of speed PA7 | 47 | 27.826 | 1.437 | 24.700 | 33.000 | 0.282 |
| 8 | Strength test of arm and back muscles PA8 | 47 | 297.128 | 44.131 | 210.00 | 400.000 | 0.313 |
| 9 | Vertical jump height standing $PA_9(PA_2–PA_1)$ cm | 47 | 35.766 | 4.691 | 27.00 | 50.00 | – |
| 10 | Vertical jump height running $PA_{10}(PA_3–PA_1)$ cm | 47 | 39.723 | 5.360 | 31.00 | 58.00 | – |
| | **Tests of technical elements of volleyball*** | | | | | | |
| 11 | Overhead pass with clap behind the back VT1 | 51 | 16.647 | 5.32 | 2.00 | 20.00 | |
| 12 | Overhead pass with squat VT2 | 51 | 7.176 | 4.719 | 2.00 | 20.00 | – |
| 13 | Forearm pass into $1m^2$VT3 | 51 | 22.255 | 11.269 | 1.000 | 30.000 | – |
| 14 | Spike along the sideline VT4 | 51 | 4.588 | 2.032 | 0.000 | 8.000 | – |
| 15 | Spike diagonally VT5 | 51 | 3.941 | 1.515 | 0.000 | 7.000 | – |
| 16 | Feint into the centre of the court VT6 | 51 | 4.176 | 1.819 | 0.000 | 8.000 | – |
| 17 | Serve straight VT7 | 51 | 5.392 | 1.845 | 0.000 | 8.000 | – |

| No | Variable | N | $\bar{x}$ | SD | Min | Max | Statistically significant correlation with age |
|---|---|---|---|---|---|---|---|
| 18 | Serve diagonally VT8 | 51 | 5.059 | 1.805 | 1.000 | 8.000 | – |
| 19 | Reception into zone 2 or 3 VT9 | 51 | 4.863 | 1.709 | 2.000 | 8.000 | – |
| | **Psychophysiological tests** | | | | | | |
| 20 | Average score of first-time speed perception tests in points A1 | 46 | 4.217 | 3.915 | –8.000 | 10.000 | – |
| 21 | Average reaction time in first-time speed perception tests. sec A2 | 46 | 0.712 | 0.254 | 0.210 | 1.880 | – |
| 22 | Average score of second-time speed perception tests in points A3 | 46 | 6.130 | 2.933 | 0.000 | 12.000 | – |
| 23 | Average reaction time in second-time speed perception tests. sec $A_4$ | 46 | 0.682 | 0.152 | 0.500 | 1.270 | – |
| 24 | Average score of third-time speed perception tests in points A5 | 46 | 2.913 | 2.723 | –2.000 | 12.000 | – |
| 25 | Average reaction time in third-time speed perception tests. sec A6 | 46 | 0.790 | 0.139 | 0.580 | 1.440 | – |
| 26 | Average reaction time in first-time sound perception tests (right hand). sec B1 | 46 | 0.235 | 0.061 | 0.169 | 0.447 | – |
| 27 | Average reaction time in first-time sound perception tests (left hand). sec B2 | 46 | 0.230 | 0.058 | 0.175 | 0.452 | – |
| 28 | Average reaction time in second-time sound perception tests (right hand). sec B3 | 46 | 0.211 | 0.052 | 0.119 | 0.387 | – |
| 29 | Average reaction time in second-time sound perception tests (left hand). sec B4 | 46 | 0.215 | 0.057 | 0.125 | 0.429 | – |
| 30 | Average reaction time in third-time sound perception tests (right hand). sec B5 | 46 | 0.216 | 0.041 | 0.160 | 0.368 | – |

| No | Variable | N | $\bar{x}$ | SD | Min | Max | Statistically significant correlation with age |
|---|---|---|---|---|---|---|---|
| 31 | Average reaction time in third-time sound perception tests (left hand). sec B6 | 46 | 0.211 | 0.044 | 0.110 | 0.374 | – |
| 32 | Average reaction time in first-time colour perception tests (right hand). sec C1 | 35 | 0.199 | 0.058 | 0.129 | 0.364 | – |
| 33 | Average reaction time in first-time colour perception tests (left hand). sec C2 | 35 | 0.200 | 0.059 | 0.121 | 0.369 | – |
| 34 | Average reaction time in second-time colour perception tests (right hand). sec C3 | 35 | 0.203 | 0.073 | 0.101 | 0.495 | – |
| 35 | Average reaction time in second-time colour perception tests (left hand). sec C4 | 35 | 0.201 | 0.075 | 0.069 | 0.501 | – |
| 36 | Average reaction time in third-time colour perception tests (right hand). sec C5 | 35 | 0.199 | 0.053 | 0.107 | 0.326 | – |
| 37 | Average reaction time in third-time colour perception tests (left hand). sec C6 | 35 | 0.197 | 0.053 | 0.091 | 0.319 | – |
| 38 | Anticipatory reflection of reality. first attempt. sec D1 | 45 | 0.509 | 0.251 | 0.002 | 1.541 | – |
| 39 | Anticipatory reflection of reality. second attempt. sec D2 | 45 | 0.477 | 0.172 | 0.103 | 1.059 | – |
| 40 | Anticipatory reflection of reality. third attempt. sec D3 | 45 | 0.586 | 0.149 | 0.281 | 1.237 | – |

* the tests measured the number of successful repetitions

with the other tests of the same group, with all the other of tests and, one at a time, with all the single anthropometric variables. We used the significant correlations we found in order to predict the results of technical tests of volleyball on the basis of other characteristics significantly connected with them (see Table 4). As we see, precise prediction is possible within the range of 17–58%.

**Table 4.** Prediction of tests of technical elements of volleyball by anthropometric characteristics, tests of physical ability and psychophysiological tests

| No | Criterion variable* | Regression equations | R-square |
|---|---|---|---|
| 1. | $B_1$<br>$C_2$<br>Calf skinfold (48)<br>Biacromial breadth/pelvis breadth (96) | Overhead pass with squat<br>$VT_2$=–11.99–15.30($B_1$)+ +20.67($C_2$)–4.46(48)+0.24(96) | 0,3711 |
| 2. | $A_3$<br>Relat pelvis circumf. (74)<br>Relat. upper chest circumf.(71)<br>Arm circumf. (34)<br>Arm circumf./upper limb length (81)<br>Femur breadth/lower limb length (90)<br>Biacromial breadth/pelvis breadth (96)<br>Biacromial breadth/upper chest circumf.(98)<br>Fat rate of the cross-sectional area of arm (108) | Forearm pass into 1m$^2$ square<br>$VT_3$=11.70+0.94($A_3$)–0.47(74)+ +0.42(71)+3.17(34)–2.11(81)– –0.52(90)+0.78(96)–1.06(98)– –0.87(108) | 0.4180 |
| 3. | $PA_1$<br>$PA_2$<br>$PA_3$<br>Trunk length (7)<br>Head circumference (23) | Spike along the side line $VT_4$= –31.73–0.09($PA_1$)+0.04($PA_2$)+ +0.12($PA_3$)–0.01(7)+0.26(23) | 0.3229 |
| 4. | Head circumference (23)<br>Wrist breadth/upper limb length (85) | Spike diagonally<br>$VT_5$=17.71+0.27(23)+0.97(85) | 0.1744 |
| 5. | $PA_2$<br>$PA_3$<br>$PA_8$<br>$A_1$<br>$D_3$<br>Humerus breadth (21)<br>Ankle breadth (20)<br>Abdomen depth (18) | Feint into the centre of the court<br>$VT_6$ =–32.23+0.17($PA_2$)–0.09($PA_3$)+ +0.01($PA_8$)+0.08($A_1$)+1.76($D_3$)– –3.15(21)–0.66(20)+0.28(18)+ +0.13(37)+7.59(68) | 0.4025 |

