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Doctoral thesis

Body composition especially external skeletal robustness in association with physical activity and recreation in pre-pubertal children – a national and international investigation

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I. List of abbreviations

ANOVA - Analysis of variance

BMI - Body Mass Index

df - degrees of freedom

e.g. - exempli gratia (for example)

F - F-value

KMO - Kaiser-Meyer-Olkin-criterion

MANCOVA – Multivariate analysis of covariance

min/d - minutes per day

n - sample size

n. d. a. - no data available for Russian children

n. s. - no significance

p - p-value

PCA - Principal Component Analysis

p. w. - per week

P50 - 50th percentile, median

r - correlation coefficient

rho - Spearman`s correlation coefficient

T - T-Test

U - Mann-Whitney-Test

X^2 - Chi Quadrat

* - significance level .05

** - significance level .01

*** - significance level .001

‡ - significance level .017

† - significance level .01

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1. Summary

In children the way of life, nutrition and recreation changed in recent years and as a consequence body composition shifted as well. It is established that overweight belongs to a global problem. In addition, German children exhibit a less robust skeleton than ten years ago. These developments may elevate the risk of cardiovascular diseases and skeletal modifications. Heredity and environmental factors as nutrition, socioeconomic status, physical activity and inactivity influence fat accumulation and the skeletal system. Based on these negative developments associations between type of body shape, skeletal measures and physical activity; relations between external skeletal robustness, physical activity and inactivity, BMI and body fat and also the progress of body composition especially external skeletal robustness in comparison in Russian and German children were investigated.

In a cross-sectional study 691 German boys and girls aged 6 to 10 years were examined. Anthropometric measurements were taken and questionnaires about physical activity and inactivity were answered by parents. Additionally, pedometers were worn to determinate the physical activity in children. To compare the body composition in Russian and German children data from the years 2000 and 2010 were used.

The study has shown that pyknomorphic individuals exhibit the highest external skeletal robustness and leptomorphic ones the lowest. Leptomorphic children may have a higher risk for bone diseases in adulthood. Pyknomorphic boys are more physically active by tendency. This is assessed as positive because pyknomorphic types display the highest BMI and body fat. Results showed that physical activity may reduce BMI and body fat. In contrast physical inactivity may lead to an increase of BMI and body fat and may rise with increasing age. Physical activity encourages additionally a robust skeleton. Furthermore external skeletal robustness is associated with BMI in order that BMI as a measure of overweight should be consider critically. The international 10-year comparison has shown an increase of BMI in Russian children and German boys. Currently, Russian children exhibit a higher external skeletal robustness than

the Germans. However, in Russian boys skeleton is less robust than ten years ago. This trend should be observed in the future as well in other countries.
All in all, several measures should be used to describe health situation in children and adults. Furthermore, in children it is essential to support physical activity in order to reduce the risk of obesity and to maintain a robust skeleton. In this way diseases are able to prevent in adulthood.

2. Introduction

In children the way of life, interests and nutrition changed recently due to globalization, this development exists in many countries. These changes have an effect on body composition and health situation. Children are situated in a stage of development therefore investigation of body composition is particularly important. In this period requirements will be created for the health situation in the adult age. In childhood it is useful to detect deficiency because along the way prevention or intervention programs can be implemented.

In general, to determine body composition and body shape anthropometric measurements and different indices are used. Every individual has a typical body shape. Different researchers created somatotype concepts which showed bipolar or tripolar systems. Sheldons (1940) theory based on the three germ layers. Therefore his types were called: endomorphic, mesomorphic and ectomorphic. Carter and Heath (1990) advanced this concept for which several anthropometric measurements were needed. Strömgren (1937) and Conrad (1961) developed a concept which based on the Metrik-Index. Three anthropometric measures were used to calculate this index. Three types of body shape were defined: pyknomorphic, metromorphic and leptomorphic type. Over the time human beings changed with the result that the Metrik-Index has to be adapted (Greil and Möhr, 1996). These three somatotypes exhibit specific physical attributes in statistical cumulative combinations. Normal weighted pyknomorphic children and adults possess a higher percentage of body fat than normal weighted leptomorphic individuals. Pyknomorphic people therefore need fewer energy intake than leptomorphic ones. During periods of food shortage pyknomorphic individuals had a higher opportunity to survive. Today a surplus of food exists at least in industrial countries as a result the former advantage is no longer needed. Therefore, the risk to be overweight is higher in pyknomorphic individuals (Greil, 1993; Trippo and Klipstein-Grobusch, 1998; Scheffler and Schüler, 2009). Further on, pyknomorphic girls showed an android type of body shape and leptomorphic ones a gynoid type. Android types exhibited higher trunk fat which is a problem when children are overweight (Scheffler and Obermüller, 2012).

To classify individuals as overweight, normal weight or underweight the Body Mass Index is used (Cole et al., 2000; Krohmeyer-Hausschild et al., 2001). More and more children are classified as overweight. Meanwhile this is not only a problem in industrial but also in emergent and developing countries (Popkin et al., 2012). In Germany 15%, in India 70%, in Saudi Arabian 23%, in Brasilia 15% of the children and adolescent are overweight (Kurth & Schaffrath Rosario, 2007; El Mouzan et al., 2010; Alexius et al., 2012; Schönfeld Janewa et al., 2012). Children who are overweight have the elevated risk to get cardiovascular diseases, diabetes or skeletal system disorders (Melanson et al., 2001; Visscher & Seidell, 2001; Esposito et al., 2013).

In addition to the finding of increased obesity another new development arises concerning the skeletal system. In German schoolchildren a ten year comparison showed a significant decrease of external skeletal robustness in 6-12 years-olds. The reduction of external skeletal robustness can be found in the 3rd and 10th percentile. In the 10th percentile external skeletal frame size is reduced in boys by 9-19% and in girls by 7-11%. In 2010 the values of the 10th percentile are lower than the 3rd percentile in 2000 (Scheffler, 2011a). Moreover, results have shown that shoulder and pelvic widths were also significantly reduced. The skeleton was narrower than ten years ago (Scheffler, 2011b). Children with a decreased external skeletal robustness will have it their whole lifetime. When they are seniors and especially overweight the prevalence of joint diseases and osteoporosis may increase. This would result in a high cost factor for the health system.

There are various interacting factors which influence body fat accumulation and the skeletal system. Body fat deposition and the skeletal system are affected by genetic factors (Stunkard et al., 1986; Bouchard et al., 1988; Pollitzer & Anderson, 1989). Besides personality traits and environmental factors also have an impact on them, e.g. impulsivity, nutrition, socioeconomic status, leisure activities and physical activity.

In children, the personality trait impulsivity is positively related with Body Mass Index. Children who showed a higher Body Mass Index acted impulsively. Impulsivity predicts Body Mass Index indirectly through overeating (Nederkoorn et al., 2007; Pauli-Pott et al., 2010; Van den Berg et al., 2011). Nutrition is another important factor. Food systems and dietary habits changed which leads to an increased energy intake worldwide (Popkin, 2012). This may encourage fat deposition. The skeletal system is influenced by the diet of pregnant women and calcium intake especially at an early age (Tobias et al., 2005; Johnston et al., 1992; Slemenda et al., 1991). In German children calcium intake is sufficient due to regularly intake with the result of no deficiency (Flynn et al., 2009).

Furthermore, socioeconomic conditions are promoting overweight. In India which is a developing country the risk to be overweight is associated with high socioeconomic status (Schönfeld Janewa et al., 2012). In contrast German children are overweight whose parents have a low socioeconomic status (Danielzik et al., 2004). Shrewsbury and Wardle (2008) also showed these opposed results in their literature review. On the other hand leisure activities changed in many countries. Sedentary behavior like TV viewing or playing video games increased and at the same time physical activity is reduced. Both together elevate the risk of obesity (Jackson et al., 2009; Basterfield et al., 2010; Beyerlein et al., 2011; Lissner et al., 2012; Hohensee and Nies, 2012). Socioeconomic status as well influences TV viewing and physical activity such as an Eastern European study showed. Children with a low socioeconomic status spent more time with TV viewing and they participated in the sports club less frequently with the result of lower physical activity (Klimatskaya et al., 2011; Lämmle et al., 2012). Nevertheless, physical activity does not only affect body fat accumulation in a positive way but also the skeletal system even more than calcium intake (Forwood and Burr, 1993; Welten et al., 1994; Gutin et al., 1999). Furthermore, physical activity positively affects external skeletal robustness in preschool children (Scheffler et al., 2007). It is also crucial which form of sport is performed. Sportsman who practice rugby, soccer, fighting sports or athletic sports exhibit a higher bone mineral density as swimmers or cyclists (Morel et al., 2001). The reason for this is that a specific threshold of strain (≥ 1000 mircostrain) has to be exceeded to build additional bone mass. 1000 microstrain leads to a bone about 0.1% (Baumann, 2005).

Worldwide, the physical activity is lower than a few years ago. Ten year comparisons showed that the physical fitness, which is a result of physical activity, is reduced in British children and in Czech Republic adolescents

(Sandercock et al., 2010; Sigmundová et al., 2011). The WHO has recommended that youth accumulate 60 minutes of physical activity each day (WHO, 2010). In Germans, only 13.1% of girls and 17.4% of boys were 60 minutes physically active daily (Jekauc et al., 2012). In a country comparison between children from Greece, Netherlands, Belgium, Switzerland and Hungary only 4.6% of girls and 16.8% of boys reached the level of 60min/day. Swiss children are more physically active than their contemporaries (Verloigne et al., 2012). Furthermore, it was represented that Russian children performed better fitness tests than Americans. Russian children spent more time in structured training sports clubs and walk to and from school (Hastie et al., 2010). Probably, a trend which has been enforced from the end of the 90th where only 33% of the Russian households held a car and no school busses were available, so 92% of the children went to school by walking (Tudor-Locke et al., 2002). However, active commuting decreased in US, Canada, UK and Australia which encourage daily physical activity (McDonald, 2007; Buliung et al., 2009; Southward et al., 2012).

The associations between body composition and physical activity are sophisticated. In the following open problems and hypotheses are represented.

2.1 Open problems and hypotheses

a) It is established that the somatotype is associated with percentage of body fat and android/gynoid body shape. However, it is not clarified whether these types are linked with skeletal measurements respectively external skeletal robustness. It is supposed that pyknomorphic children exhibit a higher external frame size than leptomorphic and metromorphic ones. Additionally, question will be answered if type of body shape influences physical activity.

b) External skeletal robustness and physical activity decreased in children. It is assumed that both are associated and physical activity measured by pedometer influences external skeletal robustness. Furthermore, the link between physical activity, leisure activities, BMI, percentage of body fat and external skeletal robustness is investigated.

c) Moreover, questions arise whether that negative trend of decreased external skeletal robustness is a global development such as obesity and how the trend proceeds as compared to other countries. In this study anthropometric data of German children were compared with data of Russian children from 2000 and 2010. Due to the globalization, the political development, the lower physical activity in Eastern Europe states and the fact that Russian children are fitter than the American children it is suggested that the negative changes reach the Russian population after a time delay. Differences between Russian and German body composition in 2000 and an approach in 2010 are supposed.

3. Subjects and Methods

3.1 Ethics statement

Investigations were approved by relevant institutions: Senate Department of Education, Science and Research Berlin (Permit number: VI D 1) and Ministry of Education, Youth and Sports Brandenburg (Permit number: 60/2010). The study was implemented on a voluntary basis with parents` permission. They signed a written informed consent but finally the children should agree with participation as well. All data was anonymized.

3.2. Sample

In this cross-sectional study 691 boys and girls aged from 6 to 10 completed years were examined between November 2010 and March 2012 (Tab. 1). Measurements were taken at twelve elementary schools from different districts in Berlin (Steglitz, Zehlendorf, Prenzlauer Berg, Treptow) and federal state Brandenburg (Groß Glienicke, Potsdam, Erkner, Dabendorf, Fredersdorf-Vogelsdorf, Teltow). Therefore children were from varying social backgrounds (Häussermann et al., 2011) which, however cannot be assigned to an individual level due to German data protection laws.

Table 1. Sample allocation

	age					
sex	**6**	**7**	**8**	**9**	**10**	**all**
boys	53	85	58	89	53	338
girls	53	76	77	92	55	353
all	106	161	135	181	108	691

Comparisons of the body composition from Russian and German children were realized. Therefore, data from Russian children aged 6 to 10 completed years from the years 2000 and 2010 were placed at the disposal. Data collection was authorised by the Department of Education of Moscow city and was implemented at schools in Moscow.

Data of the German children from the years 2000 and 2010 was taken from the data base of the AG Human Biology (University of Potsdam). Furthermore, data from 2010 of the data base was supplemented by 691 children who were measured by the author. Allocation of samples in sex and nationality is represented in Table 2.

Table 2. Sample allocation of Russian and German children 2000/2010

		age					
year/country/sex		**6**	**7**	**8**	**9**	**10**	**∑**
2000	Russian all	69	267	279	276	132	1023
	Russian girls	38	117	137	118	68	478
	Russian boys	31	150	142	158	64	545
	German all	407	333	386	487	490	2103
	German girls	177	175	209	248	241	1050
	German boys	230	158	177	239	249	1053
2010	Russian all	3	93	68	59	45	268
	Russian girls	0	44	33	21	18	116
	Russian boys	3	49	35	38	27	152
	German all	226	407	358	426	333	1750
	German girls	121	204	201	211	163	900
	German boys	105	203	157	215	170	850

3.3 Anthropometric measurements and indices

3.3.1 Anthropometric measurements

Anthropometric measurements were followed by standardized methods due to receive reproducible data. Based on the bilateral symmetry of the human body it was defined that measurements were taken on the right side of the body. All measurements were done in a standing position. The stance in the standing position was upright and taut but not over flexed. Body mass was consistently distributed on each foot, heels were closed to each other and the tiptoe were a bit spread. Shoulders were relaxed and the arms hanged stretched aside the body. The head had to regulate in the Frankfurt horizontal plane (Flügel et al., 1986; Knußmann, 1988). Anthropometric instruments were from DKSH Switzerland. Caliper Holtain LTD (UK) was used to measure skin folds (Fig. 1). Measured parameters were illustrated in Tab. 3 and data was registered in a measuring report (VI. Appendix).

