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SIGNIFICANCE OF THE ANTHROPOMETRIC FACTOR IN YOUNG FEMALE VOLLEYBALLERS' PHYSICAL ABILITIES, TECHNICAL SKILLS, PSYCHOPHYSIOLOGICAL PROPERTIES AND PERFORMANCE IN THE GAME

Dissertation

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CONTENTS

LIST OF ORIGINAL PUBLICATIONS

The thesis is based on the papers listed below:

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II Каарма Х. Т., Велдре Т. В., Стамм Р. А., Линтси М. Э., Касмел Я. Я., Майсте Э. А., Коскелъ С. К. Особенности телосложения у эстонских девушек и юношей. Морфология, 2001, 120, 6, 80-82.

III Stamm, R., Stamm, M. The anthropometric factor in assessment of physical abilities of young female volleyballers (aged 13-16). Mankind Quarterly 2004, 45, 1, 3-21.

IV Kaarma, H., Stamm, R., Kasmel, J., Koskel, S. Body build classification for ordinary schoolgirls (aged 7-18 years) and volleyball girls (aged 13-16 years). Anthropologische Anzeiger, 2005, 63, 1, 77-92.

V Stamm, R., Stamm, M., Koskel, S. Adolescent female volleyballers' (aged 13-15 years) body build classification and proficiency in competitions. Anthropologische Anzeiger, 2006, 64 (4), 423-433.

VI Stamm, R., Stamm, M., Oja, A. A system of recording volleyball games and their analysis. Int J Volleyball Res, 2000, 2, 1, 18-22.

VII Stamm, R., Veldre, G., Stamm, M., Kaarma, H., Koskel, S. Young female volleyball players' anthropometric characteristics and volleyball proficiency. Int J Volleyball Res, 2001, 4, 1, 8-11.

INTRODUCTION

Present-day volleyball requires from players quick reaction to changing situations in the game and accurate and precise movement for handling the ball. All this requires, in particular from young female players, development of volleyball technical skills as well as physical and psychophysiological abilities and assessment of the quality of these abilities. According to literature (Thissen-Milder and Mayhew, 1991; Farkas et al., 1991; Bale et al., 1992; Kiomourtzoglou et al., 2000; Avloniti et al., 2001), these abilities are in close connection with the girls' age-related constitutional peculiarities. Therefore, detailed assessment of the body build of this contingent is of great significance.

Respective studies about elite women volleyballers emphasise their greater height and weight, length of extremities, shoulder breadth, highly developed bone and muscle structure of extremities and upper body (Häkkinen, 1993; Viviani and Boldin, 1993; Gualdi-Russo and Zaccagni, 2001). Still, we can state that very few detailed anthropometric studies have been carried out on female players, both adults and adolescents. Usually, the number of body dimensions examined is very limited, being restricted to height, weight and body fat content. Practically no attention has been paid to extremities' length and many circumferences of the extremities and the trunk, which could be essential in the adolescence period.

In literature, physical abilities of young women volleyballers are assessed by means of a series of physical ability tests specially designed to be used in volleyball (Lee et al., 1989; Viitasalo., 1988). These include jumping tests, speed, endurance, flexibility tests, strength and explosive strength tests. The results of many tests are in correlation with one another and depend on body build. However, as researchers have no detailed anthropometric data at their disposal, it has not been possible to establish the exact nature or correlations proceeding from body build.

Testing of volleyballers' psychophysiological abilities has great prospects; at present, such studies are systematically carried out in relatively few countries — India (Sharma et al., 1986), Turkey (Hascelik et al., 1989), Greece (Kiomourtzoglou et al., 2000), Germany

(Hackfort and Schmidt, 2001) — and also in Estonia (Thomson, 1992, 1997). Research along these lines has to be continued.

In addition to methods for testing the technical skills necessary for young female volleyballers in the game (Oslin et al. 1998; Harrison et al. 1999), methods have also been devised for evaluating the performance of each player as well as the technical and tactical peculiarities of the entire match. For this purpose, several recording systems have been created abroad, the best-known being Volleyball Win Vis version, which was successfully applied at European men's championships (Oulu EM 1993) and Volleyball Information System (FiVB, 1997). In Estonia, also, different recording systems have been used (Huimerind, 1971; Амалин, 1973; Aunin, 1979; Nõlvak, 1995a, b), but, until now, only a few studies have been carried out on young female volleyballers.

The aim of the present study, therefore, was to examine the dependence of young female volleyballers' performance on their body build, physical abilities, technical skills and psychophysiological properties.

REVIEW OF LITERATURE

1.1. Anthropometric studies

1.1.1. A brief overview of studying the regularities of adults' body build

Anthropology as an independent branch of science took shape in the mid-19th century. The first department of anthropology was founded at the National Museum of Natural History in Paris in 1885 and the first anthropological society was established in Paris in 1895. One of its founders was the French scholar P. Broca (1824–1880), who designed the instruments of anthropological research and carried out the first measurements (Broca, 1879).

The underlying principles of anthropometric research were devised by R. Martin (1864–1924). His textbook became an authoritative handbook of anthropometric measurement methods and has served as the foundation for measurement methodology until the present (Martin, 1928).

Researchers understood that modelling of the human body as a whole presupposes detailed knowledge of the external body build (Бауэр, 1900; Rautmann, 1921, 1928; Вишневский, 1926; Игнатьев, 1927; Вейденрейх, 1929). The collected measurement data needed analysis. The oldest method of statistical data processing was to study the empirical distribution of individual anthropometric variables (Bach, 1931; Fink, 1955). Systematic study of the variation coefficient of individual variables showed that this coefficient had stable values for variables of one and the same category. It became an essential indicator of variability of measured characteristics (Pearson and Davin, 1924). Each tissue of the body was also found to have a characteristic degree of variability (Рогинский, 1959).