| No | Criterion variable* | Regression equations | R-square |
|---|---|---|---|
| | Wrist circumf. (37)<br>Relat. humerus breadth. (68) | | |
| 6. | $PA_8$<br>$B_1$<br>$B_2$<br>$B_6$<br>Biacromial breadth/pelvis breadth (96)<br>Bona-muscle rate of the cross-sectional area of fhigh/total cross-sectional area of thigh (113) | Serve streight<br>$VT_7$=–6.88+0.01($PA_8$)–6.94($B_1$)–<br>–5.10($B_2$)+0.12($B_6$)+0.04(96)+<br>+0.47(113) | 0.4089 |
| 7. | $PA_5$<br>$PA_8$<br>$B_6$<br>$D_2$<br>Relat. lower limb length (58) | Serve diagonally<br>$VT_8$=14.62+0.01($PA_5$)+0.01($PA_8$)–<br>–8.77($B_6$)+2.19($D_2$)–0.27(58) | 0..5261 |
| 8. | $PA_5$<br>$A_2$<br>$A_5$<br>$B_1$<br>$B_5$<br>$B_6$<br>$C_2$<br>$D_1$<br>Head circumf. (23)<br>Trunk length/upper chest circumf (99) | Reception into zone 2 or 3<br>$VT_9$=5.10+0.01($PA_5$)–35.41($A_2$)–<br>–0.10($A_5$)+5.58($B_1$)–23.17($B_5$)–<br>–2.66($B_6$)+26.18($C_2$)+34.24($D_1$)+<br>+0.17(23)–0.07(99) | 0.5853 |

* Psychophysiological tests ($A_1$–$D_3$) and tests of physical ability ($PA_1$–$PA_{10}$) have been presented by respective abbreviation. See Table 3 for their meaning

The evaluation system that is being created by the authors should enable the comparison and systematisation of all the individual test results. Therefore, in addition to the original results of the tests, we established a system of grades. This was based on SD classes calculated for all the tests (from 1 to 5: very poor, poor, average, good and very good results).

We formed an anthropometric statistical model representing the body as a whole on the basis of the above mentioned five SD classes and calculated the average complex grades for the tests of physical abilities, technical elements of volleyball and psychophysiological tests (Table 5).

Table 5. Average scores of tests administered to girl volleyballers by height-weight classes (n=49)

| No | Variable | Class 1 Small | | | Class 2 Medium | | | Class 3 Large | | | Class 4 Pycnics | | | Class 5 Leptosomes | | | Significance of statistical difference between the classes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | n | $\bar{x}$ | SD | n | $\bar{x}$ | SD | n | $\bar{x}$ | SD | n | $\bar{x}$ | SD | n | $\bar{x}$ | SD | |
| 1. | Age | 9 | 13.44 | 1.13 | 9 | 15.11 | 1.05 | 6 | 15 | 1.27 | 13 | 14.54 | 0.97 | 12 | 14.25 | 1.22 | 1+2 |
| 2. | Average score of tests of physical abilities (PA 1–10) | 12 | 2.698 | 0.498 | 8 | 3.031 | 0.427 | 5 | 3.475 | 0.670 | 11 | 2.841 | 0.478 | 11 | 3.318 | 0.441 | 1+2+3,4+5 |
| 3. | Average score of tests of technical elements of volleyball (VT 1–9) | 12 | 3.093 | 0.360 | 8 | 3.181 | 0.336 | 6 | 3.074 | 0.791 | 13 | 2.906 | 0.648 | 12 | 3.093 | 0.546 | none |
| 4. | Average score of psychophysiological tests (A1–D3) | 13 | 2.945 | 0.428 | 8 | 3.124 | 0.407 | 5 | 3.122 | 0.183 | 11 | 3.203 | 0.237 | 11 | 2.919 | 0.526 | none |

As the table reveals, namely the tests of general physical abilities were in correlation with different types of body build. According to average grades, these tests were best performed by big and leptosomic girls.

The tests of technical elements of volleyball were best performed by medium-sized girls (class 2) and psychophysiological tests by pycnics (class 4), but the differences between the classes in the two last mentioned types of tests were insignificant.

## DISCUSSION

In principle, the results of the present study coincide with the data from literature which state that the peculiarities of body build and level of physical fitness are significant for the performance of volleyball technical elements [2, 6, 12, 14, 19, 22].

If in literature only a few body measurements have been used to characterise body build (such as height and weight [13], weight and lean body mass [6], skinfolds [20], weight, thigh and arm circumferences and subcutaneous adipose tissue on the basis of skinfolds [7]) then we characterised the girls' anthropometric status as exactly as possible. We found the correlations of each body measurement and index with all the tests.

Until now, only the Heath-Carter method [3, 25] has been used for typification of volleyballers' body build. In our study, we applied the classification of 5 SD classes that has been widely publicised in literature. We demonstrated that all the anthropometric characteristics used in this classification could be well systematised.

This classification can also be used in order to systematise the data of all the other tests for girls according to different classes. So, we could prove that physical fitness tests were better performed by big and leptosomic girls.

Summing up the results of our investigation, we can state that the evaluation system that is being created for volleyball coaching should include anthropometric data and physical fitness tests as well as psycho-physiological tests because all of them determine the level of volleyball skills.

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# UNIFORMITY OF PATHOMORPHOLOGICAL CHANGES IN VARIOUS ORGANS IN RESPONSE TO THE EXPERIMENTAL SEPSIS.

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ABSTRACT

The objective was to assess the character and severity of pathomorphological changes in 12 organs of septic rats. Rats were inoculated intraperitoneally with a suspension of E. coli: group 2 (5 rats): 2.5 $cm^3$, groups 3 (6 rats) and 4 (9 rats): 1 $cm^3$. The rats died (6 rats) or were executed (group 3 on the second day and group 4 on the fifth day of the experiment). Tissue samples of 12 different organs for evaluation of relative wet organ weights and for histological evaluation were obtained.

All the organs revealed similar histologic changes: dilatation of capillaries, hyperemia, haemorrhages, thrombi and cell destruction, but of different degree of severity. Relative wet organ weights showed no uniform dynamics.

Conclusions: In experimental intraabdominal sepsis similar pathomorphological changes occur in all organs within 24 hours after the insult. Microvascular lesions dominate, leading to tissue destruction and necrosis. Lungs, liver, spleen, kidney and pancreas seem to be affected most.

Sepsis is infection with systemic inflammatory response syndrome (SIRS), that very often leads to the multiple organ dysfunction syndrome (MODS) [1]. In clinical settings, disturbances of organ function have been described comparatively thoroughly [9]. Less attention has been paid to pathomorphologic changes, the underlying organ dysfunction. The lesions have been identified as microcirculatory injury, polymorphonuclear accumulation and destruction and necrosis of tissue cells [13, 16]. Most attention has been paid to the lung [3, 14], but also to the heart, liver, kidneys and spleen [11, 15]. There is no parallel study of the severity of pathomorphological changes in different organs in sepsis or SIRS of other etiology. Also the time of occurrence

of the pathomorphological lesions has not been determined very clearly.

This study was undertaken to assess the type, severity and time of occurrence of the pathomorphological lesions, underlying MODS in a large number of different organs.

## MATERIALS AND METHODS

### *Experimental animals*

A live suspension E. coli of $1.5\times10^8$ bacteria per $cm^3$ was used for intraperitoneal infection of the rats. 25 white Wistar rats, weighing 220–270 g were divided into 4 groups:

Group 1 (5 rats) received intraperitoneally 2.5 $cm^3$ of hemolysed human red blood cells and served as controls. The rats of this group were sacrificed on the second day of the experiment.