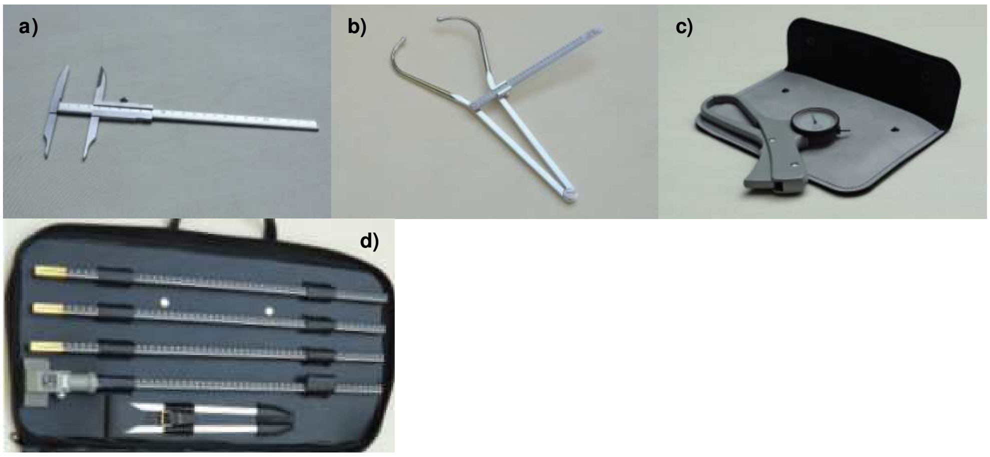

Figure 1. Anthropometric instruments. Pictures: DKSH Switzerland a) Sliding caliper b) Spreading caliper c) Skinfold caliper d) Anthropometer

Table 3. Measure, section of measurements and used instruments

Measure	Section of measurements	Instrument
Weight		Calibrated scale
Measure of length		
Height	Floor space-Vertex	Anthropometer
Measure of breadth and depth		
Elbow breadth	Humerale mediale - humerale laterale	Spreading caliper
Wrist breadth	Linear distance stylion radiale-stylion ulnare	Sliding caliper
Ankle breadth	Linear distance supratarsale fibulare-supratarsale tibiale	Sliding caliper
Knee breadth	Merion medial - merion lateral	Spreading caliper
Thoracic width	Max. breadth at a hight of Xyphiale	Spreading caliper
Thoracic depth	Xyphiale - spinous process of the thoracic vertebra in the horizontal plane	Spreading caliper
Skin folds		
Subscapular skin fold	Skewed below scapula	Skinfold caliper
Triceps skin fold	Skin fold above Musculus triceps brachi	Skinfold caliper

3.3.2 Indices – Assessment of body mass, body composition and type of body shape

Body Mass Index

Body Mass Index is used to assess the nutritional status of children and adults. In children overweight/obesity and underweight status is determined by 95th, 97th, 3rd and 10th percentiles. Normal weight children exhibit values between 10th and 90th respectively 95th percentile (Cole et al., 2000; Krohmeyer-Hausschild et al., 2001).

$$\text{BMI} = \frac{\text{weight in kg}}{(\text{height in m})^2}$$

Percentage of body fat

Slaughter et al. (1988) developed a formula to evaluate percentage of body fat at prepubescent children aged 0-12 years. For this measurement of triceps skin fold and subscapular skin fold are used. Different calculations are needed if the sum of triceps skin fold and subscapular skin fold is < 35mm respectively > 35mm.

Total triceps skin fold and subscapular skin fold

Boys: % body fat = 1.21*(triceps skin fold+subscapular skin fold) – 0.008*(triceps skin fold + subscapular skin fold)^2 - 1.7

Girls: % body fat = 1.33*(triceps skin fold+subscapular skin fold) – 0.013*(triceps skin fold + subscapular skin fold)^2 - 2.5

Total triceps skin fold and subscapular skin fold > 35mm

Boys: % body fat = 0.783*(triceps skin fold+subscapular skin fold) + 1.6

Girls: % body fat = 0.783*(triceps skin fold+subscapular skin fold) + 9.7

External skeletal robustness

By use of Frame-Index it can be concluded on external skeletal robustness. For this purpose height and elbow breadth are used. Elbow breadth is a measure which is low correlated with body fat and is well measurable on individuals with a high fat proportion. In addition Frame-Index is positively related to skeletal mass (Frisancho & Flegel, 1983; Frisancho, 1990; Greil, 1998).

$$\text{Frame-Index} = \frac{\text{elbow breadth in mm*100}}{\text{height in cm}}$$

Skeletal mass

Matiegka (1921) supposed that the fat mass is determinable through skin folds, muscle mass is assignable through skin folds/volumes and skeletal mass is definable through bone widths. Therefore he developed a formula to calculate skeletal mass for what four bone widths in cm, height in cm and somatotype is used.

$$\text{Skeletal mass} = \frac{\left(\frac{\text{elbow breadth+knee breadth+wrist breadth+ankle breadth}}{4}\right)^2 * \text{height}}{1000} * K_{1,2,3}$$

K_1 = 1.0 leptomorphic type

K_2 = 1.1 metromorphic type

K_3 = 1.2 pyknomorphic type

Metrik-Index

Metrik-Index is a proportion index which depends on sex and age. It is calculated through height, breast depth and breast width. As a result basic form of the body may recognized as a cylinder with a round or oval shape. Low values of the Metrik-Index mark the leptomorphic type (tall-willowy) who shows a tall and oval shape. High values define the pyknomorphic type (small-wide bodied) who exhibits a round and barrel-shaped profile. Metromorphic type is located between the leptomorphic and pyknomorphic type (Fig. 2). Somatotypes are determined by 20^{th} and 80^{th} percentiles. 20% of the lowest values are classified as leptomorphic and 20% of the highest values are accessed as pyknomorphic. 60% are ranged as metromorphic (Greil, 1998).

In view of the low number of cases (691 subjects) 20^{th} and 80^{th} percentile was not calculated for this sample size. Assignment of the somatotypes is ensued by reference to calculated percentiles of Schilitz (2001) due to the major sample size (VI. Appendix).

Metrik-Index was calculated in the following way (Greil and Möhr, 1996; Greil, 1997):

Metrik-Index$_{male}$ =

-0.3647-(0.0401*height in cm)+(0.1253*thoracic breadth in cm)+(0.1540*thoracic depth in cm)

Metrik-Index$_{female}$ =

-2.6539-(0.0348*height in cm)+(0.1640*thoracic breadth in cm)+(0.1799*thoracic depth in cm)

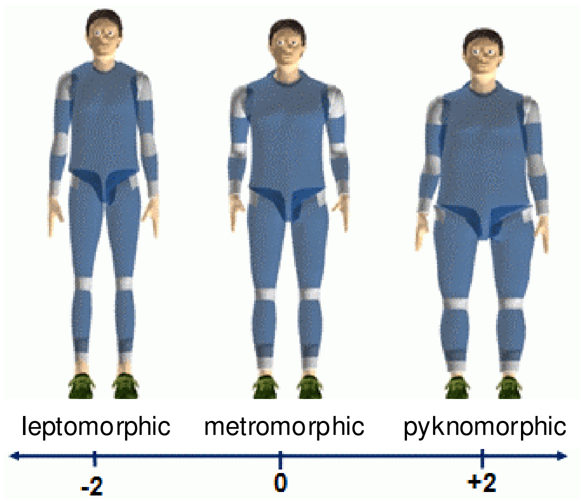

Figure 2. Somatotyping by Conrad (1961) and Greil and Möhr (1996). Variation series: leptomorphic, metromorphic and pyknomorphic type with typical body shape.

Comparison of the body composition in Russian and German children

Through anthropometric data of Russian and German children from the years 2000 and 2010 BMI and Frame-Index were calculated. BMI, Frame-Index and height were compared.

3.4 Physical activity and recreation in children

Physical activity was measured by pedometer. Leisure activities which included sports activity and TV time were investigated through parents` questionnaire in 691 German children.

Physical activity was analysed using a pedometer (Fig. 3). A pedometer counts steps and is attached close to the hip. It possesses piezoceramic sensors which register hip movements. The movements will convert steps by means of internal mathematic formula. For this study *Kenz Lifecorder e-step* pedometers were used which were rated suitable for scientific studies (Schneider et al., 2004; Nakae et al., 2008). A pedometer was worn consecutively for 7 full-days excluding night and shower/bath time (variable: total steps per week – total steps p.w.). One week was shown to be sufficient to obtain reliable data (Kang et al., 2009). However, it was a problem to get pedometer data for 7 full-days. Children and parents did not wear and monitor pedometer consistently. The investigator only got data for 7 full-days in 377 children.

Figure 3. *Kenz Lifecoder e-step* pedometer – its size and position close to the hip.

Furthermore, a questionnaire was answered by parents about visiting sports club, rate of visiting sports club per week, the training time per day and type of sport. In addition, TV viewing time in minutes per day was prompted. This variable belongs to physical inactivity (VI. Appendix). Questionnaire also contained other information about children but the investigator did not use them for this study because they were not important in this context. Moreover, the author did not recover every survey and in some cases parents did not answer every question. Nevertheless, more than 610 surveys were available.

3.5 Fault analysis and correction

Different faults may occur during the measurement, listening and data transfer. Body mass are determined by electrical weighing scale which exhibited a measuring error of 0.05kg. It should be noted that body mass vary during the day, e.g. in the morning individuals are lighter than in the evening.

Anthropometric instruments were in a good state therefore reading errors due to faded increments were impossible. Anthropometer, skinfold caliper, sliding caliper and spreading caliper displayed a measurement accuracy of 1mm thus measuring error lay at 0.05mm. During the day height also vary because backbone is compressed over the day. Measurements of height were taken in the morning till early in the afternoon.

Measurements of skinfolds were made by skinfold caliper. Strength of the fascia and the connection between the single histoid components exacerbated the measurements. As a consequence each skin fold was measured three times and the average was calculated.

Measured values were announced loudly and clearly at a minute taker due to ensure a fast progress at the measurement. Listening defects were unable to absolutely exclude.

Anthropometric measured values, values of pedometer and also information of the survey were transferred in the PC. Each value was twice proved.

Faults of the anthropometric measurements were determined by

a) histograms
b) investigation of the values which displayed triple of standard deviation
c) the concept of impossibility (thoracic breadth is higher than thoracic depth, knee breadth is higher than ankle breadth, elbow breadth is higher than wrist breadth).

3.6 Statistical analysis

Normal distribution

Normal distribution was tested using a Kolmogorov-Smirnov-Test. Variables Frame-Index and total steps p.w. showed normal distribution and the data of the parameter percentage of body fat underwent log-transformation for normal allocation. The other data of the variables showed no normal distribution.

Type of body shape, skeletal measurements and physical activity

Skeletal mass was not normal distributed therefore Kruskal-Wallis-Test was used to identify type of body shape as influencing factor. To clarify the differences between the types of body shape (leptomorphic-metromorphic, metromorphic-pyknomorhic, leptomorphic-pyknomorphic) Mann-Whitney-Test was applied therefore significance level had to be changed using Bonferroni correction p = .05/3 = .017 (‡).

Frame-Index and total steps p.w. were normal distributed therefrom one-way analysis of variance (ANOVA) was used to show whether type of body shape affected these variables.

Associations between body composition, physical activity and recreation

Multivariate analysis of covariance (MANCOVA) was implemented to investigate whether physical activity explains body measures and how this is affected by sex and age. Two factors - age and sex - and one covariate - total steps p.w. - were used. The dependent variables were Frame-Index and percentage of body fat. Additionally, one-way ANOVA was used to clarify the effects of age and sex on total steps and the differences between the age groups. Moreover, the same test was used to clarify whether type of sport and the quantity of type of sport affect Frame-Index. In girls and boys it was additionally investigated whether visiting sports club influences total steps per week. For this purpose two tailed T-Test was used.

The other variables were tested using Mann-Whitney-Test to identify sex effects and Kruskal-Wallis-Test was used to illustrate age effects. To identify differences between the five age groups Bonferroni correction was needed p = .05/5 = .01 (†) and for every age combination (e.g. 6 and 7, 7 and 8 etc.) Mann-Whitney-Test was used.

Correlation-tests from Pearson and Spearman were implemented to clarify the relationships between the variables Frame-Index, BMI, percentage of body fat, TV viewing time in min/d, sports club rate p.w., training time in min/d and total steps p.w..

Principal Component Analysis (PCA) with varimax rotation was used to structure and illustrate these associations. Kaiser-Meyer-Olkin-criterion (KMO) was used to show whether data set is suitable for PCA. Values between 0.5 and

0.7 are mediocre (Field, 2009). KMO-value (.523) and Bartlett-test ($\chi^2 = 769.5$, df = 21, $p < .001$) showed that a useful analysis can be realized.