Great significance in further studies of body build structure belonged to mutual correlation analysis of anthropometric data (Николаев, 1927; Rautmann, 1928). This has been clearly expressed by V. G. Vlastovski (Властовский, 1958), who asserts that mutual correlations between the characteristics, their strength and direction are determined first and foremost

by the general growth and development regularities of the particular organ and the organism as a whole.
A necessity arose to find a leading characteristic among the mutually correlated variables. For a long time height as the most stable among body characteristics was considered the leading characteristic (Hammond, 1957; Рогинский, 1962; Clarke, 1973). Another leading characteristic was found to be body weight (Rautmann, 1928; Тийк, 1965;
Дерябин, 1975).

Great significance in the interpretation of the anthropometric whole of the body belongs to the work of G. I. Akinshchikova (Акинщикова, 1969). Studying the anthropometric variables of 70 female students, she found that, although it was essential to establish which characteristics were the leading ones, it was difficult to do it as all characteristics were in mutual correlation. In her opinion, the leading characteristics should be located outside of the system. She did not say anything about the role of height and weight, as she had not taken into consideration their correlations.

Thus, thanks to the system of mutual correlations that had been found to exist between bodily characteristics, different research trends develop in anthropology – studies on proportions, physical development, body composition, and constitution.

To study body proportions, the method of correlations (Ярхо, 1924), factor analysis (Дерябин, 1976) and the method of indices (Langmaack, 1956; Рогинский, 1957; 1959) were used. Body proportions were found to be dependent on age and gender (Aul, 1940; Башкиров, 1957), but not on ethnic origin neither in men (Чтецов, 1961) nor in women (Смирнова, 1960).

The method of indices was expected to be useful for viewing the body as a whole, as body dimensions were expected to change isomorphously in relation to one another. This, however, did not prove to be the case; more often proportions change heteromorphously (Башкиров, 1962), and therefore the changes in proportions in different people were difficult to interpret.

Attempts were made to classify and type all subjects by factor analysis (Muller, 1940; Thurstone, 1947; Burt, 1947; Howells, 1951). Using a sample of women, B. H. Heath

(1952) differentiated between two factors: the factor of adipose tissue and that of bone tissue. V. H. Janina (Янина, 1974), who studied 836 women aged 20–35 years, differentiated 3 factors on the basis of 10 body measurements: 1) weight – chest circumference; 2) skinfolds; 3) pelvis breadth – thorax depth.

Unfortunately, factor analysis did not yield such uniform results as expected. Authors started from different sets of initial measurements, used different methods for factors extraction and rotation, and, therefore, as a result, a different number of factors having different interpretations were obtained (Hammond, 1957).

Studies of body composition have proved the existence of regularities between body build and body composition. Thus, correlations have been found between total body fat, lean body mass, skinfolds, body density, body weight and a great number of other body dimensions (Matiegka, 1921; Edwards, 1951; Behnke, 1959, 1961; Young et al., 1961; Wilmore and Behnke, 1970; Katch and McArdler, 1973; Noppa et al., 1980; Jackson et al. 1980; Smith and Boyce, 1977). One of the most essential skinfolds is the suprailiac skinfold; its correlation with the summary skinfold is r = 0.92 (Garn, 1957) and with total body fat r = 0.71 (Sloan et al. 1962).

Trying to predict components of body composition from anthropometric variables, different authors found that not a great number of body measurements were needed. Thus, M. L. Pollock et al (1975) predicted body density (R^2 = 0.83) from four body measurements; J. H. Wilmore and A. R. Behnke (1970) calculated lean body mass from five body measurements (R^2 = 0.93); Raja and Singh (1978) the amount of lean body mass (R^2 = 0.84) from four body measurements.

The long history of somatotyping and constitution studies testifies to the existence of certain regularities in variations of body build. First, the somatoscopic classification was applied, and an interesting fact was found that the somatoscopically determined extreme types – the leptosomic and the eurosomic type (Вейденрейх, 1929; Kretschmer, 1961) – appeared in people of different ethnic origin. From that one can conclude that subjects of intermediate types should also exist in many ethnic groups.

In research, more attention was paid to extreme types. G. Viola (1935, 1936) showed that extreme types differ significantly in the relation between trunk length and lower extremity length. He differentiated between two extreme types – microsplanchic (tall stature, small trunk) and macrosplanchic (short stature, relatively big trunk). The average, normal proportions between the trunk and the extremities were, in his opinion, characteristic of the intermediate type. A principally similar classification into eurosomic and leptosomic types was used by Russian authors (Шевкуненко, Геселевич, 1935).

It has been concluded that for somatotyping an at least bivariate system of coordinate axes should be used, where one axis represents a row of asthenomorphous-pycnomorphous variations of height and the other – a row of macrosomic-microsomic variants (Knussmann, 1961), or hypo- and hyperplastic variants (Conrad, 1941, 1963).

The authors who have devised somatotyping schemes of major importance include W. H. Sheldon (1940), V. V. Bunak (Бунак, 1940), R. W. Parnell (1954), B. H. Heath and J. E. L. Carter (1967). At present, Heath-Carter's scheme is preferred in the USA; in Russia Galant's (Галант, 1927) scheme is used for women and Shtefko-Ostrovski's (Штефко-Островский, 1929) scheme for children. Factor types are used by Holle Greil in Germany (Greil, 1987).

Summarizing the results of body build research, one can say that the discovered body structure regularities make it possible to systematize anthropometric data in different ways for a number of purposes. However, no classification has been invented yet that would be satisfying in all respects.

1.1.2. Adolescent girls' body build

Postnatal growth may be divided into four phrases (Kinanthropometry and Exercise Physiology Laboratory Manual, 1996): infancy (from birth to one year), early childhood (preschool), middle childhood (to adolescence) and adolescence (from 8–18 years for girls and 10–22 years for boys).