To group 2 (5 rats) 2.5 $cm^3$ of live E. coli suspension (approximately $1.5\times10^8$ bacteria per $cm^3$) together with 2.5 $cm^3$ of hemolysed human red blood cells was injected intraperitoneally. All the rats of this group died during the first 24 hours.

Groups 3 (6 rats) and 4 (9 rats) received intraperitoneally 1 $cm^3$ of the same suspension together with 2.5 $cm^3$ of hemolysed human red blood cells. The rats of group 3 were sacrificed by decapitation on the second day of the experiment, and of group 4 on the fifth day of the experiment. One of the rats of group 3 died on the second day of the experiment.

Autopsy of the dead and sacrificed animals was performed.

### *Relative organ weights*

During autopsy specimens of the following organs: lungs, heart, spleen, pancreas, liver, adrenals, kidney, brain, stomach, small intestine, large intestine and the psoas muscle were dissected and weighed. Then the specimens were dried at 38°C during 48 hours and weighed again. Using the difference of wet and dry weights relative wet weight was calculated per gram of dry tissue according to the following formula: Relative wet weight (g/g dry tissue)=(Wet organ weight(g)–dry organ weight(g))/dry organ weight(g).

*Histological methods*

Tissue samples of the above described organs were taken, fixed in 10% buffered formalin and embedded into paraffin. Sections of 7 micrometers were cut. The tissue sections were stained with hematoxylin-eosin. All the investigations were carried out with the light microscope from Ceti, model Topic (Belgium), using magnification up to ×1000.

For assessing the presence of red blood cell aggregates, heart blood was fixed in 2.5% glutaraldehyde with phosphate buffer to preserve aggregates, and smears were stained according to Pappenheim for light microscopy.

## RESULTS

*Relative organ weights*

Relative wet organ weights are shown in Table 1. No statistically significant difference of relative wet weights between the control and the study groups were found in the heart, spleen and brain. In the second

**Table 1.** Relative wet organ weights

| Organ | Control group (n=5) mean±SD | Group 2 (n=4) mean±SD | Group 3 (n=4) mean±SD | Group 4 (n=9) mean±SD |
|---|---|---|---|---|
| Lung | 3.27±0.08 | 3.48±0.08* | 3.58±0.29 | 3.14±0.79 |
| Heart | 3.16±0.12 | 3.28±0.16 | 3.15±0.29 | 3.10±0.28 |
| Spleen | 3.06±0.16 | 3.33±0.26 | 3.27±0.13 | 3.03±0.30 |
| Pancreas | 1.26±0.22 | 2.62±0.14* | 1.68±0.23 | 2.65±0.23* |
| Liver | 2.5±0.20 | 2.84±0.04* | 2.56±0.20 | 2.13±0.17* |
| Suprarenals | 1.71±0.25 | 2.25±0.16* | 1.77±0.13 | 2.36±0.15* |
| Kidney | 2.28±0.13 | 3.33±0.14* | 3.34±0.11* | 3.56±0.23* |
| Brain | 3.01±0.20 | 3.01±0.27 | 3.11±0.23 | 3.22±0.19 |
| Stomach | 3.32±0.16 | 3.38±0.35 | 3.31±0.15 | 2.85±0.24* |
| Ileum | 1.92±0.19 | 1.83±0.27 | 2.33±0.24* | 2.45±0.17* |
| Caecum | 2.75±0.81 | 3.92±0.52 | 3.32±0.19 | 3.23±0.27 |
| Muscle | 2.16±0.10 | 2.96±0.23* | 3.14±0.21* | 2.95±0.19* |

* $p<0.05$ in comparison with control group

group (higher inoculation dose, survival ≤24 hours) increase of relative wet weight in comparison to the control group was found in the lung, pancreas, liver, suprarenals, kidney and muscle. In the third and fourth groups (lower inoculation dose, longer survival) stable increase of relative wet weight was observed in the kidney, ileum and muscle. Endocrine organs (suprarenals, pancreas) showed increase in relative wet weight on the fifth day after inoculation (group 4), while the relative wet weight of the stomach and liver on day five was significantly lower than that of the controls. The relative wet weight of caecum was significantly increased on the fifth day after the septic insult.

*Pathomorphological changes*

No pathomorphological changes were found in the animals. In the study groups histological evaluation of tissue samples revealed strikingly similar pathological changes in all organs but of different degree of severity (Table 2). As groups 3 and 4 revealed a similar degree of lesions, their data are shown together in the table. The vascular changes — dilatation of capillaries and marked hyperemia was found in almost all organs. More severe damage, such as hemorrages, thrombi and cell destruction were found mostly in the organs of the rats of group 2. The changes were accentuated in the kidney, lung, liver, spleen and pancreas.

*Liver lesions*

In the livers of the rats, who died within 24 hours (group 2) hyperemia and intestitial edema, widening of sinusoids and lymphocytary infiltration were seen. Sinusoidal dilatation varied largely according to the degree of cellular atrophy. Destructive changes — cloudy swelling, necrosis of hepotocytes and their vacuolation were observed in five of the six rats (Figure 1). In the rats of groups 3 and 4, however hyperemia and interstitial edema were prevalent. Destructive changes were found in half of the cases.

**Table 2.** Character and severity of pathomorphological changes in the organs of rats of different study groups.

| Organ | Group 2 (n=6) | | | | | | | | | | | | | | | | | | | | Groups 3 and 4 (n=14) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hyperemia | | | | Hemorrhage | | | | Thromb | | Edema | | Lymphocytary infiltration | | | | Destruction and necrosis | | | | Hyperemia | | | | Hemorrhage | | | | Thromb | | Edema | | Lymphocytary infiltration | | | | Destruction and necrosis | | | |
| | I | II | III | T | I | II | III | T | N | Y | N | Y | I | II | III | T | I | II | III | T | I | II | III | T | I | II | III | T | N | Y | N | Y | I | II | III | T | I | II | III | T |
| Lungs | 1 | 2 | 3 | 6 | 0 | 3 | 2 | 5 | 6 | 0 | 1 | 5 | 1 | 4 | 1 | 6 | 2 | 3 | 0 | 5 | 6 | 5 | 0 | 11 | 5 | 1 | 0 | 6 | 13 | 1 | 4 | 10 | 8 | 1 | 0 | 9 | 5 | 0 | 0 | 5 |
| Kidney | 0 | 5 | 1 | 6 | 0 | 2 | 3 | 5 | 5 | 1 | 0 | 6 | 1 | 2 | 0 | 3 | 0 | 1 | 5 | 6 | 8 | 2 | 1 | 11 | 2 | 0 | 0 | 2 | 14 | 0 | 8 | 6 | 1 | 0 | 0 | 1 | 4 | 2 | 2 | 8 |
| Liver | 1 | 3 | 2 | 6 | 1 | 0 | 0 | 1 | 6 | 0 | 0 | 6 | 0 | 4 | 0 | 4 | 4 | 0 | 1 | 5 | 7 | 3 | 0 | 10 | 1 | 1 | 0 | 2 | 14 | 0 | 2 | 12 | 7 | 2 | 0 | 9 | 4 | 2 | 1 | 7 |
| Spleen | 2 | 3 | 0 | 5 | 1 | 0 | 0 | 1 | 6 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6 | 6 | 1 | 0 | 7 | 0 | 0 | 0 | 0 | 14 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pancreas | 2 | 0 | 4 | 6 | 0 | 1 | 0 | 1 | 6 | 0 | 2 | 4 | 3 | 0 | 0 | 3 | 5 | 1 | 0 | 6 | 6 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 14 | 0 | 5 | 9 | 4 | 0 | 0 | 4 | 8 | 0 | 0 | 8 |
| Adrenals | 2 | 2 | 0 | 4 | 3 | 0 | 0 | 3 | 6 | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 1 | 0 | 7 | 0 | 0 | 0 | 0 | 14 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Heart | 4 | 0 | 2 | 6 | 2 | 3 | 0 | 5 | 6 | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 1 | 0 | 11 | 8 | 2 | 0 | 10 | 8 | 2 | 0 | 10 | 6 | 0 | 0 | 6 | 0 | 0 | 0 | 0 |
| Brain | 2 | 2 | 1 | 5 | 1 | 0 | 0 | 1 | 3 | 3 | 6 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 3 | 1 | 0 | 0 | 1 | 14 | 0 | 14 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Stomach | 3 | 1 | 2 | 6 | 1 | 0 | 0 | 1 | 6 | 0 | 4 | 2 | 1 | 0 | 0 | 1 | 3 | 0 | 0 | 3 | 6 | 4 | 2 | 12 | 3 | 0 | 0 | 3 | 14 | 0 | 10 | 4 | 7 | 0 | 0 | 7 | 1 | 0 | 0 | 1 |
| Small int. | 0 | 3 | 2 | 5 | 0 | 0 | 0 | 0 | 6 | 0 | 5 | 1 | 1 | 2 | 2 | 5 | 2 | 1 | 1 | 4 | 9 | 3 | 0 | 12 | 0 | 0 | 0 | 0 | 14 | 0 | 4 | 10 | 3 | 1 | 0 | 4 | 1 | 1 | 0 | 2 |
| Large int. | 2 | 2 | 2 | 6 | 0 | 1 | 1 | 2 | 6 | 0 | 2 | 4 | 1 | 4 | 1 | 6 | 1 | 2 | 1 | 4 | 9 | 3 | 1 | 13 | 0 | 0 | 1 | 1 | 14 | 0 | 5 | 9 | 1 | 0 | 1 | 2 | 2 | 0 | 1 | 3 |
| Muscle | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 14 | 0 | 5 | 9 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |

I, II and III indicate the degree of severity of the pathomorphological changes; **T** indicates total; the arabic numerals in the table indicate the number of rats, who had pathomorphological changes.

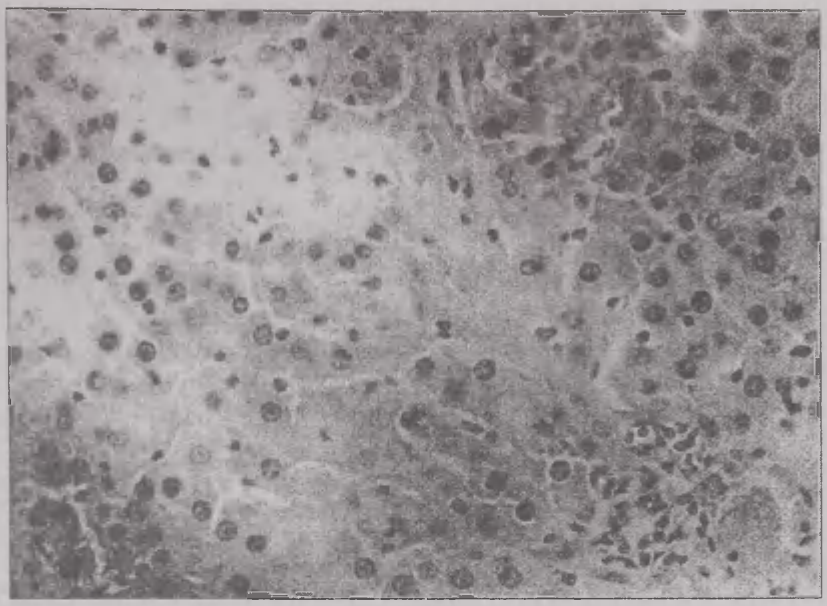

**Figure 1.** Liver. Cloudy swelling and necrosis of hepatocyts. HE 400x

*Kidney lesions*

The rats of group 2 revealed severe damage of the kidney — hyperemia, hemorrhage, interstitial edema, perivascular lymphocytary infiltration. In all the rats destructive changes — necrosis of tubular epithelium and microthrombi — were found. The glomerular tufts were in some cases so intensively hyperaemic as to fill completely all intracapsular spaces; the intracapsular spaces contained extravasated red cells. The tubuli contained extravasated pink-staining albuminous material.

In the rats of groups 3 and 4 (lower inoculation dose) the vascular response — hyperemia — was found almost in all rats, interstial oedema and necrosis of the tubular epithelium in half of the cases.

*Lung lesions*

After 24 hours (2nd group) there was evidence of hyperemia and hemorrhages. Severe hemorrhagic lesions were obvious and found in 5 rats of the 6. There was intestitial and intraalveolar edema, the alveolar walls were thickened, some alveoli were filled with pink-

stained fluid (Figure 2). Minor atelectases were found in half of the cases. In the rats sacrificed after 5 days (4th group) hyperemia and hemorrhagic foci were present but rather small and insignificant. Variable numbers of red cells were also present in the alveolar exudate. Destructive changes, like necrosis, minor atelectasis were present in one third of the rats.

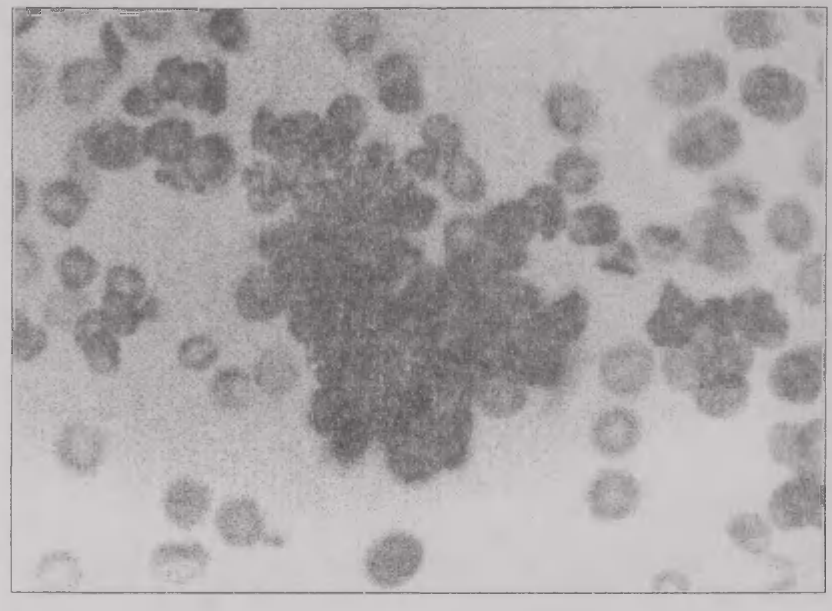

**Figure 2.** Lung. Hyperemia intraalveolar and interstitial edema. HE 400x

*Pancreatic lesions*

After 24 hours (2nd group) pancreas was found to be edematous. Microscopically there were intense hyperaemia, interstitial edema, some destructive changes of the exocrine ducts' cells of the terminal parts, with lymphocytary infiltration between them.

At 2 and 5 days (third and fourth group) the pancreatic tissue within the islands was sometimes normal, but more often showed various changes — mostly deformed and some necrotic cells of the endocrine parts.

In the small and large intestine, heart, spleen and brain moderate hyperemia and interstitial edema was seen in 24 hours. In half of the cases thrombi were revealed in the brain. Some destructive changes

were found in the epithelium of the small and the large intestine. In the skeletal muscle we could not find any significant morphological changes.

Red blood cell aggregates were present in all the blood smears of the experimental animals (Figure 3) but not in the controls.