Comparison of body composition in Russian and German children

Samples sizes of the different years 2000/2010 and States Russian/German differ greatly (Tab. 2). Therefore to determine differences between the groups non-parametric test - Mann-Whitney-Test - was used. Furthermore 3rd, 10th, 50th, 90th and 97th percentiles were calculated and the curves were smoothed with LMS method of Pan and Cole (2011).

Significance levels

The following significance levels were used: $p < .001$ (***), $p < .01$ (**), $p < .05$ (*). Statistical analysis was realized using the program SPSS 19 and 21 IBM for Windows.

4. Results

4.1 Relationships between type of body shape, skeletal measurements and physical activity

4.1.1 Association between type of body shape and Frame-Index

In boys and girls analysis showed differences between leptomorphic, metromorphic and pyknomorphic type of body shape concerning the Frame-Index (Fig. 4). The pyknomorphic type exhibited the highest Frame-Index values in contrast to the leptomorphic type. In girls type of body shape is significantly associated with Frame-Index (ANOVA: $F = 25$, $df = 2$, $p < .001$). Frame-Index was different between the leptomorphic and metromorphic type ($p = .002$), the leptomorphic and pyknomorphic type ($p < .001$) and also between the metromorphic and pyknomorphic ones ($p < .001$).

In boys type of body shape was also significantly related to Frame-Index (ANOVA: $F = 16.267$, $df = 2$, $p < .001$). Frame-Index differed between the leptomorphic and metromorphic type ($p < .001$) and as well between the leptomorphic and pyknomorphic ones ($p < .001$). There was no difference between the metromorphic and pyknomorphic type ($p = .025$).

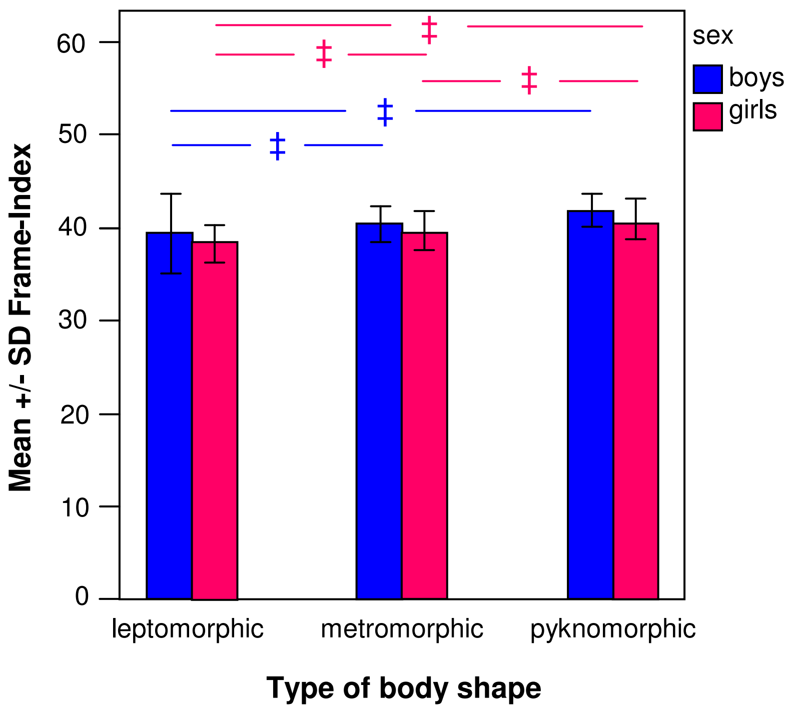

Figure 4. Bar plots indicate Frame-Index for each type of body shape. Blue bars - boys; pink bars - girls; (‡) $p = .017$

4.1.2 Association between type of body shape and skeletal mass

Boxplots showed skeletal mass and type of body shape in girls and boys (Fig. 5). In general, girls exhibited a lower skeletal mass than boys. In both sexes the pyknomorphic type displayed the highest skeletal mass and the leptomorphic type the slightest mass.

In girls the difference between the type of body shape was significant (χ^2 = 72.704, df = 2, p < .001). Differences existed between the leptomorphic and metromorphic type (U = 4796, p < .001), the leptomorphic and pkynomorphic type (U = 711, p < .001) and also between the metromorphic and pyknomorphic ones (U = 3576, p < .001).

In boys the difference between the type of body shape was also significant (χ^2 = 35.27, df = 2, p < .001). Skeletal mass was different between the leptomorphic and metromorphic type (U = 6963, p = .002), the leptomorphic and pyknomorphic type (U = 765, p < .001) and also between the metromorphic and pyknomorphic type (U = 2685, p <.001).

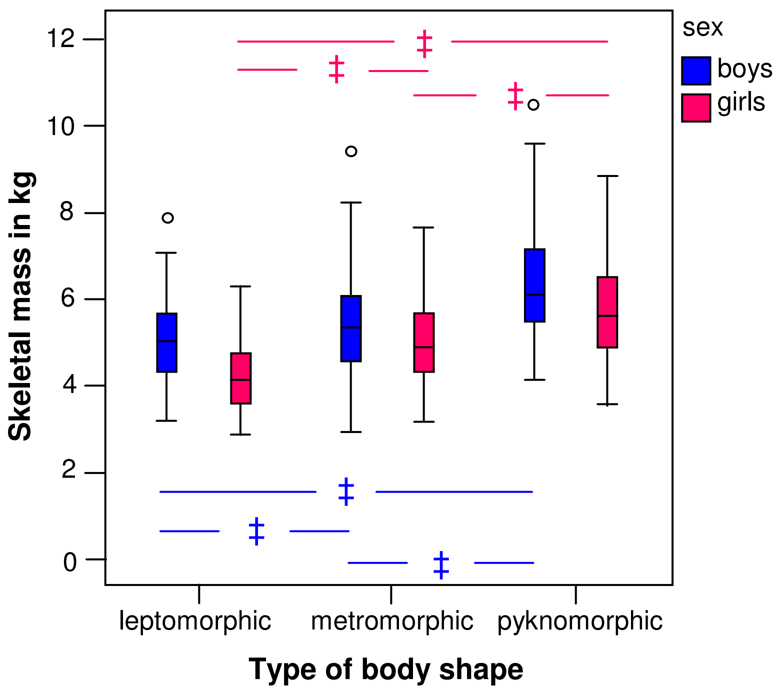

Figure 5. Boxplot shows skeletal mass in kg for each type of shape. Medians are indicated by solid lines and circles are light outliers. Blue boxes - boys, pink boxes – girls; (‡) p = .017

4.1.3 Association between type of body shape and physical activity

Figure 6 displays total steps per week and type of body shape in girls and boys. Girls who had a metromorphic type of body shape exhibited the most total steps per week. The leptomorphic type showed the fewest total steps per week. However, type of body shape did not influence total steps per week (ANOVA: F = 0.999, df = 2, p = .370).

Pyknomorphic boys went the most steps per week. Subjects who exhibited the leptomorphic and metromorphic type showed a similar amount of total steps per week. Type of body shape did not had an effect on total steps per week (ANOVA: F = .513=, df = 2, p = .600).

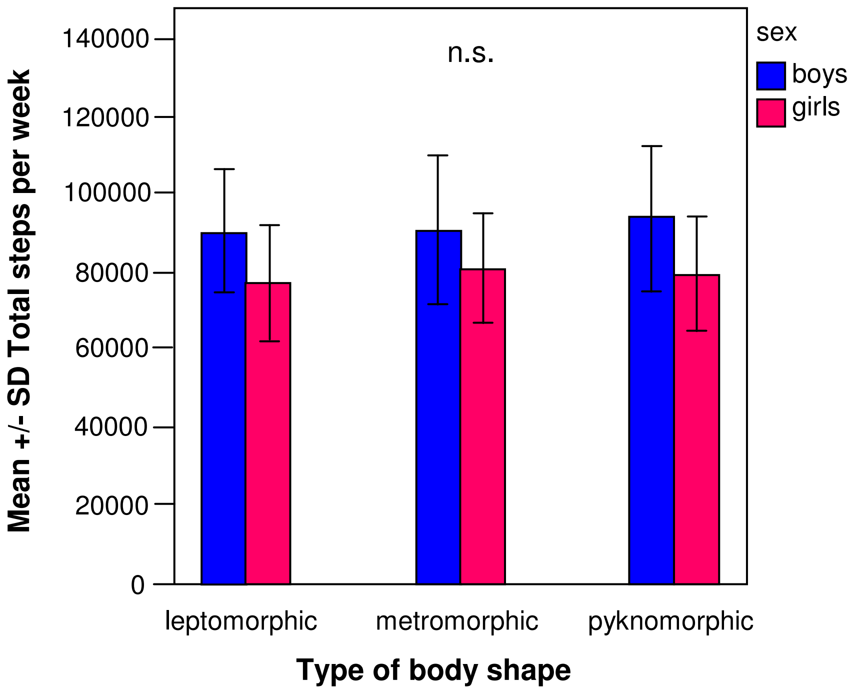

Figure 6. Bar plots depict total steps per week for each type of body shape. Blue bars - boys, pink bars - girls; n.s. - no significance

4.2 Associations between external skeletal robustness, BMI, percentage of body fat, physical activity and recreation

4.2.1 Descriptive analysis and influencing factors

Table 4 depicts mean and standard deviation of the variables: Frame-Index, BMI, % body fat, total steps, sports club rate, training time and TV viewing time.

Table 4. Mean and standard deviation (SD) for each variable by sex

	Boys		Girls		All	
Variable	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Frame-Index	40.42	1.78	39.24	1.97	39.82	1.97
BMI in kg/m²	16.98	2.57	17.11	2.53	17.07	2.47
% body fat	13.78	5.25	15.72	6.02	14.78	5.72
Total steps per week	90422	18723	79252	14441	85030	17677
Sports club rate per week	1.32	1.25	0.97	1.02	1.25	1.15
Training time in min/d	87.14	40.71	81.94	31.46	53.5	50.11
TV viewing time in min/d	56.1	32.31	52.42	30.13	54.18	31.23

Frame-Index

Frame-Index was lower in girls 39.24±1.97 than in boys 40.42±1.78 on average. Frame-Index is effected by sex (MANCOVA: Wilks-Lambda F = 27.41, df = 1, p < .001) and total steps p.w. (MANCOVA: Wilks-Lambda F = 4.83, df = 1, p = .029). Age did not influence Frame-Index (MANCOVA: Wilks-Lambda F = .69, df = 4, p = .593) (Fig. 7).

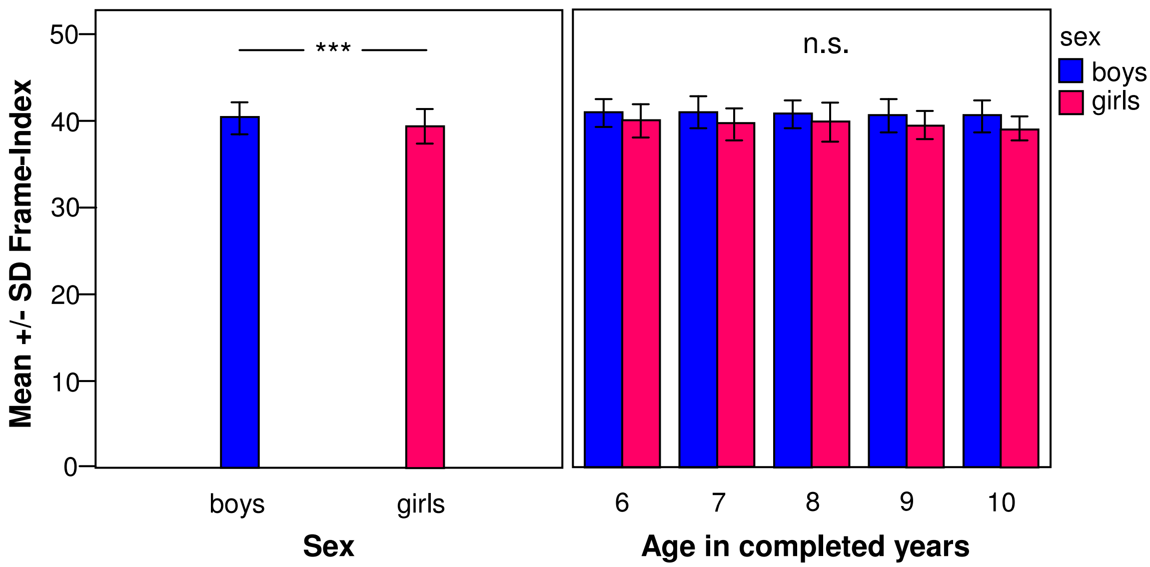

Figure 7. Bar plots depict mean +/- SD Frame-Index for 6 to 10 year-old boys and girls. Blue bars - boys, pink bars - girls; n. s. - no significance, (***) p < .001

Frame-Index and type of sport

The preferred type of sport differed between girls and boys. 53% of the girls preferred dancing, 19% judo/karate and 14% athletics. The most unpopular type of sport was soccer. In boys, the most-popular type of sport was soccer 49%, followed by judo/karate 22% and athletics 10%. Dancing was not preferred (2%).

In general, 85% of the girls and 80% of the boys performed one type of sport. All the rest did two or three types of sport. In both sexes quantity of type of sport did not influence Frame-Index (ANOVA girls: $F = .250$, $df = 2$, $p = .779$ and ANOVA boys: $F = .809$, $df = 2$, $p = .448$). In addition, type of sport did not affect Frame-Index as well (ANOVA girls: $F = .790$, $df = 5$, $p = .559$ and ANOVA boys: $F = .510$, $df = 5$, $p = .768$) (Fig. 8).