The adolescence period is characterized by great changes in growth, development and maturation, which are influenced by individual constitutional peculiarities and manifest

themselves in the great variability of anthropometric characteristics (Никитюк, 1972; Malina and Bouchard, 1991; Dasgypta and Hauspie, 2001).
The greatest characteristic change during this period is adolescent spurt. This means short-term acceleration of the growth in anthropometric variables. In girls it happens at the age of 11–13 and in boys at the age of 14–15 years. The variability of characteristics reaches its culmination at age 13 in girls and at age 15 in boys.

Systematic studies of children's anthropometric variables were begun by the well-known Belgian anthropologist Quetelet in 1840 (Quetelet, 1842). He was the first to carry out an extensive study of body height and weight of children aged 6 and older and establish age standards, which were used in Europe for three quarters of a century.

The problem has been studied in detail, among others, by Estonian scholars. J. Aul (1977) describes changes in anthropometric indices in the adolescent period – Rohrer index decreases, relative sitting height decreases, relative length of extremities increases. J. Aul calls the complex of changes in individual anthropometric characteristics and indices that determines the beginning of sexual maturity morphological puberty. L. Heapost (1993), who carried out a detailed study of 7–18-year-old schoolchildren in Tallinn (n = 5034), has recorded analogous changes – acceleration in the growth of body measurements and changes in the individual variability of body measurements and proportions.

In recent years changes in children's height and weight have been studied on large samples of schoolchildren in Estonia (Aul, 1982), Sweden (Lindgren, 1990), Hungary (Eiben, 1995, 2001) and the Czech Republic (Blaha, Vignerova, 1999). Most European countries use their own national standards for assessment of 7–18-year-old children's height and weight. In Estonia the first systematic measurements of 7–18-year-old schoolchildren's height and weight were carried out by Juhan Aul in 1956 (Aul, 1974). He also collected analogous data in 1978 (Aul, 1982) and both sets of data were used as norms at that time. The book *Health of Estonian Youth* (1989, in Estonian) by R. Silla and M. Teoste provides a detailed overview of Estonian children's health and physical development in the 1970s and 1980s.

The latest methodological instructions for assessing children's physical development are based on the data collected from 1996–1997 (Grünberg, Adojaan, Thetloff, 1998) on the height, weight and body mass index of 2–18-year-old boys and girls (10,029 boys and 10,347 girls). These latest measurement results are used as national norms in all schools and medical institutions of Estonia, while J. Aul's data from 1978 are used for comparison.

Detailed characterization of adolescents considering their age, sex and maturity differences needs extensive work in order to establish the regularities of body structure for this age period. Major studies on this development stage of children include the papers by J. M. Tanner (1962), T. Onat and B. Ertem (1974), M. Prokopec (1982), O. G. Eiben (1985), R. N. Baumgartner et al. (1986), M. Prokopec and A. Stehlik (1988), J. Tutkuviene (1986), T. Olds et al. (1998), E. Maiste (1999b), G. Beunen et al (2000), A. L. Claessens et al. (2001) and G. Veldre et al. (2001).

The Centre for Physical Anthropology at the University of Tartu has attempted to study the whole body structure throughout the adolescence period. M. Thetloff (1992) analysed 34 body measurements of 1920 girls aged 7–17 and considered the possibilities of prediction of anthropometric variables from body height, weight and age in different age groups (7–11 years, 12–15 years, 16–17 years). The results showed that body structure was similar in all age groups, and all variables in all age groups were statistically significantly (within 13–96%) determined by age, height and weight. Variables with a predictive value over 70% were cervical, acromial and waist height, lower limb length, waist, pelvis and arm circumferences.

A more detailed study of the body structure of 16–18-year-old girls (Kaarma et al., 2000) showed that in all age classes individual anthropometric variables formed a closely connected complex where all the individual variables correlated closely with height and weight. Relying on this, the Centre for Physical Anthropology at the University of Tartu devised a 5 SD classification of height and weight for all age groups of 16–18-year-old girls.

Such a classification proved to be applicable for systematization of all the height, breadth and depth measurements and circumferences and body fat content indicators in the age groups of 16-year-olds (Kaarma et al., 1997), 17-year-olds (Saluvere et al., 1998) and 18-year-olds (Peterson and Saluvere, 1998).

As the greatest changes in the adolescence period occur in the 12–15-year age group, G. Veldre, R. Stamm and S. Koskel (2002b) also studied the anthropometric body structure of children of this age. This age group was found to have the same regularities as other samples, and a comparative classification of age, height and weight was elaborated for them as well.

There are no generally recognized classifications for somatotyping pubertal girls. For example, in Belarus Shtefko-Ostrovski's (Штефко-Островский, 1929) somatoscopic classification is used, which consists of four cohorts (thin-framed, muscular, digestive and unidentified cohort). Comparing the connections between 8–11-year-old girls' anthropometric data and their classification into somatotypes (Polina et al., 1992), reliable correlations between the two were found.

The most often used classification for the adolescent period is Heath-Carter classification (Ducquet and Carter, 1996; Carter et al., 1997) that differentiates between three components of the physique (endomorphy, mesomorphy and ectomorphy).

In Estonia, Heath-Carter classification has been used for somatotyping of 12–15-year-old boys and girls (Veldre, 2002a). The author found that the 12–15-year-old children of Tartu differ from their peers in other countries by somewhat greater ectomorphy and smaller endomorphy; that means, Tartu children were more linear, with a less roundish body shape.

Summing up what has been said above, one might say that the interesting period of growth is among the most complicated ones in anthropology. Along with researchers from several countries, Estonian scientists have made their own contribution to establishing the body build regularities of that period. Still, the question how to classify adolescent girls' highly variable data has not found a definite solution yet.