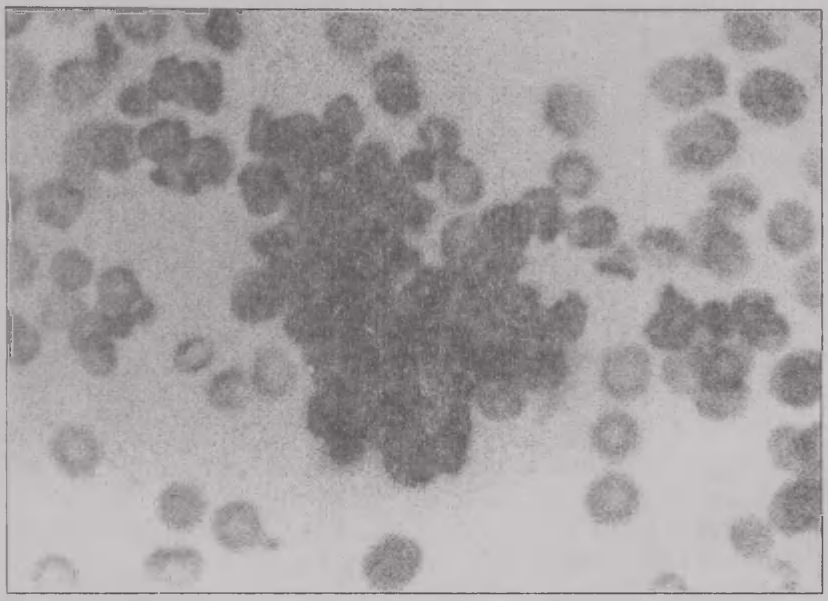

**Figure 3.** Red blood cell aggregates in a blood smear. Pappenheim 1000x

## DISCUSSION

In the study in a rat model of intraperitoneal sepsis uniform pathomorphologic changes in all the investigated organs were found to occur within 24 hours after severe septic insult. The changes included microvascular lesions (hyperaemia, haemorrhages, thrombi, perivascular and interstitial edema), intracellular edema, perivascular lymphocytary infiltration and tissue destruction and necrosis. Similar lesions in a smaller number of organs have been described as the morphological basis of multiple organ dysfunction in sepsis [16] and SIRS of other etiology [11]. Thus, even in the absence of evident organ dysfunction, the morphological lesions of all organs may be present already 24 hours after the onset of severe sepsis.

Microvascular lesions were found in almost all the examined organs in all study groups, while tissue cell destruction and necrosis and lymphocytary infiltration were seen much less frequently. Thus, microvascular lesions appear to precede the lesions of tissue cells. Lymphocytary infiltration, if present, was located circularly around bigger blood vessels and not in the regions of destructive tissue damage. Differently from other authors [11, 16] we did not see polymorphonuclear accumulation in the damaged tissues. Microcirculation is known to be a major site of attack during sepsis [7]. In the study we found congestion, haemorrhage, increase in capillary permeability, reflected as interstitial edema and increase in relative wet organ weight, aggregation of red blood cells and formation of thrombi in some cases. These lesions lead to obstruction of blood flow and consequently to tissue destruction and necrosis [10]. The absence of polymorphonuclear accumulation and relatively rare occurrence of circular lymphocytary infiltration around bigger blood vessels might also be caused by disturbances in microcirculation that leads to the impaired transport of immunocompetent cells to damaged tissues.

In severely septic animals (group 2) no changes in relative wet weight of the brain and heart were observed. In these organs, in contrast to lungs and kidneys, no severe haemorrhages, tissue destruction or necrosis were seen either. The predominating change in microcirculation was hyperaemia. The better preservation of microcirculation in these organs could be explained by redistribution of blood flow in critical conditions either due to changes in vascular tone [8, 17] or formation of blood cell aggregates in the capillaries [2]. The presence of red blood cell aggregates in all septic animals in our study supports the idea of capillary plugging.

In the study, increase in the lung, pancreas, liver, suprarenal, kidney and skeletal muscle relative wet weight was observed in severely septic animals 24 hours after the onset of sepsis (group 2). In a mouse model of MODS of nonseptic origin, the maximum of wet/dry organ weight ratio has also been found to occur between 12 and 24 hours after the insult [12]. In groups 3 and 4 the relative wet weight of the kidney, ileum and skeletal muscle were significantly higher as compared to the control group. Increase in wet/dry weight ratio of intraabdominal organs (liver, pancreas, small and large intestine) has been found in a rat model of intraabdominal sepsis, while extraabdominal organs (heart, lung, skeletal muscle) and the kidney showed no significant changes [6]. Other authors have found increased wet weights of the lung and liver in baboon sepsis [13], and increased relative

weights of the lung, heart and spleen in trauma patients, who died of multiple organ failure [11]. These differences are difficult to comment. Unlike in other studies our animals did not receive any intravenous fluids; that might modify oedema formation, reflected by relative wet organ weight.

Pathomorphological changes were similar in all the investigated organs, differing only in severity. More severe changes were found in the rats of group 2. Of course, the rats of this group received a higher inoculation dose and probably had hypotension; that might modify the development of tissue injury [4]. Besides, the extent of organ damage has been found to depend on the dose of bacterial challenge [13]. The lungs, liver, kidneys, spleen and pancreas were the organs involved most. These organs showed most severe morphological damage, also increase in their relative wet weight (except spleen) was observed most frequently.

In conclusion, in experimental intraabdominal sepsis uniform pathomorphological changes, characteristic of the MODS occur in all organs within 24 hours after the insult. Microvascular lesions dominate, leading to tissue destruction and necrosis. Lungs, liver, spleen, kidney and pancreas seem to be affected most.

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# COMPARISON OF ANTHROPOMETRIC VARIABLES OF 12–15-YEAR-OLD PRE- AND POST-MENARCHEAL GIRLS FROM TARTU

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ABSTRACT

The study was aimed at comparing absolute and relative anthropometric dimensions in pre- and post-menarcheal girls. The subjects were 392 Tartu schoolgirls aged from 12 to 15.

Student's t-test was used to determine the differences of means of the pre-menarcheal and post-menarcheal subgroups in each age group. Post-menarcheal girls were superior in mean body height, body weight ($p<0.01$), and in BMI, sitting height and trunk length ($p<0.05$), also in body widths and girths. There were also remarkable differences in subcutaneous fat distribution (skinfolds). For example, the triceps skinfold in pre-menarcheal girls differently from post-menarcheal girls decreased with age from 12–15.

Generally pre-menarcheal girls tended to have relatively longer limbs and a shorter trunk and relatively narrow hips, and until age 14 also relatively larger head dimensions. Their skinfolds were smaller, especially on the trunk and lower limbs.

Substantial differences in the anthropometric variables of menstruating and non-menstruating girls should also be taken into account in population reference data and in comparisons of adolescence data.

## INTRODUCTION

Influenced both by heredity and environment the period of physical maturation is marked by great biological diversity. For this reason assessing body measurements of teenagers solely on the basis of age is unreliable, but reliability can be improved if we take into account the degree of maturity.

The relationship between morphometric characteristics and sexual maturation has been of interest for many studies. Age at menarche is one of the most commonly used indicators of sexual maturation in girls [1]. Generally, earlier menarche is accompanied by advanced growth [2, 3, 4, 5, 6].

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-menarcheal girls aged from 12 to 15 years and to find main tendencies of differences of these subgroups in 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 392 schoolgirls at 12–15 years of age.

Each girl was asked whether she had yet begun to menstruate, and if she had then the exact age (date) at which she begun to menstruate was asked (*status quo* and retrospective methods).

Anthropometric measurements were carried out by the author according to the rules described in "Anthropometrica" [7] 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 were taken with a Holtain calliper. Head measurements were taken according to methods developed by R. Martin [8].

Cross-sectionally obtained data were divided at each age into groups of pre- and post-menarcheal girls, and descriptive statistics were calculated for all variables by age- and menarcheal-groups. Student's t-test were used to determine the differences of means of the pre-menarcheal and post-menarcheal subgroups in each age group.