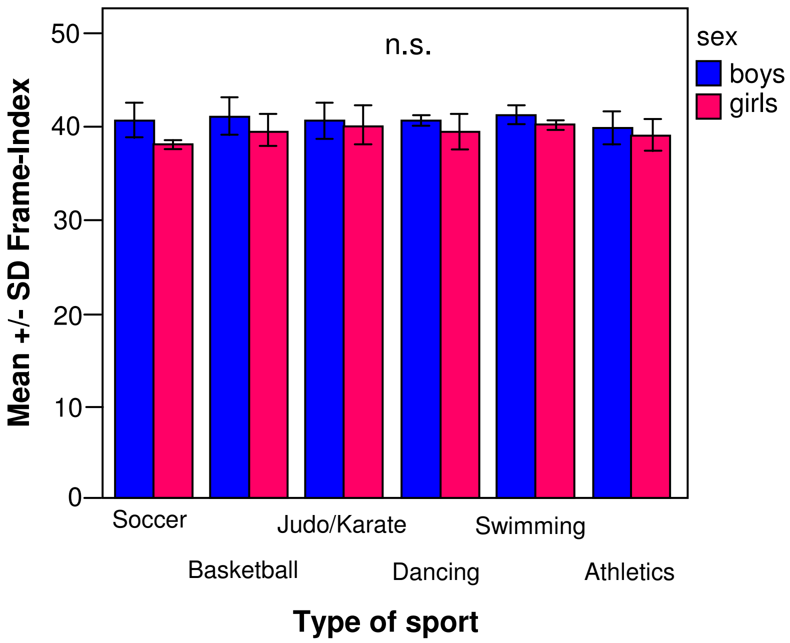

Figure 8. Type of sport in relation with Frame-Index in boys and girls. Blue bars - boys, pink bars - girls; n.s. no significance

Body Mass Index

Girls showed higher BMI 17.11±2.53 kg/m² as opposed to boys' 16.98±2.57 kg/m². Sex did not influence BMI ($U = 58800$, $p = .795$). BMI is only affected by age ($\chi^2 = 66.032$, $df = 4$, $p < .001$). In girls BMI was different in 6 and 9 year-olds ($U = 1534$, $p < .001$), 6 and 10 year-olds ($U = 699$, $p < .001$), 7 and 9 year-olds ($U = 2446$, $p < .001$), 7 and 10 year-olds ($U = 1147$, $p < .001$) and 8 and 10 year-olds (U

= 1479, p = .003). In boys BMI was different in 6 and 9 year-olds (U = 1571, p < .001), 6 and 10 year-olds (U = 640, p < .001), 7 and 9 year-olds (U = 2855.5, p = .005), 7 and 10 year-olds (U = 1214, p < .001) and 8 and 10 year-olds (U = 1012, p = .002) (Fig. 9).

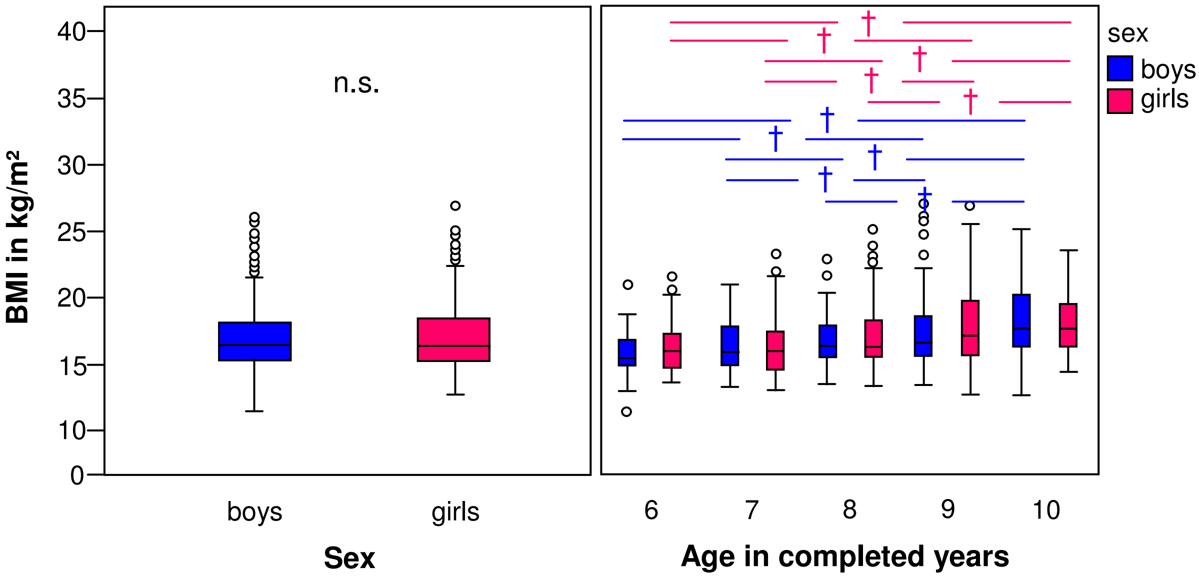

Figure 9. Boxplots show BMI in kg/m² for 6 to 10 year-old boys and girls. Blue boxes - boys, pink boxes - girls; Medians are indicated by solid lines, circles are light outliers and stars are extreme outliers; n.s. - no significance, (†) p = .01

Percentage of body fat

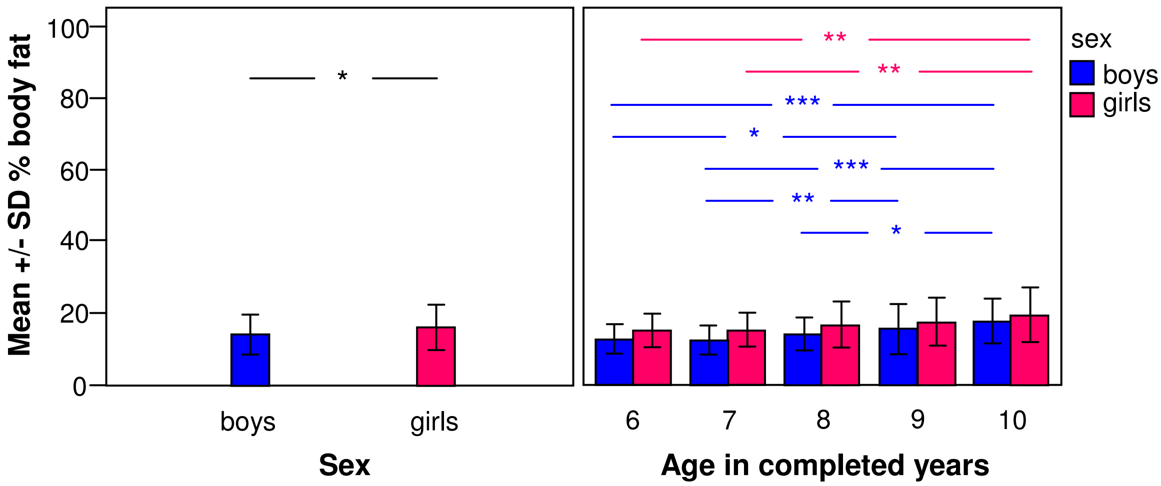

Figure 10. Bar plots indicate percentage of body fat for each sex and age group. Blue bars - boys, pink bars - girls; (***) p < .001, (**) p < .01, (*) p < .05

Girls exhibited a higher percentage of body fat 15.72±6.02 % than boys 13.78±5.25 %. Girls showed a higher percentage of body fat than boys in every age group. The older the children the higher were the percentage of body fat. In girls significant differences between 6 and 10 year-olds (p = .009) as well between 7 and 10 year-olds (p = .002) can be found. In boys percentage of body fat was different between 6 and 9 year-olds (p = .037), 6 and 10 year-olds (p < .001), 7 and 9 year-olds (p = .009), 7 and 10 year-olds (p < .001) and also 8 and 10 year-olds (p = .016) (Fig. 10). Factors age (MANCOVA: Wilks-Lambda F = 6.82, df = 4, p < .001), sex (MANCOVA: Wilks-Lambda F = 4.86, df = 1, p = .028) and the covariate total steps p.w. (MANCOVA: Wilks-Lambda F = 9.92, df = 1, p = .002) were influencing percentage of body fat.

Physical activity - total steps per week

Figure 11 shows total steps p.w. for 6 to 10 year old boys and girls. In a week girls went 79252±14441 steps as against to boys who went 90422±18723 steps. Sex and age effected total steps p.w. (MANCOVA: Wilks-Lambda F = 41.2, df = 1, p < .001 respectively Wilks-Lambda F = 6.7, df = 4, p < .001). In both sexes, total steps p.w. decreases with increasing age. In boys the differences between the age groups are not significant. In girls, 6 and 10 year-olds (p = .014), move more than 7 and 9 year-olds (p = .013) and 7 and 10 year-olds (p = .004).

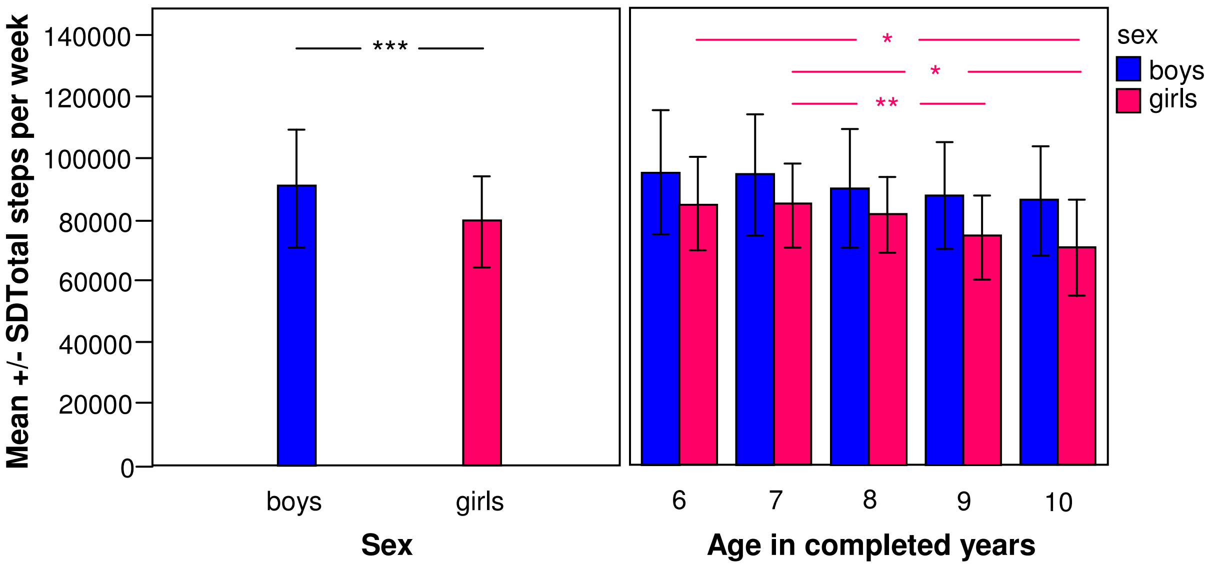

Figure 11. Bar plots indicate total steps per week for each sex and age group. Blue bars - boys, pink bars – girls; (***) p < .001, (**) p < .01, (*) p < .05

Physical activity – sports club rate per week

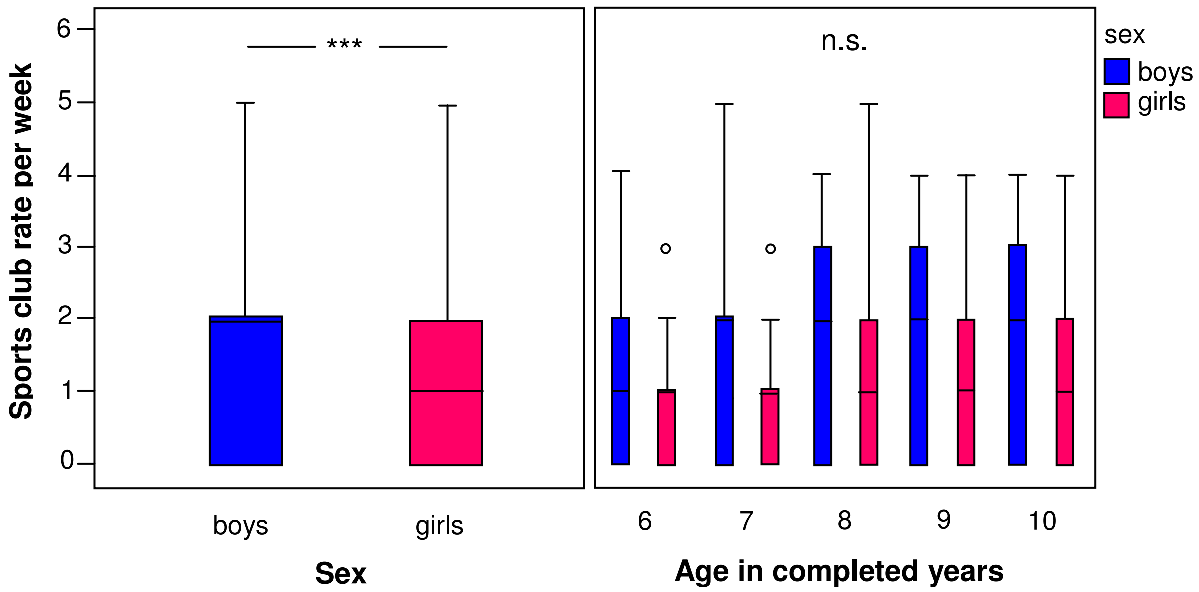

Figure 12. Boxplots depict sports club rate per week for each sex and age group. Medians are indicated by solid lines and circles are light outliers. Blue boxes - boys, pink boxes - girls; (***) p < .001

67.3% of boys and 62.5% of girls participated in sports club regularly. Sports club rate p.w. differed in boys and girls. Girls participated 0.97±1.02 times per week in sports clubs and boys visited 1.32±1.25 times per week sports. Sex (U = 51009, p < .001) is influencing sports club rate p.w.. Boys and girls tend to visit sports club more frequently as they grow older. Age (χ^2 = 10.8, df = 4, p = .029) has an impact on sports club rate p.w. However, only between 6 and 8 year-olds sports club rate p.w. was different (U = 4627, p = .006). Between the age groups in boys and girls no significant differences can be found (Fig. 12).