1.1.3. Female volleyballers' body build

In each sport attention is concentrated on the specific features of top athletes' body build. In elite women volleyballers, researchers have emphasised their greater height and weight, length of extremities, shoulder breadth, highly developed bone and muscle structure of extremities and upper body, and foot structure (Hosler et al., 1978; Spence et al., 1980; Fleck et al., 1985; Häkkinen, 1993; Viviani and Boldin, 1993; Gualdi-Russo and Zaccagni, 2001).

There is no definite answer to the question what the ideal body composition of an elite female volleyballer should be like, about the proportion between body fat content and lean body mass. This question has been studied in greater detail by Z. Hascelik et al. (1989), J. Wilmore (1992), D. J. Smith et al. (1992), W. E. Sinning (1996), L. B. Houtkooper and S. B. Going (1994).

According to L. B. Houtkooper, elite female volleyballers belong among athletes with medium body fat content. Like in speed skaters and swimmers, their body fat content varies from 10–20%.

The earlier results of J. Puhl et al. (1982) support this conclusion. The authors present the average data of an elite female volleyballers' team: the average age of the 14 players was 21 years, height 178.3 cm, weight 70.5 kg, and fat percentage 17.9%.

Attempts have been made to find the optimum standards for elite female volleyballers from the data of Olympic finalists. T. Khosla and V. C. McBrown (1985) studied 824 female Olympic finalists representing 47 events and found that the weight of woman with the height of 171 cm varied from 56 kg in runners to 85 kg in discus throwers. The weight range from 59 to 62 kg belonged to swimmers, runners, paddlers, volleyballers and handballers. Later, D. Kielak (1999) studied female and male volleyballers, finalists of three Olympic Games (Seoul, 1988; Barcelona, 1992; Atlanta, 1996) and found that within this time interval women's height had grown by 1.3 cm and weight increased from 68.4 to 72.1 kg.

Comparison of elite female volleyballers has shown that more successful players were taller and heavier (Spence et al., 1980; Fleck et al., 1985). W. W. Hosler et al. (1978) compared 180 female volleyballers from 16 teams and found that the more successful players were taller, heavier, had narrower hips and their body fat percentage was smaller.

Detailed studies of elite female volleyballers' body composition have been made in Sweden by H. Alfredson et al. (1997). Bone mineral density was compared in 13 female volleyballers and in 13 women not engaged in sports, aged 20.9 and 25.0 years respectively. They found that volleyballers had significantly greater bone density in the total body, lumbar spine, femoral neck, trochanter and in the femur.

Relatively few studies have been published on adolescent female volleyballers. R. M. Malina (1994), studying the height of 9–13-year-old volleyballers, found that they were taller than their peers. The reason, in his opinion, was selection.

Young volleyballers' body composition has also been assessed by means of body mass index, by measuring thicknesses of individual skinfolds and by calculating lean body mass. According to C. Riddoch et al. (1991), the increase of body mass index in 11–16-year-old girls from 18.6 to 21.5 is a better characteristic of adolescents' body composition than measuring of skinfold thicknesses. According to J. Durnin and M. Rahaman (1967) the sum of four skinfold thicknesses in girls of that age varies from 37.2 to 43.1 mm.

M. Thissen-Milder and J. L. Mayhew (1991) present the following data on 50 high school girl volleyballers aged 14–16 years: average age 15.65, height 167.0 cm, weight 50.7 kg and body fat percentage 19.6.

The height of 13–15-year-old female volleyballers of Budapest (n=118) (Farkas et al., 1991) varies from 161.24 to 168.76 cm, weight from 51.53 to 56.17 kg and body fat percentage from 21.13 to 22.27%.

R. M. Malina and R. F. Shoup (1985) conducted a comparative study of 74 female volleyballers belonging to four categories in Austin, Texas. The sample included both beginners and Olympic athletes. The latter surpassed all the others in the breadth of their skeleton and dimensions of extremities muscles; their body fat percentage was smaller.

Usually only height, weight and body fat percentage have been used for players' anthropometric characterization. Out of the numerous somatotyping schemes only that of Heath-Carter has been used.

One of the most thorough-going studies has been carried out by E. Gualdi-Russo and L. Zaccagni (2001). They studied Italian A_1 and A_2 league volleyballers during the 1992–93 and 1993–94 seasons. The sample included 234 male players (average age 23.1 years) and 244 female players (average age 23.1). The women's average somatotype was 3.0–3.3–2.9 and it differed according to teams and players' roles on court. In A_1 league the players' ectomorphy was higher and endo- and mesomorphy lower than in A_2. Ectomorphy was the highest in centre players and mesomorphy in setters. The same applies to anthropometric data according to Heath-Carter's scheme, which includes height, weight, lower leg and upper arm circumferences, humerus and femur breadth, and four skinfolds – triceps, subscapular, suprailiac and calf.

J. Méscáros and J. Mohács (1982) conducted a comparative study of male and female A-class basketball, handball and volleyball players in the early 1970s and in 1979–1980 using the Heath-Carter classification. In addition, Conrad's plastic index was measured.

Male volleyballers' height, Conrad's plastic index, endomorphy, mesomorphy, relative robustness were found to be greater in the later study. In women there were no essential changes, only endomorphy had moderately increased. The authors concluded that body build had changed conforming to the change evolved in the conditions of playing these games during these years.

Although all the authors dealing with volleyballers' body build recognise the importance of the morphological factor, the number of body dimensions used is very limited. Practically no attention has been paid to extremities' length, many circumferences of the extremities and the trunk, which could be essential for proficiency in the game, particularly in the period of adolescence. In recent times the situation has been changing, and measuring of the full range of anthropometric variables has been recommended as can be seen in the works of E. G. Martirosov (2001) and A. Avloniti et al. (2001).