The statistical package SAS was used for data processing.

In addition to the basic statistics (mean, standard deviation) the following indexes were calculated: BMI (body mass index), acromiocristal index (ratio of bicristal diameter to biacromial diameter in %), thoracal index (ratio of depth and width of the chest in %), cranial index (cephalic index: ratio of the maximum width of the skull to its maximum length in %) and also relative measurements (% of the variable from body height).

## RESULTS AND DISCUSSION

Table 1 lists the percentages of menstruating and non-menstruating girls at each age.

**Table 1.** Distribution of 12–15-year-old Tartu girls according to incidence of menarche and comparison with data of Tallinn girls in 1971 (Silla, Teoste, 1989) [9]

| Age | Without menarche | | Menarche occurs | | Total n | Without menarche in 1971 | | Menarche occurs in 1971 | | Total n in 1971 |
|---|---|---|---|---|---|---|---|---|---|---|
| (years) | n | % | n | % | | n | % | n | % | |
| 12 | 73 | 87.95 | 10 | 12.05 | 83 | 92 | 90.20 | 10 | 9.80 | 102 |
| 13 | 80 | 72.73 | 30 | 27.27 | 110 | 65 | 57.52 | 48 | 42.48 | 113 |
| 14 | 31 | 30.39 | 71 | 69.61 | 102 | 31 | 28.18 | 79 | 71.82 | 110 |
| 15 | 12 | 12.37 | 85 | 87.63 | 97 | 5 | 5.05 | 94 | 94.95 | 99 |
| Total | 196 | | 196 | | 392 | 193 | | 231 | | 424 |

Comparison of incidence of menarche in Tartu girls with earlier data (Table 1) indicates that in girls of Tartu the differences in the age of beginning of menstruation are somewhat bigger than in Tallinn girls in 1971 [9]. Though at age 12 a little more than 10% (12%) of girls have menarche (vs. 9.8% in 1971), at age 15 in the current study there were more than 10% of girls without menarche instead of 5% in 1971.

The earliest age when menarche occurred in Tartu girls was 10.44.

Comparison of somatic measures and indices between pre- and post-menarcheal girls is presented in Tables 2–8.

Post-menarcheal girls have larger ($p<0.01$) mean body height, body weight and larger ($p<0.05$) sitting height and trunk length (Tables 2 and 3). Body widths (Table 4), girths (Table 5) and most of skinfolds (Table 6) were also larger in post-menarcheal girls than in pre-menarcheal girls of the same age before 15 years of age. The same is known from literature [3, 6, 10].

There are remarkable differences in skinfolds, especially in iliac crest, subscapular, supraspinal skinfolds, also in sizes of abdominal and front-thigh and calf skinfolds between pre- and post-menarcheal girls. Thus pronounced differences of pre- and post-menarcheal girls are, first and foremost, manifest in the skinfolds of the trunk and the lower limb. This indicates the relevant differences in fat distribution between pre- and post-menarcheal girls and proves the necessity of considering the menarcheal status in calculating the mean anthropometric variables by age groups in adolescents.

**Table 2.** Means and standard deviations (SD) of weight and height in 12- to 15-year-old girls by menarcheal status

| Variable | Age (years) | Pre-menarcheal | | Post-menarcheal | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| weight | 12 | 41.81 | 8.54 | 50.80** | 10.07 |
| | 13 | 43.84 | 7.60 | 52.99** | 10.50 |
| | 14 | 44.77 | 6.85 | 53.92** | 8.46 |
| | 15 | 48.59 | 5.19 | 54.59** | 8.09 |
| height | 12 | 153.56 | 7.80 | 160.83** | 6.87 |
| | 13 | 156.38 | 6.84 | 161.86** | 6.01 |
| | 14 | 159.18 | 6.40 | 163.78** | 6.02 |
| | 15 | 163.37 | 5.88 | 165.01 | 5.37 |

** Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.01$)

* Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.05$)

**Table 3.** Means and standard deviations (SD) of lengths in 12- to 15-year-old girls by menarcheal status

| Variable (cm) | Age (years) | Pre-menarcheal | | Post-menarcheal | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| head-plus neck length | 12 | 28.75 | 1.44 | 29.66 | 1.35 |
| | 13 | 28.85 | 1.70 | 29.91** | 1.26 |
| | 14 | 29.57 | 2.22 | 30.11 | 1.44 |
| | 15 | 29.83 | 0.82 | 29.87 | 1.21 |
| trunk length | 12 | 45.19 | 2.59 | 48.22** | 2.41 |
| | 13 | 46.04 | 2.69 | 48.31** | 2.33 |
| | 14 | 46.98 | 2.70 | 49.83** | 2.52 |
| | 15 | 48.11 | 1.74 | 50.36** | 2.22 |
| sitting height | 12 | 79.54 | 3.85 | 83.23** | 3.75 |
| | 13 | 80.50 | 3.95 | 84.26** | 3.12 |
| | 14 | 82.53 | 3.42 | 85.82** | 3.49 |
| | 15 | 83.86 | 1.81 | 86.67** | 2.71 |
| lower limb length | 12 | 83.47 | 4.96 | 86.79 | 5.55 |
| | 13 | 85.50 | 4.47 | 88.01** | 4.41 |
| | 14 | 86.72 | 3.60 | 88.23* | 3.63 |
| | 15 | 89.49 | 4.58 | 88.89 | 3.98 |
| upper limb length | 12 | 66.75 | 3.80 | 69.66* | 4.67 |
| | 13 | 68.40 | 3.38 | 70.4** | 3.13 |
| | 14 | 69.74 | 3.72 | 71.07 | 3.03 |
| | 15 | 71.80 | 3.51 | 71.43 | 2.85 |

** Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.01$)

* Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.05$)

**Table 4.** Means and standard deviations (SD) of widths and depths in 12- to 15-year-old girls by menarcheal status

| Variable | Age (years) | Pre-menarcheal | | Post-menarcheal | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| biacromial width | 12 | 32.16 | 1.97 | 33.00 | 2.37 |
| | 13 | 32.83 | 1.53 | 34.40** | 2.23 |
| | 14 | 33.23 | 1.87 | 34.29** | 1.65 |
| | 15 | 34.25 | 1.42 | 34.26 | 1.97 |
| chest width | 12 | 22.66 | 1.80 | 23.93* | 2.32 |
| | 13 | 22.80 | 1.30 | 24.00** | 1.79 |
| | 14 | 23.13 | 1.46 | 24.50** | 1.28 |
| | 15 | 23.89 | 1.20 | 24.56 | 1.68 |
| waist width | 12 | 20.74 | 1.84 | 21.96 | 2.27 |
| | 13 | 21.03 | 1.38 | 22.14** | 2.01 |
| | 14 | 20.94 | 1.45 | 22.14** | 1.72 |
| | 15 | 21.77 | 1.43 | 22.40 | 1.64 |
| bicristal width | 12 | 24.17 | 1.76 | 25.52* | 1.82 |
| | 13 | 24.68 | 1.61 | 26.18** | 1.70 |
| | 14 | 25.13 | 1.61 | 26.76** | 1.50 |
| | 15 | 26.33 | 0.88 | 26.75 | 1.69 |
| chest depth | 12 | 15.83 | 1.38 | 17.23** | 1.38 |
| | 13 | 16.43 | 1.50 | 17.57** | 1.54 |
| | 14 | 16.24 | 1.29 | 17.28** | 1.58 |
| | 15 | 16.58 | 1.13 | 17.36 | 1.41 |
| abdominal depth | 12 | 15.41 | 1.71 | 16.48 | 1.98 |
| | 13 | 15.57 | 1.54 | 16.66* | 2.19 |
| | 14 | 15.17 | 1.31 | 16.36** | 1.71 |
| | 15 | 16.14 | 1.22 | 16.62 | 1.69 |
| elbow width | 12 | 5.85 | 0.35 | 5.92 | 0.32 |
| | 13 | 5.84 | 0.33 | 5.97 | 0.30 |
| | 14 | 5.89 | 0.29 | 6.03* | 0.31 |
| | 15 | 6.07 | 0.20 | 6.00 | 0.29 |
| knee width | 12 | 8.36 | 0.45 | 8.65 | 0.47 |
| | 13 | 8.34 | 0.40 | 8.58* | 0.54 |
| | 14 | 8.39 | 0.42 | 8.61* | 0.46 |
| | 15 | 8.40 | 0.30 | 8.59 | 0.42 |
| head length | 12 | 17.68 | 0.60 | 17.66 | 0.41 |
| | 13 | 17.82 | 0.75 | 17.97 | 0.58 |
| | 14 | 17.84 | 0.70 | 18.02 | 0.65 |
| | 15 | 17.79 | 0.60 | 18.03 | 0.67 |
| head width | 12 | 14.06 | 0.49 | 14.24 | 0.50 |
| | 13 | 14.09 | 0.51 | 14.27 | 0.49 |
| | 14 | 14.14 | 0.43 | 14.28 | 0.44 |
| | 15 | 14.12 | 0.39 | 14.26 | 0.49 |

** Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.01$)

* Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.05$)

**Table 5.** Means and standard deviations (SD) of girths in 12- to 15-year-old girls by menarcheal status

| Girths (cm) | Age (years) | Pre-menarcheal | | Post-menarcheal | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| head | 12 | 54.22 | 1.58 | 54.51 | 1.51 |
| | 13 | 54.46 | 1.76 | 55.23* | 1.69 |
| | 14 | 54.77 | 1.61 | 55.57* | 1.52 |
| | 15 | 54.83 | 1.59 | 55.54 | 1.47 |
| chest (mesosternale) | 12 | 76.57 | 5.97 | 80.29 | 7.47 |
| | 13 | 75.64 | 5.19 | 81.50** | 6.34 |
| | 14 | 76.35 | 4.95 | 81.63** | 5.26 |
| | 15 | 78.81 | 3.75 | 82.56* | 5.70 |
| waist (minimum) | 12 | 61.87 | 5.51 | 66.57* | 7.14 |
| | 13 | 62.42 | 4.78 | 66.14** | 6.98 |
| | 14 | 62.15 | 3.93 | 66.78** | 5.51 |
| | 15 | 64.55 | 4.10 | 67.19 | 5.78 |
| gluteal (hips) | 12 | 80.93 | 7.51 | 88.22** | 7.14 |
| | 13 | 82.60 | 6.35 | 90.74** | 7.70 |
| | 14 | 83.51 | 6.22 | 92.07** | 6.24 |
| | 15 | 86.47 | 3.47 | 92.18** | 5.11 |
| thigh (medial) | 12 | 42.35 | 4.30 | 46.56** | 5.13 |
| | 13 | 43.17 | 4.09 | 47.30** | 5.31 |
| | 14 | 42.80 | 3.76 | 47.52** | 4.52 |
| | 15 | 44.31 | 2.67 | 47.37** | 3.35 |
| upper arm (relaxed) | 12 | 22.17 | 2.74 | 24.29* | 2.73 |
| | 13 | 22.45 | 2.36 | 24.79** | 3.16 |
| | 14 | 22.25 | 2.11 | 24.96** | 2.72 |
| | 15 | 22.90 | 1.53 | 24.96** | 2.34 |

**Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.01$)

*Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.05$)

**Table 6.** Means and standard deviations (SD) of skinfolds in 12- to 15-year-old girls by menarcheal status

| Skinfold (mm) | Age | Pre-menarcheal | | Post-menarcheal | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| triceps | 12 | 10.23 | 3.64 | 12.54 | 4.61 |
| | 13 | 10.20 | 3.29 | 12.68** | 4.99 |
| | 14 | 9.81 | 2.87 | 13.11** | 4.66 |
| | 15 | 9.83 | 2.45 | 13.73** | 4.08 |
| subscapular | 12 | 7.25 | 3.62 | 9.82* | 4.39 |
| | 13 | 7.46 | 3.15 | 9.68** | 3.86 |
| | 14 | 6.96 | 1.98 | 10.39** | 4.30 |
| | 15 | 7.18 | 2.07 | 10.64** | 5.26 |
| biceps | 12 | 6.08 | 2.53 | 7.47 | 2.01 |
| | 13 | 6.24 | 2.99 | 7.40 | 3.23 |
| | 14 | 5.09 | 1.68 | 7.60** | 3.28 |
| | 15 | 6.00 | 2.44 | 7.52 | 2.75 |
| iliac crest | 12 | 9.24 | 4.47 | 15.06* | 6.93 |
| | 13 | 9.97 | 5.82 | 13.94** | 7.19 |
| | 14 | 9.08 | 4.11 | 13.71** | 6.01 |
| | 15 | 9.21 | 3.98 | 14.99** | 6.86 |
| supraspinal | 12 | 6.09 | 3.03 | 9.57 | 5.70 |
| | 13 | 6.36 | 3.20 | 8.83** | 5.13 |
| | 14 | 5.86 | 3.02 | 8.85** | 4.10 |
| | 15 | 6.07 | 2.94 | 9.36** | 5.32 |
| abdominal | 12 | 10.76 | 6.40 | 14.61 | 8.30 |
| | 13 | 10.63 | 6.01 | 14.25* | 8.01 |
| | 14 | 9.18 | 4.35 | 15.18** | 7.03 |
| | 15 | 11.98 | 7.97 | 15.86 | 7.49 |
| front thigh | 12 | 19.97 | 8.17 | 23.96 | 9.46 |
| | 13 | 20.04 | 8.82 | 24.49* | 9.69 |
| | 14 | 19.37 | 7.81 | 23.72* | 9.24 |
| | 15 | 20.22 | 10.27 | 27.93** | 9.34 |
| medial calf | 12 | 11.91 | 4.86 | 16.22* | 5.84 |
| | 13 | 11.90 | 4.98 | 14.48* | 6.02 |
| | 14 | 11.56 | 3.64 | 14.48* | 5.14 |
| | 15 | 10.93 | 3.86 | 15.06** | 4.57 |

**Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.01$)

*Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.05$)

The comparison of skinfolds in pre- and post-menarcheal girls (Table 7) shows that with age the mean skinfold changes differently in these

subgroups. For example, the differences in triceps and subscapular skinfolds were especially expressive. We can see that in post-menarcheal girls triceps and subscapular skinfolds as most skinfolds increase with age but in pre-menarcheal girls, on the opposite, the triceps skinfolds decrease from the age of 12 to 15. Subscapular skinfolds remain relatively stable in non-menstruating girls regardless of age.

**Table 7.** BMI in 12–15-year-old Tartu girls by menarcheal status

| Index | Age (years) | Pre-menarcheal | | Post-menarcheal | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| BMI | 12 | 17.61 | 2.40 | 19.57* | 3.31 |
| | 13 | 17.83 | 2.10 | 20.15** | 3.36 |
| | 14 | 17.62 | 2.13 | 20.06** | 2.70 |
| | 15 | 18.21 | 1.73 | 19.97* | 2.36 |

** Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.01$)

* Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.05$)

Table 7 compares the BMI. Post-menarcheal girls consistently have higher means of BMI (as means of body weight) than pre-menarcheal girls over all ages 12–15 ($P<0.05$). Increase in age from 12 to 15 did not cause any remarkable differences in the BMI in the pre-menarcheal as well as the post-menarcheal group.

In literature it has been similarly reported that later maturers tended to have a more linear physique [3, 11] and lower values for the BMI and skinfolds than earlier maturers [6, 10].