Girls practiced 81.94±31.46 min per day in contrast to boys who exercised 87.14±40.71 minutes. Sex (U = 42429.5, p = .037) and age (χ^2 = 9.613, df = 4, p = .047) influence training time in min/d.

Boys who visited sports club went 92029±19339 total steps p.w. in contrast to them who did not visit sports club. They exhibited 85586±16445 total steps p.w. (T = 2.176, df = 178, p = .031). In girls total steps p.w. were not significantly different between girls who attended sports club 79537±14810 and who did not 78337±14254 (T = .519, df = 172, p = .605).

Physical inactivity - TV viewing time in minutes per day

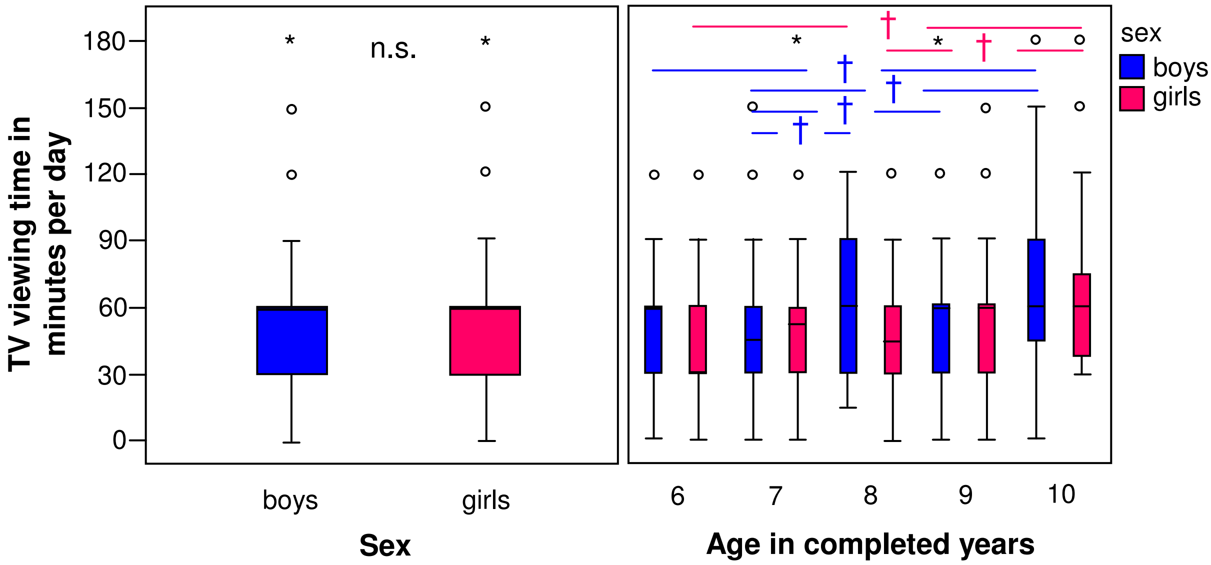

Figure 13. Boxplot shows TV viewing time in minutes per day which is affected by age but not by sex. Medians are indicated by solid lines, circles are light and stars are extreme outliers; blue boxes - boys, pink boxes - girls; (†) p = .01.

In girls 11.8% owned a PC, 17.8% a TV, 9.3% both and 61.1% none of the two. In boys 12.9% possessed a PC, 13.5% TV, 13.2% both and 60.4% neither. In Figure 13 TV viewing time in minutes per day in boys, girls and for each age group are presented. Girls watched less TV per day 52.42±30.13 min than boys' 56.1±32.31 min. But sex has no effect on TV viewing time (U = 45689, p = .124) in contrast to age ($\chi^2 = 27.2$, df = 4, p < .001). In girls TV viewing time in min/d was different between 6 and 10 year-olds (p = .001) and between 8 and 10 year-olds (p = .003). In boys differences between 6 and 10 year-olds (p = .006), 7 and 8 year-olds (p = .001), 7 and 9 year-olds (p = .002) and 7 and 10 year-olds (p < .001).

4.2.2 Correlations between Frame-Index, total steps, percentage of body fat, BMI, sports club rate, training time and TV viewing time

Correlation combinations are represented in Table 5. Sports club rate p.w. and training time p.d. are positively correlated with total steps p.w. and negatively related with percentage of body fat. Furthermore, total steps p.w. are positively associated with Frame-Index and negatively related with BMI and percentage of body fat. Additionally, BMI and percentage of body fat are positively correlated with Frame-Index. Moreover, BMI and percentage of body fat are positively associated with TV viewing time p.d.. Finally, BMI is positively related to percentage of body fat.

There is no correlation between total steps and TV viewing time p.d., sports club rate p.w. and Frame-Index, sports club rate p.w. and BMI, sports club rate p.w. and TV viewing time p.d., TV viewing p.d. and training time p.d. and TV viewing time p.d. and Frame-Index.

Table 5. Correlation matrix with seven variables including r, rho, n and p-values.

Correlation	Frame-Index	Total steps per week	% body fat	BMI in kg/m²	Sports club rate per week	Training time in min/d	TV viewing time in min/d
Frame-Index							
	1						
Total steps per week	r = .222[a]						
	p < .001* **	1					
	n = 377						
% body fat	r = .086[a]	r = -.263[a]					
	p = .024*	**p < .001*** **	1				
	n = 690	n = 376					
BMI in kg/m²	rho = .308	rho = -.123	rho = .758				
	p < .001* **	**p = .017***	**p < .001*** **	1			
	n = 690	n = 376	n = 689				
Sports club rate per week	rho = .033	rho = .187	rho = -.130	rho = -.047			
	p = .406	**p < .001*** **	**p = .001** **	p = .237	1		
	n = 634	n = 354	n = 633	n = 633			
Training time in min/d	rho = -.003	rho = .142	rho = -.155	rho = -.078	rho = .828		
	p = .946	**p = .009** **	**p < .001*** **	p = .053	**p < .001*** **	1	
	n = 612	n = 341	n = 611	n = 611	n = 612		
TV viewing time in min/d	rho = -.063	rho = -.063	rho = .203	rho = .169	rho = .011	rho = .000	
	p = .118	p = .118	**p < .001*** **	**p < .001*** **	p = .786	p = .995	1
	n = 627	n = 350	n = 626	n = 626	n = 627	n = 605	

[a]Pearson`s correlation test; others Spearman`s correlation test
r = Correlation coefficient
rho = Spearman´s correlation coefficient
p = p-value, significant correlations in bold
n = sample size

4.2.3 Principal Component Analysis

Table 6 shows variables, variances and rotated component matrix of the Principal Component Analysis. Seven variables were used for the PCA. Three important variables resulted after rotation with following percentage of variation: total steps p.w. 29.3%, TV viewing time in min/d 25.2% and sports club rate p.w. 18.3%. Rotated component matrix showed three components: Component 1 "Bone activity" charges total steps p.w. and Frame-Index. Component 2 "Inactivity" contains TV viewing time, BMI and percentage of body fat. Sports club rate and training time describes component 3 "Physical activity".

Table 6. Principle component analysis: percentage of total variance explained and rotated component matrix

Variable	Total variance explained: Initial Eigenvalues		Extraction Sums of Squared Loadings		Rotation Sums of Squared Loadings		Rotated component matrix: 1	2	3
	Total	% of variance	Total	% of variance	Total	% of variance			
Total steps	2.191	31.303	2.191	31.303	2.052	29.313	-.338	.189	**.684**
TV viewing time	1.699	24.276	1.699	24.276	1.770	25.288	**.481**	.123	-.265
Sports club rate	1.206	17.231	1.206	17.231	1.275	18.209	-.024	**.920**	.098
Training time	.866	12.374					-.033	**.923**	.005
BMI	.617	8.820					**.897**	-.072	.248
Frame-Index	.268	3.828					.275	-.023	**.815**
% body fat	.152	2.169					**.907**	-.125	-.019

In bold – the highest loading values for each component

4.3 Comparison of body composition in Russian and German children

Results will be illustrated in the following way - Russian children: comparison 2000 and 2010, German children: comparison 2000 and 2010, Russian and German children in 2000, Russian and German children in 2010.

4.3.1 Russian children: Comparison 2000 and 2010

In Russian children the comparison between 2000 and 2010 showed that only BMI ($U = 109163$, $p < .001$) was distinguished but not height ($U = 130448$, $p = .222$) and Frame-Index ($U = 102801$, $p = .343$).

Russian boys were taller (height: 134.7 cm; $p = .034$) and exhibited a higher BMI ($p < .001$) in almost every age group in 2010. Frame-Index was decreased (2000: 42.1 vs. 2010: 41.41; $p = .002$) (Tab. 7, 8). Percentiles of Frame-Index are presented in Figure 14. The curves fluctuate in 2010. In 6 year-olds values were lower and in 8 year-olds they were higher than in the other age groups. In 6, 7, 9 and 10 year-olds every value of the percentiles in 2010 laid below of those from 2000.

In girls, only BMI ($p < .001$) was higher in 2010 (BMI: 16.79 m^2/kg) than in 2000 (BMI: 15.99 m^2/kg) (Tab. 7, 8). Russian girls were taller till the age of 10 in 2000. Frame-Index did not differ between the years. Figure 15 displays 3rd to 97th percentiles of Frame-Index. Data of 6 year-olds is missing. However, in every age group percentiles were higher in 2010 than in 2000.

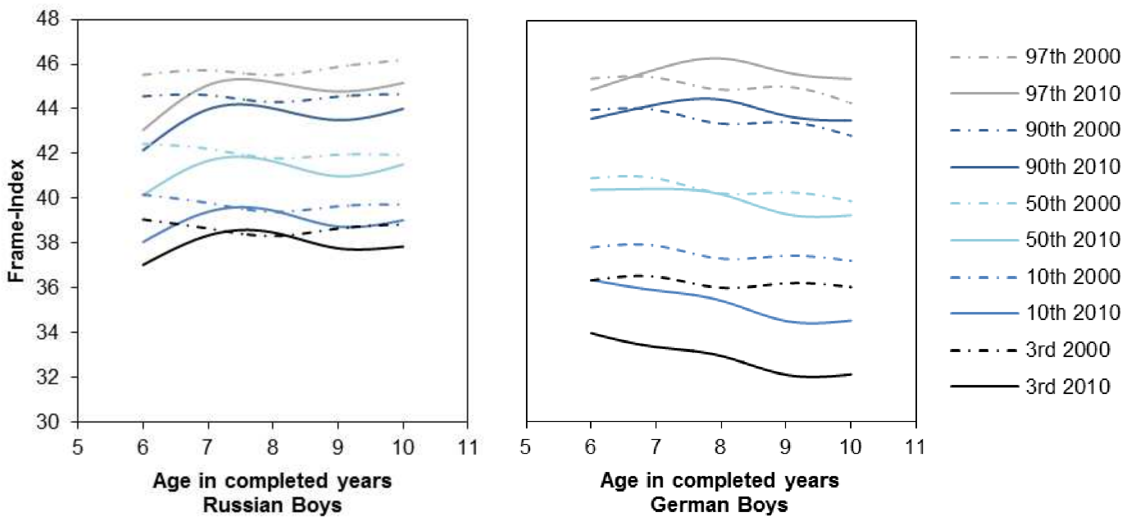

Figure 14. Percentiles of the parameter Frame-Index for Russian and German boys for the years 2000 (dashed lines) and 2010 (solid lines).

4.3.2 German children: Comparison 2000 and 2010

In German children height (U = 1734657, p = .002), Frame-Index (U = 1668006, p < .001) and BMI (U = 1749894, p = .009) were different in 2000 and 2010.

German boys showed a higher BMI (p = .002) but a decreased Frame-Index (p = .001) especially at the 3rd and 10th (Fig. 15) percentiles in 2010. 10th percentile is located below the 3rd percentiles of the year 2000. In 2010 90th and 97th percentiles laid above of those from the year 2000. Height did not differ between the years in contrast to the German girls (2000: 135 cm vs. 2010: 132.7 cm; p = .001).

In girls, BMI did not vary over the years (p = .528) but Frame-Index decreased like in boys and the same percentiles (Tab. 7, 8; Fig. 15).