E. G. Martirosov (2001) studied 2948 male and 1541 female athletes (aged 19–31 years) representing 44 and 25 sports events respectively. Each individual was measured for 67 morphological characteristics (length and transverse measurements and circumferences). Factor analysis of body composition of athletes of different sex and representing different events gives reason to believe that each event is characterized by a distinctive structure of body build. This concerns from factors of generalized variance from valid morphometric parameters inside the group and for the representatives of different specializations. Detailed valid parameters have the largest intragroup differences in sportsmen of each kind and to a large extent determine their sport results.

Special attention should be devoted to anthropometric study of female athletes during growth (Avloniti et al. 2001). The authors emphasize that, although knowledge about the effect of exercise and sport training on child growth has been expanding rapidly in recent years, there are not many studies that compare the effects of training on body composition and morphological characteristics in female athletes practising different sports during childhood. A. Avloniti et al studied 208 subjects aged 11-14 years representing 7 sports events. They measured height, body mass, sitting height, armspan, skinfold thickness of triceps and calf, 13 circumferences (shoulder, chest, waist, abdominal, buttocks, thigh – proximal, midthigh and distal, calf, ankle, arm, forearm, wrist) and 8 diameters (biacromial, chest, biiliac, bitrochanteric, knee, ankle, elbow, wrist). The authors found that, although it is difficult to differentiate between two factors – growth and training – on this sample, it is still necessary to study in greater detail individual differences between adolescent female athletes in order to define some components in the process of talent identification.

From what has been said above, we can see that female volleyballers' proficiency in the game is essentially dependent on their morphological characteristics. A conclusion has been reached that more detailed anthropometric studies of players are needed, and research in this area will continue.

1.2. A brief overview of testing volleyballers' abilities and correlations of tests results with body build

1.2.1. Physical ability tests

Volleyball might generally be characterized as a game with active motion that requires relatively short-time physical effort with maximum exertion of the will (Loko, 1996). Periods of action alternate with rest; therefore, the game proceeds in the aerobic phase, which is intermingled with a high proportion of the anaerobic component (Gionet, 1980; Künstlinger et al., 1987; Driss et al., 1998).

Volleyball belongs among the events which are primarily characterised by explosive movements (Viitasalo, 1988; Heimer et al. 1988). Volleyballers' fundamental abilities include jumping skills, speed, and upper body muscles explosive strength that is necessary for successful block and spike (Hoeger et al., 1987; Morrow et al. 1979; Smith et al, 1992; Häkkinen, 1989, 1993). Another important quality is endurance, which enables the players to play repeated sets. All of these should be combined with high-level technical skills.

Although technical skills are important in volleyball, their application in the game is limited by the physical fitness of each player (Smith et al., 1992). The level of motor activities, in its turn, is influenced by peculiarities of body build, which secure conformity between body dimensions and biomechanical character of rational movement of the body (Carter, 1985; Crawford, 1996).

Everything mentioned above refers to the need to assess players' abilities either at competitions or by means of a series of specially designed physical ability tests. Tests usually compare players of elite teams or teams with different playing skills or adolescent volleyballers of different age groups. Authors usually apply a number of tests simultaneously. Below we present literature data on the most essential physical ability tests, discussing them in combination with the data of other simultaneously performed tests and body build data.

Vertical jump tests are one of the main criteria of volleyballers' physical abilities (Fleck et al., 1985; Marey et al. 1991; Smith et al., 1992; Lee et al., 1989; Häkkinen et al., 1989; Engel et al., 2001).

Among volleyballers of different technical proficiency, elite volleyballers had better jumping abilities; they also had bigger height and weight (Matsudo et al., 1987; Viitasalo et al. 1987). Better results in jumping tests also correlated with the results of a number of other motor ability tests and enabled 6 highly skilled women volleyball players out of 15 to move on to a more advanced training group (Spence et al., 1980).

The study by Fleck et al. (1985), which compared the age, height, weight, body fat percentage, vertical jumping height, maximum oxygen consumption, maximum heart rate and respiratory exchange ratio, demonstrated essential differences between the national team and a college team in age (23 and 21.5 years), body fat percentage (11.7 and 18.3%) and vertical jumping height (52.4 and 45.5 cm). The national team was significantly older but had lower body fat percentage and better vertical jumping abilities. These results indicate that trainers of elite volleyball players should in future apply techniques that reduce the percentage of body fat and increase vertical jumping height.

Analogous studies have also been carried out in adolescent female volleyballers. M. Thissen-Milder and J. L. Mayhew (1991) applied the jumping test, specific ball handling tests, flexibility markers in combination with height, weight and body fat percentage for selection and classification of 50 adolescent female volleyballers (aged 14–15). The combination of tests enabled the authors to predict the players' proficiency in three different groups. Jumping height was predictable from other tests within 68–78%.

A. Farkas et al. (1991) attempted to find a simple set of variables for adolescent boys (n=70) and girls (n=168), which would contain both body build parameters and some motor abilities. The parameters studied included stature, body mass, body fat content, Conrad's metric and plastic indices, explosive strength score of the leg and reaction and movement times of the hand, and jump and reach tests. Increase in age brought about growth in anthropometric dimensions and improvement of test results. In the group of 15-year-old girls anthropometric data and test results were in statistically significant correlation.