As pre- and post-menarcheal girls have different body height, then the comparison of relative measurements is more relevant.

Comparing the relative measurements it can be seen that relative sitting height of post-menarcheal girls exceeds statistically reliably ($p<0.05$) that of pre-menarcheal girls at age 13–15. On the opposite, the relative length of the lower limb was larger in pre-menarcheal girls, though these differences were statistically reliable in older ages. This shows, as it has also been suggested by the results of a study of Chinese girls [6], that pre-menarcheal girls tend to have relatively longer legs than post-menarcheal girls of the same age.

The mean relative sitting height of 12–15-year-old post-menarcheal girls slightly increases with age, the means of pre-menarcheal girls were relatively stable at ages 12–14, with a slight decrease at age 15.

Relative upper limb also tended to be larger in pre-menarcheal girls, though these differences were not statistically reliable in all age-groups.

It appears that pre- and post-menarcheal girls did not differ in relative biacromial width. However, the difference revealed itself in relative bicristal width in favour of post-menarcheal girls. Thus post-menarcheal girls had broader hips than pre-menarcheal girls, and the larger acromiocristal index indicates the same, though these differences were not statistically trustworthy for all ages (Table 8).

Relative chest width and relative chest depth were bigger in post-menarcheal girls, but these differences were not statistically reliable. At that post-menarcheal girls exceed pre-menarcheal girls in relative chest girth. Thoracal indexes of pre- and post-menarcheal girls were not statistically reliably different, while pre-menarcheal girls tended to have a somewhat flatter thorax than post-menarcheal girls.

Pre-menarcheal girls have statistically reliably a relatively longer and wider head, and also their relative circumference of the head was bigger at ages 12–14. At age 15 these difference in relative head measurements disappeared (Table 8). This indicates again that pre- and post-menarcheal girls have different rates in growth toward caudal direction. Some references [12] demonstrate that there is a relationship between reproduction and head form in a twentieth-century population. Therefore it was interesting to learn if there were any differences in the cephalic index between pre-and post-menarcheal girls. Our data did not confirm the differences in the cephalic index between pre-and post-menarcheal girls (Table 8).

Although some authors note that interpretation of pre-and post-menarcheal differences should be done with care because of small numbers of post-menarcheal girls in the younger age groups and of pre-menarcheal girls in the older ones [6], this kind of comparison helps us to understand the main trends in these differences and their range. As these differences are substantial and might also relevantly influence the adolescence reference data, it is important to know them in the current population.

In conclusion we can say that differences in anthropological variables of pre- and post-menarcheal girls were visible, and it is important to take them into account in population standards.

Pre-menarcheal girls tend to have relatively longer limbs and a shorter trunk and relatively narrow hips, and until age 14 also a relatively larger head. Their skinfolds are smaller, especially on the trunk and lower limbs. Thus their changes towards the gynoid type were weaker as their growth rate differs from the faster maturing girls.

**Table 8.** Some indexes (in per cent) in 12–15-year old girls

| Variable | Age (years) | Pre-menarcheal | | Post-menarcheal | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| rel. sitting height | 12 | 51.81 | 0.98 | 51.76 | 1.42 |
| | 13 | 51.48 | 1.35 | 52.07* | 1.39 |
| | 14 | 51.85 | 1.12 | 52.40* | 1.04 |
| | 15 | 51.37 | 1.27 | 52.53** | 1.02 |
| rel. biacromial width | 12 | 20.95 | 0.83 | 20.52 | 1.15 |
| | 13 | 21.01 | 0.78 | 21.26 | 0.88 |
| | 14 | 20.87 | 0.82 | 20.94 | 0.90 |
| | 15 | 20.99 | 1.18 | 20.77 | 1.13 |
| rel. bicristal width | 12 | 15.74 | 0.72 | 15.86 | 0.80 |
| | 13 | 15.78 | 0.83 | 16.18* | 0.96 |
| | 14 | 15.78 | 0.70 | 16.34** | 0.75 |
| | 15 | 16.13 | 0.50 | 16.21 | 0.80 |
| rel. chest width | 12 | 14.76 | 0.93 | 14.90 | 1.50 |
| | 13 | 14.59 | 0.69 | 14.83 | 1.03 |
| | 14 | 14.54 | 0.89 | 14.97* | 0.79 |
| | 15 | 14.64 | 0.81 | 14.88 | 0.90 |
| rel. chest depth | 12 | 10.31 | 0.72 | 10.72 | 0.80 |
| | 13 | 10.50 | 0.78 | 10.85* | 0.83 |
| | 14 | 10.21 | 0.81 | 10.56 | 1.01 |
| | 15 | 10.16 | 0.79 | 10.52 | 0.84 |
| rel. chest girth | 12 | 48.86 | 3.30 | 49.94 | 4.33 |
| | 13 | 48.18 | 2.74 | 50.21* | 3.72 |
| | 14 | 47.93 | 2.97 | 49.87** | 3.19 |
| | 15 | 48.21 | 2.23 | 50.04 | 3.19 |
| rel. length of lower limb | 12 | 54.34 | 1.04 | 53.94 | 1.81 |
| | 13 | 54.67 | 1.24 | 54.36 | 1.26 |
| | 14 | 54.49 | 1.15 | 53.87** | 0.99 |
| | 15 | 54.76 | 1.09 | 53.85* | 1.24 |
| rel. length of upper limb | 12 | 43.47 | 1.03 | 43.29 | 1.84 |
| | 13 | 43.75 | 1.19 | 43.49 | 1.01 |
| | 14 | 43.80 | 1.14 | 43.39 | 1.01 |
| | 15 | 43.94 | 1.12 | 43.29* | 0.99 |
| acromiocristal index | 12 | 75.21 | 3.79 | 77.43 | 4.14 |
| | 13 | 75.20 | 4.20 | 76.17 | 4.58 |
| | 14 | 75.65 | 3.17 | 78.15** | 4.40 |
| | 15 | 76.97 | 3.30 | 78.22 | 5.38 |
| thoracal index | 12 | 69.99 | 5.45 | 72.38 | 7.08 |
| | 13 | 72.06 | 5.08 | 73.38 | 6.34 |
| | 14 | 70.30 | 5.01 | 70.62 | 6.46 |
| | 15 | 69.47 | 4.91 | 70.83 | 5.71 |

| Variable | Age (years) | Pre-menarcheal | | Post-menarcheal | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| rel. head length | 12 | 11.54 | 0.58 | 10.99** | 0.42 |
| | 13 | 11.41 | 0.50 | 11.11** | 0.36 |
| | 14 | 11.22 | 0.56 | 11.00* | 0.47 |
| | 15 | 10.90 | 0.46 | 10.93 | 0.40 |
| rel. head width | 12 | 9.17 | 0.44 | 8.86* | 0.37 |
| | 13 | 9.02 | 0.41 | 8.83* | 0.48 |
| | 14 | 8.89 | 0.35 | 8.72* | 0.40 |
| | 15 | 8.65 | 0.42 | 8.65 | 0.37 |
| rel. head girth | 12 | 35.37 | 1.45 | 33.93** | 1.23 |
| | 13 | 34.86 | 1.28 | 34.15** | 1.15 |
| | 14 | 34.45 | 1.45 | 33.96 | 1.25 |
| | 15 | 33.59 | 1.31 | 33.68 | 1.02 |
| cephalic index | 12 | 79.57 | 3.31 | 80.66 | 2.91 |
| | 13 | 79.17 | 3.74 | 79.50 | 3.96 |
| | 14 | 79.36 | 3.49 | 79.33 | 4.01 |
| | 15 | 79.40 | 2.59 | 79.19 | 3.89 |

** Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.01$)

* Statistically significant difference between pre-menarcheal and post-menarcheal girls ($p<0.05$)

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ISSN 1406–0140