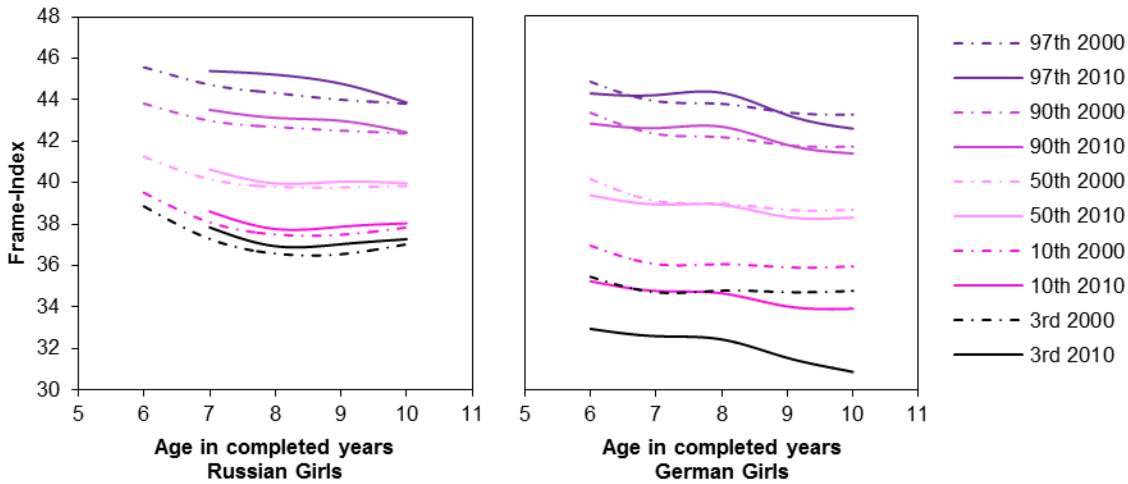

Figure 15. Percentiles of the parameter Frame-Index for Russian and German girls for the years 2000 (dashed lines) and 2010 (solid lines).

4.3.3 Russian and German children in 2000

In 2000 between Russian and German children, BMI (U = 998556, p = .001), Frame-Index (U = 565949, p < .001) and height (U = 929587, p < .001) were different.

This result can be found in girls as well. German girls were taller (German: 135 cm vs. Russian: 132.1 cm), exhibited a higher BMI (German: 16.47 m^2/kg vs. Russian: 15.99 m^2/kg) but a lower Frame-Index (German: 38.95 vs. Russian:

40.17). In every age group a significant difference in Frame-Index can be found (Tab. 7, 9). 50th up to 97th percentile curves laid on the same level.

Russian boys had a higher Frame-Index (German: 40.38 vs. Russian: 42.1). Starting in 50th percentile values of the German boys are situated below of those from the Russian boys. 10th percentile curve of the German boys is located below the 3rd percentile curve of the Russian boys. Russian boys were smaller than German boys (German: 134.5 cm vs. Russian: 132.7 cm) in 2000 (Fig. 14).

4.3.4 Russian and German children in 2010

In 2010, BMI (U = 216372, p = .043) and Frame-Index (U = 149073, p < .001) were distinguished but not height (U = 227552, p = .434).

In contrast to the 2000 analysis in 2010 in children of both sexes only Frame-Index was different in every age group (Tab. 7, 9). Russian boys (German: 40.24 vs. Russian: 41.41) and girls (German: 38.86 vs. Russian: 40.15) had a higher Frame-Index than the Germans. Starting in 50th percentile values of the German boys and girls are situated below of those from the Russian boys and girls. 10th percentile curve of the German boys and girls are located below the 3rd percentile curve of the Russian boys and girls (Fig. 14, 15).

Table 7. P50 values of the parameters BMI (kg/m²), Frame-Index, height (cm) of Russian and German boys and girls from the years 2000 and 2010

		P50 value							
		Russian boys		Russian girls		German boys		German girls	
age	parameter	2000	2010	2000	2010	2000	2010	2000	2010
all	BMI	16.21	16.82	15.99	16.79	16.21	16.52	16.47	16.49
	Frame-Index	42.1	41.41	40.17	40.15	40.38	40.24	38.95	38.86
	height	132.7	134.7	132.1	131.5	134.5	133.9	135	132.7
6	BMI	15.82	15.29	15.19	n.d.a.	15.4	15.82	15.75	15.61
	Frame-Index	42.59	40.76	41.14	n.d.a	40.84	40.56	40.3	39.69
	height	122.9	125.1	121.6	n.d.a	123	123.8	122	121.2
7	BMI	15.7	16.33	15.89	17.06	15.87	15.81	15.85	15.93
	Frame-Index	42.29	41.5	40.38	40.61	40.75	40.61	39.1	39.1
	height	126.2	127.7	126.2	125.2	127.7	127	127	126.4
8	BMI	16.38	16.52	16.11	16.78	16.02	16.39	16.94	16.39
	Frame-Index	41.82	41.63	39.82	39.74	40.46	40.63	39.16	39.01
	height	132.9	131.8	132.6	130.5	134	133.2	134.2	131.8
9	BMI	16.56	17.86	16.25	16.67	16.6	16.88	16.73	17.03
	Frame-Index	41.9	40.86	40.18	40.15	40.37	39.94	38.47	38.4
	height	137.1	140.4	137.5	135.4	139.5	138.8	139.65	139.1
10	BMI	16.93	18.1	15.98	17.37	17.09	17.49	17.11	17.78
	Frame-Index	41.9	41.72	39.88	39.75	39.82	39.57	38.65	38.59
	height	142.2	139.4	138.8	142.6	144.5	144.1	144.5	143.1

n.d.a. = no data available for Russian children

Table 8. Data comparison of the parameters BMI (kg/m²), Frame-Index, height (cm) of the years 2000 and 2010 for Russian and German boys and girls children.

		2000 vs. 2010							
		Russian boys		**Russian girls**		**German boys**		**German girls**	
age	**parameter**	**U**	**p**	**U**	**p**	**U**	**p**	**U**	**p**
all	**BMI**	33535	**< .001*****	21732	**< .001*****	410562	**.002****	464152	.528
	Frame-Index	26055	**.002****	20883	.290	406989	**.001****	433953	**.002****
	height	36769	**.034***	26683	.530	436508	.355	430634	**.001****
6	**BMI**	n.d.a	n.d.a	n.d.a	n.d.a	10556	.065	10260	.621
	Frame-Index	n.d.a	n.d.a	n.d.a	n.d.a	10810	.139	8912	**.014***
	height	n.d.a	n.d.a	n.d.a	n.d.a	11537	.513	10668	.956
7	**BMI**	2830	**.016***	1941	**.016***	15981	.955	17115	.490
	Frame-Index	2251	.115	1929	.241	14228	.066	17124	.495
	height	2883	**.024***	2417	.553	15110	.346	16894	.369
8	**BMI**	2199	.292	1764	.050	11903	**.024***	19082	.109
	Frame-Index	1976	.756	1572	.519	13685	.812	20215	.564
	height	2244	.376	1891	.146	12969	.293	16748	**< .001*****
9	**BMI**	2301	**.026***	1190	.819	23423	.104	24263	.180
	Frame-Index	1541	**.009****	958	.574	21648	**.004****	23701	.082
	height	1949	**.001****	1216	.892	24386	.349	24640	.282
10	**BMI**	708	.175	419	**.048***	19817	.268	16885	**.017***
	Frame-Index	553	.363	420	.766	19028	.079	17776	.105
	height	679	.109	430	.064	18802	.052	17802	.110

U = Mann-Whitney-Test
P = p-value, significant in bold
n.d.a. = no data available for Russian children

Table 9. Data comparison of the parameters BMI (kg/m²), Frame-Index, height (cm) of Russian and German boys and girls per year 2000 and 2010.

		Russian vs. German							
		2000 boys		**2000 girls**		**2010 boys**		**2010 girls**	
age	**parameter**	**U**	**p**	**U**	**p**	**U**	**p**	**U**	**p**
all	**BMI**	282725	.630	217947	**< .001*****	59011	.089	49013	.292
	Frame-Index	129504	**< .001*****	146007	**< .001*****	43494	**< .001*****	32166	**<.001*****
	height	252018	**< .001*****	213033	**< .001*****	64407	.953	47849	.144
6	**BMI**	3376	.632	3180	.599	n.d.a	n.d.a	n.d.a	n.d.a
	Frame-Index	1873	**.001****	2022	**.005****	n.d.a	n.d.a	n.d.a	n.d.a
	height	3125	.265	2923	.207	n.d.a	n.d.a	n.d.a	n.d.a
7	**BMI**	10963	.256	10153	.905	4282	.131	3546	**.029***
	Frame-Index	5786	**< .001*****	5944	**< .001*****	3603	**.003****	2656	**<.001*****
	height	9769	**.008****	9221	.151	4473	.275	3942	.206
8	**BMI**	12138	.600	11274	**.001****	2700	.873	3019	.409
	Frame-Index	6226	**< .001*****	8410	**.002****	1818	**.002****	2389	**.010***
	height	10976	.052	11704	**.004****	2347	.178	2842	.188
9	**BMI**	17963	.412	12562	**.039***	3714	.373	1809	.166
	Frame-Index	7601	**< .001*****	8470	**< .001*****	2845	**.003****	1245	**.001****
	height	13906	**< .001*****	11143	**< .001*****	3592	.236	1814	.171
10	**BMI**	7745	.730	6150	**.002****	2141	.576	1395	.733
	Frame-Index	2788	**< .001*****	3966	**< .001*****	1254	**< .001*****	826	**.002****
	height	5875	**.001****	4566	**< .001*****	1590	**.010***	1405	.771

U = Mann-Whitney-Test
P = p-value, significant in bold
n.d.a. = no data available for Russian children

5. Discussion

In this cross-sectional study body composition, recreation and physical activity in 691 German children aged 6 to 10 year-olds were investigated. Furthermore, a 10-year comparison of body composition in Russian and German children was conducted.

The association between type of body shape, external skeletal robustness, skeletal mass and physical activity were identified. Moreover, the assumption was examined whether physical activity influences external skeletal robustness. Besides the relationships between physical activity, leisure activities, BMI, percentage of body fat and external skeletal robustness was illustrated. Finally, differences and approaches concerning body composition of Russian and German children were presented. The results will be discussed hereafter.

5.1 Type of body shape, skeletal measurements and physical activity

Initially, associations between type of body shape, external skeletal robustness and skeletal mass can be confirmed. Pyknomorphic subjects showed the highest external skeletal robustness and skeletal mass in contrast to the leptomorphic ones. Leptomorphic individuals exhibit the smallest external skeletal robustness. The association between external and internal skeletal robustness as bone density is not clarified. However, data showed that pyknomorphic students exhibit the highest bone stability (Gniosdorz, 2011). In addition, Saitoglu et al. (2007) displayed in middle-aged men a correlation between type of body shape and bone mineral density. The researchers found a negative correlation between lumbar/femur bone mineral density and ectomorphy respectively a positive correlation with endomorphy. Certainly, they performed their investigation in adult men, not in children and they used the somatotyping concept by Carter and Heath (1990). However the different concepts describe same aspects: ectomorphic and leptomorphic individuals, respectively endomorphic and pyknomorphic types can be thought of as equal (Scheffler, 2013). Therefore, an association between external skeletal robustness and internal skeletal measures can be assumed.

What significance will it then have for the leptomorphic subjects who exhibit the lowest external skeletal robustness and bone mineral density? They have the possibility like the other types of body shape as well to get the maximum bone mineral density and bone mass till the age of 25 (Berger et al., 2010). Afterwards a plateau phase without an increase or decrease occurs and at an age around 30 bone mass decreases by nearly 1% each year (Bartl, 2001). Physical activity and especially extreme workload encourage an increase of bone mineral density, bone mass and breadth (Welten et al., 1994; Burr, 1997) and external skeletal robustness which the results of the present investigation showed. Especially leptomorphic individuals should be physically active to build a robust skeleton. Leptomorphic types might be the ones who have the highest risk to get osteoporosis. And in addition, if they are overweight these individuals might get joint diseases as well in adulthood.

However, type of body shape did not influence physical activity. Nevertheless, metromorphic girls and pyknomorphic boys were more physically active than the other types by tendency. In boys, this is assessed as positive due to the fact that pyknomorphic types exhibit a high percentage of body fat (Greil, 1993; Trippo and Klipstein-Grobusch, 1998; Scheffler and Schüler, 2009). Thereby they might reduce the risk to be overweight.

5.2. Associations between external skeletal robustness, BMI, percentage of body fat, physical activity and recreation

At first, results of TV viewing time and physical activity in boys and girls will be discussed. Afterwards association between external skeletal robustness and physical activity and additionally correlations between external skeletal robustness, BMI, percentage of body fat and activity will be debated.

The outcome shows a TV viewing time of 1h per day on an average in boys and girls. In contrast German and US studies depict 1.7h up to 4h per day (Grund et al., 2001; Rathgeb, 2010; Strasburger et al., 2012). How long children are allowed to watch TV depends on various reasons: education of parents, socioeconomic factors, TV in children's bedroom, rules concerning TV time. 70 to 80% of US and

Dutch parents define rules for TV viewing time (Tandon et al., 2012; De Jong et al., 2011). In our study we did not collect these data but probably our parents laid down strict rules. However, only 16% of the children hold a TV in their bedroom. Otherwise new media like iPad or smartphones are established in households which can be used for playing games and watching movies (Strasburger et al., 2012). This might be another factor for the low TV viewing time in this cohort. Another reason might be our questionnaire. Parents could choose between 15min, 30min, 45min, 60min, 75min, 90min, 120min, 180min per day. It is possible that parents have chosen a low value due to make a good impression.