Along with jumping tests, great significance should be attached to speed tests.
W. W. Hosler et al. (1978) studied a large sample of intercollegiate women volleyballers (16 teams, n=180) in a regional tournament. The authors carried out speed tests and arm and leg strength tests, and measured anthropometric variables. The speed test consisted in 20-yard sprint, where the times of running the first and the second 10 yards were measured separately. To measure strength, Cybex power leg press for legs and Cybex power bench for arms were used. The anthropometric variables included height, weight, biacromial and biiliac diameters, tricepts, suprailiac and thigh skinfolds. Body fat percentage was calculated. Factor analysis revealed three factors: body size, speed/fat and strength, which

accounted for 61% of the total variance. From all the teams studied, 34 most successful and 38 least successful players were found. These groups showed essential differences in all the characteristics measured. The group of successful players was faster, taller, with broader shoulders and hips, greater arm and leg strength, and lower body fat content.

Bale et al. (1992) studied adolescent boys (n=103) and girls (n=65) aged 13–18, finding correlations between age, anthropometric data and various motor performance tests, including speed in 40-yard dash. Performance in 40-yard dash was poorer in subjects with higher fat percentage.

Flexibility tests also form part of motor performance tests, but compared to jump tests, there are considerably fewer data on them in literature.

A thorough study of elite male and female volleyballers has been carried out by E. J. Lee et al. (1989). The authors state that it is not clear how good elite athletes' flexibility is, and how it correlates with other performance tests. The purpose of their study was to compare shoulder and hip flexibility to jumping performance of male and female Olympic Festival volleyballers. The subjects were 24 men and 22 women. Standing vertical jump and approach vertical jump were measured. Stainless steel goniometer was used to measure transverse shoulder extension and hip flexion. The authors found that jump tests were in strong mutual correlation both in women (r=0.78) and in men (r=0.84). Approach vertical jump and hip flexion correlated positively in men (r=0.42) but negatively in women (r=–0.47). Standing vertical jump and hip flexion were also in negative correlation in women. Thus, the study revealed that in men greater flexibility was correlated positively with jumping performance, in women, however, negatively. The authors were unable to substantiate their result; the reason may lie in anatomical differences of the hip joint between the sexes.

S. Marey et al. (1991) also studied the significance of flexibility tests in relation to other tests in players of two teams (average ages 19.6 and 19.). Game performance was evaluated when the two teams played each other. The authors found which tests differentiated the winning team from the losing team. Flexibility was evaluated from a test of trunk flexion, trunk extension, shoulder elevation, ankle plantar flexion, sit and reach tests. In addition to flexibility, agility, vertical jump, reaction and movement times and cardiovascular endurance were measured. Specific volleyball tests were also carried out to evaluate various aspects of the game: overhead volleying ability, forearm passing ability, bump/set volley test, serving test. Discriminant analysis was used to establish the factors that differentiated the winning team from the losing team. The best combination of factors included shoulder flexibility, agility, forearm bump test, and sit and reach flexibility (84.6%).

Bale et al. (1992) used sit and reach tests in combination with other motor performance tests to evaluate flexibility in 13–18-year-old boy (n=103) and girl (n=65) athletes. Statistical analysis revealed that in flexibility girls surpassed boys.

One of the primary subdomains of human performance is muscular strength. Muscular strength can be classified in relation to either the body segment isolated or the method of measurement (Komi, 1973; Jackson and Pollock, 1976). A. S. Jackson and R. J. Frankiewicz (1975) examined the factor structure of muscular strength and concluded that there were two general dimensions: upper body and leg. For strength measuring, at least one test should be selected from each dimension.

Muscular strength is in correlation with body build. In a study of adolescents, Bale et al. (1992) measured isometric strength using Stoeltin's grip dynamometer on both hands. The results of these tests correlated significantly with height (r=0.68), weight (r=0.83) and age.

Using Cybex power bench press for measuring arm strength and Cybex power leg press for leg strength of 180 female volleyballers, Hosler et al. (1978) found that upper body strength and fat weight were most important in differentiating between players of the most and least successful teams. Both strength and body fatness are variables that can be modified in women with training (Brown and Wilmore, 1974). Absolute peak muscle power correlates reliably with extremities circumferences, body mass and muscle mass (Tittel and Wutscherk, 1992; Ferretti et al. 1994).

E. Häkkinen (1993) carried out a detailed study of changes in strength and explosive strength tests and jump tests during various training seasons. He found that, in order to maintain the level of explosive strength performance capacity in players, loads in strength training should be applied individually and with caution; otherwise, repeated training sessions may result in significant decrease in strength and in jumping performance.

Endurance tests are applied to study the level of endurance fitness of volleyball players, the endurance capacity of the neuromuscular system. Endurance studies are carried out either in laboratory or field conditions or during play. J. T. Viitasalo et al. (1987) studied 20 Finnish men volleyballers and concluded that volleyball is an aerobic sport, having high alactic anaerobic power productions performed with fairly long recovery periods. Consequently, in training it is necessary to check carefully the intensity and duration of training drills and the duration of recovery period in order not to stress the lactic anaerobic metabolism too much.

As an endurance field test, 20 m endurance shuttle run is often used (Leger et al., 1988).

The above results show that volleyball functional abilities are influenced by peculiarities of body build in adult women as well as adolescents. Therefore, research in this area should be continued.

1.2.2. Volleyball technical skills tests

The dynamics of modern sport games consist of quick conscious orientation, decision-making and accuracy of motor performance. This includes accuracy in shooting, throwing and passing the ball, controlling and estimating the course of action from the perspective of the goal of the action and the attempted result (Wyžnikiewicz-Kopp, 1998).

Volleyball is popular in a number of countries and the rules of classical volleyball have been fixed (McGown, 1994; Viera and Ferguson, 1996). At universities traditional Aapherd tests (1969) are used for learning pass and set, and serve is tested according to Harrison (Harrison et al., 1999).

However, the literature on the analysis of the efficiency of the training process and about new tests of skills development is rather scanty.

One of the most significant recent studies has been published by J. M. Harrison et al. (1999), who analysed the results of teaching volleyball to girls (n=182) in six beginning college volleyball classes, and compared the results after teaching mastery learning or skill teaching methods.