60 to 70% of boys and girls participated on sports club regularly. This result confirmed other findings in German children (Lampert et al., 2007; Drenowatz et al. 2013) but also in Swiss and Italian infants (Federico et al., 2009; Zahner et al., 2009). However, the ENERGY project showed that only 53% of the children in Belgium, Greece, Hungary, Netherlands, Norway, Slovenia and Spain are training in organized sports structures (Timperio et al., 2013). Furthermore, German boys who took part in sports club went more steps than the ones who did not participate. In girls, no difference can be found. This might be declared by the type of sport which boys prefer. They favour hard-running sports like soccer in contrast to girls who prefer dancing. Thibault et al. (2010) showed this outcome in French adolescents as well. Already in 1991 Backx et al. displayed that boys like soccer and girls prefer gymnastics. Moreover, in adolescent girls school sport has a major impact on physical activity than participating in sports club in contrast to boys (Silva et al., 2010). In general boys are more physically active than girls. This result confirms other findings about the physical activity in boys and girls (Trost et al., 2002). This might be explained by different leisure activities. Boys more often move at school. They play sport games in contrast to girls who walk, talk or take snacks (Sarkin et al., 1997). In contrast, New Zealand girls are more active than boys (Oliver et al., 2012). However, the older children become, the less they move. Sherar et al. (2007) showed a similar association decreased physical activity correlates with increasing maturity. A decline in activity may also be explained by changing their interests, e.g. increasing media usage with age (Rathgeb, 2010). Nevertheless, how vigorous children are physically active depends on socio-economic variables, seasonal and

geographic location and parents physical activity (Timperio et al., 2013; Loucaides et al., 2004; Oliver et al., 2010; Fuemmeler et al., 2011; Craig et al., 2013).

Moreover, the assumption can be confirmed that physical activity and the external skeletal robustness are positively correlated in children. In contrast, a study in young adults did not show this relationship (Scheffler et al, 2013). This opposed findings might be explained by the different stage of bone composition. In children bone material is build and is more influenceable by physical activity as bones in young adults whereby process of building bone mass is mostly completed (Berger et al., 2010). However, it has to be discussed how physical activity which was measured through pedometer and external skeletal robustness which is calculated through elbow breadth and height are associated. In contrast to pelvic elbow breadth is highly correlated with skeletal mass and lower related to the sum of triceps and subscapular skinfolds (Frisancho & Flegel, 1983). It is an adequate measurement to conclude on skeletal frame size. Furthermore, in children physical activity is a dynamic process whereby especially in everyday life the legs are not only used. Results of our workgroup showed that every kind of movement, e.g. walking, cycling, running, climbing is positively correlated with total steps (unpublished data). Furthermore, data of the present study indicates that 15 to 20% of the children practiced more than one type of sport. Type of sport was not associated with external skeletal robustness. It was concluded that overall physical activity affects external skeletal robustness. Through the higher activity muscles are strained whereby new bone material could be built which gives higher bone strength, mass and density. However the association between external skeletal robustness and the internal skeletal properties are unexplained and should be investigated to prevent possible bone diseases (Slemenda et al., 1991; Boot et al., 1997; Scheffler et al., 2007; Karlsson et al., 2008). Even so children who move a lot could exhibit a higher external skeletal robustness.

Anyway another issue should be discussed for what reason the skeleton is narrower than ten years ago. It is possible that a large skeleton is no longer needed and this may be genetically manifested over the time due to changed environmental conditions in the form of lifestyle and way of working. However, is that skeleton sufficient to live a healthy life? Particularly obese people who are already threatened may experience problems with their narrower skeleton because it cannot manage their weight which could result in joint diseases (Scheffler, 2011b).

The relationships between physical activity, BMI, external skeletal robustness (Frame-Index) and percentage of body fat are presented in Figure 16. BMI, percentage of body fat and Frame-Index are indices which are calculated from body dimensions. These are mainly determined by genetic. The factor activity which increases or decreases the other parameters represents the environmental impact.

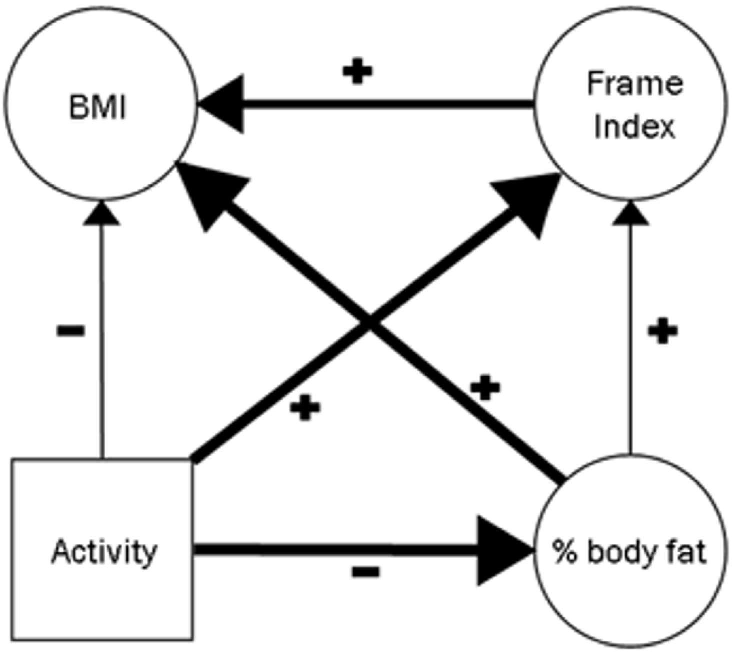

Figure 16. Associations between BMI, Frame-Index (external skeletal robustness), % body fat and activity. Parameters BMI, Frame-Index and % body fat are indices which are calculated based on body dimensions. The direction of the association is shown with arrows. The higher the association, the wider the arrows; variable leads to increase (+) and reduction (-) the other ones

The percentage of body fat was linked to BMI in all age and sex groups. A high percentage of body fat leads to a high BMI which is established at an early age (Rolland-Cachera et al., 1984; Scheffler and Schüler, 2009; Suchomlinov and Tutkuviene, 2011). Furthermore, physical activity combined with healthy nutrition results in a reduction of BMI and percentage of body fat. These relationships are sufficiently well known (Friedrich et al., 2012). Using the additional factor external skeletal robustness, further connections can be found. External skeletal robustness is positively associated with BMI in almost every age and sex group and percentage of body fat but not in every group. A high external skeletal robustness leads to a high BMI. Similar associations can be found between BMI and different internal bone measurements as BMD, BUA and QUI in adult females and males (Babaroutsi et al., 2005; Adami et al., 2004; Cobayashi et al., 2005; Edelstein and Barrett-Connor, 1993). That means that two variables correlate with BMI - a fat content and a skeletal part. This indicates that BMI is not merely high due to a high body fat content but rather due to high skeletal part.

The other association between external skeletal robustness and percentage of body fat is low. However that is a positive result due to external skeletal robustness represents an adequate skeletal measure. In prepubertal children Cole et al. (2012) and Hrafnkelsson et al. (2013) showed that an increase in fat mass leads to an increase in bone size but decreased volumetric bone density. On the contrary, in adults and adolescents results showed a positive correlation for fat mass and internal bone measurements as well bone density (Reid et al., 1992; Reid et al., 1994; Gracia-Marco et al. 2011). The relationship between fat mass and bone characteristics are difficult to explain. One short approach: fat is an active endocrine substance. Leptin which is produced by Adipocytes is integrated in the regulation of fat metabolism (Cock and Auwerx, 2003). Adipocytes and osteoblasts are formed by mesenchymal stem cells. Leptin may influence mesenchymal stem cells during differentiation to osteoblasts rather than to adipocytes (Ahdjoudi et al., 2001; Thomas et al., 1999). Osteoblasts, chondrocytes and bone marrow cells exhibit corresponding leptin receptors (Matsuda et al., 1997).

Nevertheless the relation between the two variables could be also explained in the following way: body fat still had a mass which has to be borne. These mass affects muscles and further muscles are needed to carry body fat. Higher musculature influences the skeleton. Heavier children have to utilize more muscles for motion which impacts on bone structure and external skeletal robustness.

5.3. Comparison of Russian and German body composition

Certainly, it is difficult to compare data of individuals from different ethnic groups whereas every ethnic shows specific characteristic concerning their body composition which is genetic based and is also influenced by environmental factors, e.g. Stanfield et al. (2012) shows that White European women are taller than South Asian women who might be influenced by nutrition as well. Infants of South Asian women exhibit a lower fat free mass than the infants in White European women. This is an early manifestation which indicates a genetic background.

Nevertheless, in general it is established that the inclination of obesity and especially the increased body fat deposition is a result of genetic factors (Stunkard et al., 1986; Bouchard et al., 1988). Otherwise environmental factors as high-calorie nutrition, physical activity and sedentary behaviour affect body fat production as well. An imbalance of each components leads to overweight. This development can be found in different population and has been evolved into a global problem (Popkin et al., 2012). Apart from this trend another new development can be shown in relation to the skeleton of the German children. The external skeletal robustness has decreased which may lead to a higher risk to get osteoporosis. Each element of the skeletal system as bone mass and density will be influenced by genetic factors. Furthermore environmental factors as calcium intake and physical activity effect on them (Pollitzer and Anderson, 1989; Slemenda et al., 1991; Johnston et al., 1992). This is likewise to the body fat deposition. Now a trend concerning to the skeletal system is displayed. Between two different populations (German/Russian) and within the population external skeletal robustness, BMI and height were compared. It was supposed that differences were existed between Russian and German data in 2000 and an approach in 2010. In 2010, BMI and height of the Russian children were adapted on the values of the German children while in 2000 differences existed. In Russian children BMI were increased due to the changed nutrition. More than a half of the calories were ingested in form of bread, pastries, sugar and potatoes (Kalinin et al., 2011). Furthermore, the secular trend can be observed in Russian children. Physical height increased in Russian children due to advance of socio-economic conditions (Godina, 2011). In 2000 as well as in 2010, Russian children exhibited a higher external skeletal robustness as compared with German children. This finding can be arising from genetic factors but also due to the dosage of physical activity. In German children the investigation showed a positive association between physical activity and external skeletal robustness. It is assumed that physical activity is higher in Russian children than in German children. However, at present no data is available to consider that assumption. Though, Hastie et al. (2010) exhibited that Russian children were fitter than their contemporaries in the US. After all, in 2010 compared with 2000 in Russian boys' external skeletal robustness were decreased whereas that negative development can be found in both sexes of the German children. Although the Russian children may be more physically active than the German children the development of a reduced physical activity may exist. In case of reduced physical activity in Russian children it affects boys at first. Environmental factors impact boys' body composition stronger than girls (Scheffler and Schüler, 2009). Also according to one study Moscow girls are more physically active than boys (Permyakova et al., 2012).

6. Conclusion

The investigations imply that the type of body shape is not only related with percentage of body fat and android/gynoid patterns but also with skeletal measures. The leptomorphic individuals might be the ones who exhibit the highest risk to get osteoporosis due to the lowest external skeletal robustness. In addition, physical activity influences positively the external skeletal robustness. Low physical activity can cause the reduction of external skeletal robustness, the increase of BMI and body fat. For that reason children should be physically active to maintain a robust skeleton and to be of normal weight to prevent osteoporosis and obesity. In the future, to describe state of health in children it is useful to include type of body shape, BMI, body fat and external skeletal robustness.

The results of the 10-year comparison of Russian and German children show an increase of BMI in Russian children in recent years. Thereby the prevalence of obesity will rise. In German children external skeletal robustness decreased in both sexes in contrast to the Russian children whereby only in boys external skeletal robustness is reduced. Boys might be the ones with the highest risk to get osteoporosis or joint diseases. However, external skeletal robustness is still higher in Russian children compared with Germans. The development of decreased external skeletal robustness and the physical activity should be observed prospectively.

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References figures

Figure 1

http://www.dksh.fr/htm/912/en_FR/AnthropologicalInstrument.htm?LevelId=340103
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Figure 2

http://www.ergotyping.net/index.php?title=ErgonomieGrundlagen:_Anthropomerie
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8. List of publications

2011

Rietsch K., Scheffler C., Eccard J. - Association between skeletal robustness and physical activity in schoolchildren – First results. Anthrop. Anz. J. Biol. Clinic. Anthrop 68(4), p 516 (Abstract)

2013

Rietsch K., Eccard J., Scheffler C. - Decreased external skeletal robustness due to reduced physical activity? American Journal of Human Biology. In press

Rietsch K., Godina E., Scheffler C. - Decreased external skeletal robustness – A global trend? Ten year comparison of Russian and German data. Submitted PlosONE

Rietsch K., Scheffler C. – Associations between type of body shape, external skeletal robustness and physical activity. In preparation

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V. Declaration of academic honesty

I hereby declare that I have not submitted this dissertation at any other university. Furthermore I have written this dissertation independently with no other resources other than those specified.

Date Signature

VI. Appendix

Measuring report

Messprotokoll
Grundschüler 2010-2012

Untersuchungsdatum ____________

Schule ____________

Probandennr.: [ ][ ][ ][ ]

Geschlecht [ ]

Geburtsdatum [M][M] [J][J][J][J]

Art der Bekleidung [ ]
0 unbekleidet
1 Unterwäsche
2 leichte Bekleidung
3 andere Bekleidung

Körpermasse ____________ kg

Körperhöhe ____________ cm

Stammlänge ____________ cm

Brustkorbbreite ____________ cm

Brustkorbtiefe ____________ cm

Schulterbreite ____________ cm

Ellenbogenbreite ____________ cm

Kniebreite ____________ cm

Handgelenkbreite ____________ cm

Knöchelbreite ____________ cm

Hautfaltendicken
Rücken
____________ mm
____________ mm
____________ mm

Hautfaltendicken
Bizeps
____________ mm
____________ mm
____________ mm

Hautfaltendicken
Trizeps
____________ mm
____________ mm
____________ mm

Dynamometer

re ____________

li ____________

Händigkeit

re [ ] **li** [ ]

Karten-Test 10 Züge

Zeit in s ____________

Gewinn ____________

gemachte Züge

____

____
Untersucher

Parents` questionnaire

Fragebogen Grundschüler
2010 - 2012

Bogen bitte auseinander falten!