J. L. Oslin et al. (1998) apply a special multidimensional program in school physical education pratice – the game performance assessment instrument (GPAI).

J. Šimonek (1998) analyses changes in girl' performance (24 girls aged 11–13) at school lessons after the experimental group was taught a set of special volleyball exercises that consisted of 16 reaction exercises, 12 exercises focussed on space orientation and 15 on kinaesthetic differentiation skills. Compared to the control group, good results were achieved in exercises for coordination skills, which enabled the author to devise a special exercise programme for this age group.

In addition to the aforementioned, authors have analysed the efficiency of learning single elements of volleyball like serve and overhead set by 53 students from a private school (French et al., 1991), of four volleyball skills such as set, forearm pass, serve and spike by 58 male and female university students (Buck et al., 1990), and of block play by male volleyballers (Bodys and Burda, 1998).

The authors find that it is necessary to improve teacher preparation, and for this a special programme for qualitative skill analysis has been designed (Wilkinson, 1991).

Discussions are still in progress over the technique of performing different volleyball elements. In particular, the significance of serve has changed since the adoption of the new volleyball rules by FIVB (Rally Point System – RPS), where a service error will give a point to the opponent (Fontani et al., 2001). In the same article, the author also analyses the methods of performing different variants of serve (underhand serve, overhand serve and jump serve).

Literature emphasises that not only university students but also younger volleyballers need test exercises. There is, however, no established view which tests should be applied and how they should be carried out. Thus, M. Thissen-Milder and J. J. Mayhew (1991) present in their paper specific volleyball tests for 14–16-year-old girls by the following authors: overhead volley test by Brady (1945), forearm pass test by Brumbach and Kronquist (1958), wall spike test by Cox (1981), and bump/set test for access ball control ability by Cox (1980).

Marey et al. (1991), when comparing two female volleyball teams (age 19 years, n=14 and 23), applied the following specific volleyball tests: overhead volleying ability by Brady, wall volley (Brady, 1945), and forearm passing ability was evaluated by Brumbach forearm wall volley (Brumbach and Kronquist, 1958). Serving ability was evaluated by the Russell-Lange serving test (Russell, Lange, 1940).

The common view is that young volleyballers' specific skills tests should be associated with their physical abilities.

For example, M. Thissen-Milder and J. L. Mayhew (1991) studied 50 high school female volleyball players from three teams at different levels, applying specific ball-handling tests that included overhead volley, forearm pass, wall spike and self bump/set tests. In addition to ball-handling tests, the study included height, weight, body fat percentage calculated, agility run, and vertical jump. Statistical analysis showed that, from among the abovementioned indicators, the combination of forearm pass, overhead volley, vertical jump and weight classified 68% of the players to their team level.

As seen from what has been said above, adolescent volleyballers should be more often given test-exercises. A unified methodology should be developed, which would improve the acquisition of volleyball skills.

1.2.3. Psychophysiological ability tests

Present-day volleyball requires from players quick reaction to changing situations in the game and accurate and precise movement for handling the ball. All this requires the development of various psychophysiological abilities in the players and assessment of the quality of these abilities.

The number of respective studies in sports physiology is on the increase (Philips and Summers, 1954; Abernethy, 1987, 1993; Kerr et al., 1992; Ericsson and Charness, 1994; Tenenbaum and Bar-Eli, 1995).

Pertinent research in volleyball has been carried out in India (Sharma et al., 1986), Turkey (Hascelik et al., 1989), Greece (Kioumourtzoglou et al., 2000) and Germany (Hackfort and Schmidt, 2001).

Most often, researchers have studied subjects' reaction time to visual and auditory stimuli. Thus, J. Hascelik et al. observed a junior male volleyball team (age 18 years, n=20), who underwent a training period of 8 weeks. Physical fitness tests were carried out and auditory and visual reaction times measured at the beginning and at the end of the training period. The study revealed that physical fitness improved and auditory and visual reaction times shortened.

In India (Sharma et al., 1986) reaction time and concentration levels of both recreational and competitive volleyball players were compared. The total number of subjects was 80 – 40 in both groups. An electrical chromoscope was used to test reaction time to visual and auditory stimuli, while a special test was used to measure concentration. The results showed that the competitive players had consistently better visual and auditory reactions as well as concentration abilities.

Thoroughgoing psychological research has been carried out by Greek researchers headed by E. Kioumourtzoglou (2000) at Democrites University of Thrace. Thirty men, 12 of them elite volleyballers, members of the Greek national volleyball team (age 18.5 years), and 18 physical education students were studied. The study measured 11 abilities for examining the differences in the cognitive, perceptual and motor abilities of expert volleyballers and novices. Expert volleyball players appeared to detect a moving object significantly faster than novices and were able to estimate its speed and direction more efficiently.

Regular studies on sports psychology are also carried out at the Institute of Sport Science and Sport at the University of Federal Defence in Munich (Germany). D. Hackfort and U. Schmidt (2001) have been studying Olympic athletes and young talents for many years. A newly developed computer-assisted psychomotor ability test and training system has been used to improve talent identification. The computer program assesses reaction time to optical and acoustic stimuli, discrimination of both, anticipation time to steady and increasing stimuli and concentration. Top-level athletes representing different events, among them 13 volleyballers were studied. The best results at tests were achieved by shooters and alpine skiers; volleyballers did considerably worse.

In Estonia, Kaivo Thomson (1992, 1996) from the Laboratory of Cognitive Neuroscience and Experimental Psychology at Tallinn University of Pedagogical Sciences has carried out psychophysiological studies in different athletes. Detailed tests have been administered to adolescent female volleyballers aged 13–16 years (R. Stamm et al., 2002b), and correlation has been found between test results and proficiency in the game.