Probandennummer ____________

1 Allgemeine Angaben

Schule ____________________________________

Geschlecht ☐

Geburtsdatum ________ Monat ____________ Jahr

Geschwisteranzahl ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Anzahl, der Geschwister mit denen zusammengelebt wird ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Geburtsfolge ☐ Erstgeboren ☐ Zweitgeboren ☐ Drittgeboren ☐ Viertgeboren

Weist Ihr Kind ADHS oder ADS auf? ☐ ADHS ☐ ADS ☐ nein

2 Bewegung

Besucht Ihr Kind einen Sportverein ? ☐ ja ☐ nein

Wenn ja, wie häufig in der Woche ? ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

Wie viele Minuten pro Tag? ☐ 30 ☐ 60 ☐ 90 ☐ 120 ☐ 150 ☐ 180

Welche Sportart wird ausgeübt? ____________________________________

Wie viele Stunden Schulsport gibt es pro Woche? ☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Entfernung von zu Hause zur Schule ________ km

Wie bestreitet das Kind seinen Schulweg?
Mehrfachantworten möglich

Morgens

☐ zu Fuß ☐ Auto ☐ Bus/Bahn ☐ Fahrrad

Nachmittags

☐ zu Fuß ☐ Auto ☐ Bus/Bahn ☐ Fahrrad

5 Mediennutzung

Besitzen Sie PC und TV Geräte?	☐ PC	☐ TV	☐ beides	☐ nein
Besitzt Ihr Kind PC und TV Geräte?	☐ PC	☐ TV	☐ beides	☐ nein

Wie viele Minuten pro Tag schaut Ihr Kind TV?	☐ 0	☐ 15	☐ 30	☐ 45	☐ 60	☐ 90	☐ 120	☐ 150	☐ 180
Wie viele Minuten pro Tag benutzt Ihr Kind den PC?	☐ 0	☐ 15	☐ 30	☐ 45	☐ 60	☐ 90	☐ 120	☐ 150	☐ 180

4 Schlafgewohnheiten

a) Wann steht ihr Kind zur Schulzeit innerhalb der Woche morgens auf? ______________________

Wann steht ihr Kind zur Schulzeit am Wochenende auf? ______________________

b) Wann geht ihr Kind zur Schulzeit innerhalb der Woche ins Bett? ______________________

Wann geht ihr Kind zur Schulzeit am Wochenende ins Bett? ______________________

Handhabung des Schrittzählers (Pedometer)

Liebe Eltern,
Ihr Kind trägt bereits einen Schrittzähler an seinem Hosenbund, wenn es nach Hause kommt.
Der Schrittzähler muss am linken oder rechten Hosenbund nahe aber nicht auf dem Hüftknochen angesteckt werden. Bei jedem Kleidungswechsel muss auch das Pedometer neu angebracht werden. Es wäre schön, wenn Sie Ihrem Kind noch einmal zeigen könnten, wie es angesteckt wird, damit es das Pedometer im Sportunterricht oder während sportlicher Aktivitäten im Verein selbst ab- und anlegen kann. Der Schrittzähler sollte erst abgelegt werden, wenn Ihr Kind zu Bett geht. Bitte stecken Sie es gleich am nächsten Morgen, sobald Ihr Kind aktiv ist, wieder an d.h. auch an den Schlafanzug. Diese Methode hilft uns, sehr genau die körperliche Aktivität Ihres Kindes zu erfassen. Das Pedometer muss 8 Tage in Folge getragen werden, d.h. der erste Tag ist bereits der, an dem Ihr Kind mit dem Schrittzähler an seinem Hosenbund nach Hause kommt. Der Schrittzähler wird am achten Tag in der Schule eingesammelt und abgeholt. Ein genaues Datum ist ausgewiesen. Bitte geben Sie den Schrittzähler zusammen mit dem beantworteten und kuvertierten Fragebogen an diesem Datum Ihrem Kind mit in die Schule.
Wichtig: Bitte öffnen Sie den Schrittzähler nicht und vermeiden Sie heftiges Schütteln, da dies das Ergebnis beeinflussen kann. Bei Krankheit des Kindes wird der Schrittzähler während dieser Zeit nicht getragen und am ausgewiesenen Datum in der Schule abgegeben.

Vielen Dank für Ihr Mitwirken!

Boundary values for 6 – 18 years-old children and adolescents. Leptomorphic, metromorphic and pyknomorphic types (Schilitz 2001)

Alter in Jahren	Metrik-Index P20 männlich	Metrik-Index P80 männlich	Metrik-Index P20 weiblich	Metrik-Index P80 weiblich
6	-0,92	-0,57	-1,57	-1,18
7	-1,01	-0,62	-1,69	-1,24
8	-1,07	-0,70	-1,71	-1,19
9	-1,24	-0,78	-1,74	-1,19
10	-1,30	-0,78	-1,78	-1,20
11	-1,37	-0,87	-1,79	-1,10
12	-1,41	-0,86	-1,76	-1,08
13	-1,45	-0,80	-1,74	-1,07
14	-1,47	-0,84	-1,72	-1,03
15	-1,55	-0,96	-1,61	-0,99
16	-1,59	-0,83	-1,62	-1,04
17	-1,49	-0,82	-1,59	-0,94
18	-1,38	-0,62	-1,63	-0,84

Percentiles of the different measured and calculated parameters
n = 691

Wight in kg

	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	18,36	18,94	24,20	29,30	35,32	18,88	19,48	22,60	29,92	33,04
7	21,22	22,14	25,70	34,50	36,60	20,00	20,96	25,70	33,12	35,38
8	23,49	24,00	29,55	37,41	38,48	22,29	23,54	28,30	38,34	43,18
9	25,50	27,30	32,40	45,00	50,65	24,80	26,96	32,70	42,91	48,70
10	28,06	30,30	36,90	50,44	55,37	27,38	29,06	36,80	49,52	54,36

Height in cm

	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	114,51	116,00	124,50	130,90	131,83	114,13	115,08	121,40	128,58	129,76
7	118,52	121,14	127,80	136,32	137,30	119,32	120,80	126,70	133,52	135,72
8	123,22	125,59	134,80	140,42	143,11	121,87	123,40	130,60	141,12	142,48
9	128,40	130,20	139,30	149,10	151,95	129,30	131,10	138,85	147,66	149,71
10	131,70	133,38	144,50	151,60	156,06	129,98	133,18	143,10	153,30	157,80

BMI in kg/m²

	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	13,33	14,35	15,57	18,03	21,00	13,88	14,07	15,96	18,81	20,29
7	14,15	14,41	15,87	19,03	19,89	13,50	13,90	15,98	19,48	21,09
8	14,14	14,38	16,40	19,39	20,38	13,84	14,14	16,37	21,26	22,57
9	14,55	14,74	16,64	21,05	23,94	13,58	14,74	17,21	20,94	23,88
10	14,74	15,40	17,72	22,15	24,10	14,79	15,27	17,75	21,94	23,18

Skinfold triceps in mm										
	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	4,31	5,10	6,10	9,98	13,39	5,84	6,18	8,30	13,04	14,14
7	3,96	4,64	7,10	10,60	11,54	5,18	5,66	8,70	12,46	13,70
8	3,99	4,39	7,80	12,12	12,93	4,28	5,86	8,60	13,44	15,32
9	4,75	5,20	8,40	13,50	16,70	4,30	4,75	9,10	14,50	16,24
10	4,84	5,54	9,50	16,22	18,77	4,98	6,22	9,90	17,30	19,26

Skinfold subscapular in mm										
	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	3,50	3,54	4,05	7,62	9,55	3,42	3,80	5,10	8,82	12,74
7	3,32	3,54	4,60	7,80	9,38	3,84	4,06	5,40	10,12	13,34
8	3,20	3,50	5,40	8,23	12,17	3,69	4,06	6,10	13,92	15,09
9	3,50	3,80	5,20	10,40	15,40	3,83	4,20	6,40	12,70	17,22
10	3,55	3,94	6,50	12,24	14,68	4,06	4,56	7,30	16,08	19,10

Percentage of body fat										
	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	8,49	9,05	11,16	16,58	22,06	9,04	9,97	13,28	20,02	24,02
7	7,01	7,83	11,57	18,02	19,16	8,48	9,46	14,15	20,38	23,22
8	6,93	7,88	12,78	18,18	21,03	8,25	9,50	14,15	24,27	25,81
9	8,11	9,18	13,08	22,57	28,75	8,20	9,45	15,50	24,61	26,27
10	8,21	9,41	15,42	25,82	29,32	9,03	10,97	17,31	26,36	39,22

Elbow breadth in mm										
	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	44,80	46,40	50,00	53,60	55,30	42,70	44,40	48,00	53,60	54,60
7	47,00	48,00	52,00	56,00	57,80	45,00	46,00	50,00	54,00	55,20
8	49,95	50,00	54,00	58,00	59,05	46,00	48,00	52,00	56,20	59,00
9	50,50	52,00	56,00	61,00	64,50	50,00	50,00	54,00	57,00	59,35
10	51,40	53,40	58,00	61,60	64,60	49,00	49,60	56,00	60,00	62,00

Frame-Index										
	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	37,55	38,69	40,49	42,52	43,05	36,44	36,73	40,00	41,91	43,26
7	37,02	38,16	40,70	42,82	43,66	36,29	36,97	39,29	41,68	42,20
8	37,81	38,39	40,36	42,19	43,94	36,04	36,65	39,66	42,50	42,97
9	37,05	37,33	40,27	42,74	43,55	35,87	36,58	38,78	41,61	42,88
10	37,36	38,00	40,29	42,73	43,77	35,80	37,12	38,81	40,51	40,66

Skeletal mass										
	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	3,13	3,46	4,22	5,12	5,81	2,97	3,08	3,65	4,88	4,95
7	3,92	3,99	4,79	5,92	6,06	3,30	3,60	4,37	5,19	5,66
8	4,22	4,35	5,32	6,36	6,62	3,68	3,88	4,83	6,03	6,44
9	4,70	4,90	5,94	7,26	8,33	4,35	4,53	5,53	6,55	6,97
10	5,25	5,62	6,46	7,60	8,16	4,33	4,54	5,89	7,33	7,61

Wrist breadth in cm										
	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	3,77	3,94	4,30	4,60	4,70	3,70	3,90	4,10	4,40	4,53
7	4,00	4,10	4,45	4,80	4,90	3,90	4,07	4,30	4,60	4,60
8	4,20	4,20	4,60	4,90	5,01	4,00	4,10	4,50	4,72	4,91
9	4,30	4,40	4,70	5,10	5,30	4,20	4,30	4,60	4,97	5,10
10	4,50	4,60	4,90	5,20	5,30	4,18	4,30	4,70	5,00	5,20

Ankle breadth in cm										
	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	5,20	5,54	6,00	6,40	6,50	5,17	5,24	5,60	6,10	6,13
7	5,60	5,70	6,10	6,60	6,78	5,20	5,40	5,80	6,30	6,40
8	5,69	5,79	6,40	6,90	7,10	5,50	5,60	6,00	6,40	6,50
9	5,90	6,00	6,50	7,00	7,25	5,50	5,70	6,20	6,67	6,72
10	6,10	6,24	6,60	7,06	7,20	5,60	5,70	6,20	6,60	6,72

Knee breadth in cm										
	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	6,60	6,80	7,40	8,00	8,10	6,50	6,60	7,00	7,56	7,76
7	7,00	7,10	7,70	8,10	8,20	6,60	6,70	7,30	7,90	8,02
8	7,20	7,39	7,90	8,50	8,61	6,70	6,80	7,50	8,00	8,20
9	7,45	7,60	8,10	8,80	9,10	7,00	7,10	7,70	8,27	8,40
10	7,47	8,00	8,40	8,60	8,99	7,10	7,32	7,90	8,40	8,62

Thoracic width in cm										
	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	16,74	17,18	18,80	20,90	21,18	16,54	16,94	18,20	19,66	20,22
7	17,75	18,00	19,50	21,00	21,50	17,40	17,87	19,35	20,43	20,86
8	18,68	18,89	20,30	21,61	22,01	17,59	18,06	19,50	21,40	22,05
9	18,35	18,80	20,40	22,60	23,30	18,70	19,00	20,40	22,57	23,77
10	19,14	19,94	21,70	23,06	24,26	18,16	19,22	20,90	22,78	23,12

Thoracic depth in cm										
	Boys					Girls				
Age	5th	10th	50th	90th	95th	5th	10th	50th	90th	95th
6	12,40	12,60	13,80	14,56	15,99	11,84	12,24	13,20	14,72	15,26
7	12,50	12,85	14,00	15,70	15,85	12,29	12,47	13,55	14,93	15,52
8	13,38	13,60	14,45	15,51	16,44	12,40	12,50	14,10	15,76	16,63
9	13,20	13,50	14,70	16,60	17,70	12,73	13,03	14,60	16,37	17,01
10	13,57	14,04	15,40	17,52	17,86	13,16	13,48	14,90	17,10	18,22