Relatively scanty literature on volleyballers' psychophysiological properties gives reason to continue this trend of research from the aspect of proficiency in the game.

1.3. Assessment of volleyball proficiency

The most important factor in a competitive game, depending on which the team either wins or loses points, is each player's proficiency. The ultimate aim of developing the players' technical skills and physical abilities and devising tactical plans for the team is to improve the players' proficiency. Therefore, a number of methods have been developed to assess players' performance in the game. Earlier methods registered players' activities by means of pencil and paper, newer methods use specially designed computer programs.

The general principle of all recording systems is similar: they register the player's number, the element performed by the player and the result. The main difference between the methods is how quickly the players' activities can be summarised and how data are preserved to carry out more detailed statistical analysis later.

The oldest recording method used in Estonia was a system designed by A. Huimerind (1971). Elements of the game performed by players were recorded by pencil and paper. The efficiency of serve and reception was assessed in a four-point system; spike, block, dig and the second pass in a three-point system.

M. Fiedler (1978) distinguished between two- and three-level systems for recording the game. A two-level system grades whether an element of the game was performed well or badly. In the case of a three-level system, it was assessed at the performance of each element whether the ball remained in play, or whether the element brought success or failure. Fiedler also used recording by hand, therefore it was not possible to sum up the results during the game or immediately afterwards. The author emphasised the importance of making summaries and comparing the players' proficiency in performing different elements at least at the end of the season.

M. Amalin's system (Амалин, 1973), which also used recording by hand, registered the performance of elements in a four- or five-point system. The basis for grading a serve performed by a player was how the opposing team could receive it. Reception was assessed analogously to serve. The efficiency of spike and block was assessed in a five-point system.

I. Drachov's recording system (Nõlvak, 1995) also recorded players' activities by hand. Like in Amalin's system, the efficiency of serve was recorded according to how it was possible to receive it. The efficiency of both serve and its reception was assessed in a six-point system. Assessment of the efficiency of attack was based on the players' positions on the court, which was each time recorded graphically.

H. Aunin's system (1979) also used recording by hand. The quality of serve and reception were both assessed in a five-point system. In the case of spike, the number of the player who performed the spike is recorded, then as an index, the zone from which the attack took place, and the direction and efficiency of the spike are taken into consideration. For all the spikes performed, the average efficiency is calculated, which is the difference between successful and failed spikes divided by the total number of spikes. Teams are considered successful if average efficiency in a match is higher than 35%, successful in the case of 30–35%, satisfactory in the case of 25–30% and unsatisfactory in the case of 25% and below.

The best-known computer program for recording players' activities and efficiency of performing the elements of the game is Volleyball Win Vis version (Oulu EM 1993). This program was used to record the games of the 1993 European men's championships. The performance of all elements is recorded in a three-point system, specifying whether the element was performed successfully or not, or the ball remained in play. Efficiency is calculated only on the basis of elements that were performed successfully. For example, the number of successful spikes is divided by the number of all spikes performed by the player and multiplied by 100. A spike is successful only if the ball is attacked on the floor of the opponents.

The volleyball recording system *Game* created by the author (Nõlvak, 1995a, b; R. Stamm et al., 2000b, 2002b) can be used to record nine different activities. These are serve, reception, spikes from zones 4, 3 and 2 and the end line, feint, block and dig. Serve and reception are recorded in a five-point system, spike, feint, and block in a three-point system and dig in a two-point system.

As earlier programs use different systems of points to record the technical elements, and there is a different formula for assessing the efficiency of each technical element, it is not possible to compare the efficiency of performing different technical elements. The proficiency assessment formula in the program *Game*, however, enables us to calculate for each player the index of proficiency for each technical element. A grade from 0 to 1 is obtained, where 1 is the best possible grade and 0 the weakest.

Among the earlier programs, the most labour-intensive is FIVB Volleyball Information System (Volleyball Information System, 1997). In order to apply it, three networked computers and at least three recording assistants are needed. A novelty of this program is that, by comparing the score, it automatically checks the correctness of recording. For example, if one team is marked a reception error, then the other team automatically wins a point.

In addition to recording systems, video technology is used for assessment of volleyball matches. By means of video recordings the relation between work and rest periods during matches is assessed, and accordingly, the relation between work and rest is corrected at training sessions (Gionet, 1980; Viitasalo et al., 1987; Vescovi, 2001).

Video recordings are used for both teaching and tactical purposes. It is useful to be able to show players specific action, both their own and their opponents'. Video allows a much deeper, more concrete and more precise time evaluation of the action. It permits a precise appreciation of the patterns in the game – attack patterns, offence and defence tactics and help the coach to exploit them. Data collected from video analyses are often inputted into the computer for further analysis (Hippolyte et al., 1993).

N. Westphal and W. Schöllhorn (2001) have carried out filming for tactical analysis in combination with computer recording. The authors watched and recorded the movement of the three backcourt players during three matches of four volleyball team games. They found that the movement of three backcourt players is essential as it provides strong evidence of specific strategies for every team. In the future, such a method could be effective for quantitative analysis of team actions in volleyball.

R. Peglar (2000) has designed a special UBSIM program as a simulator program, which accepts competition format and teams' performance parameters as input. On its basis, the program performs a match between teams as a computer simulation. The aim of such a simulation is to study which changes in single or multiple parameters would improve which competition characteristics. The author has based his simulation on a Monte Carlo simulation program.

PURPOSE OF THE STUDY

The purpose of the study was to examine young female volleyballers' body build, physical abilities, technical skills and psychophysiological properties in relation to their performance at competitions.

The specific aims were:

1) to analyse young female volleyballers' anthropometric body structure as a whole and, based on that, find possibilities for classifying their body measurements and using them for evaluating their performance;
2) to test young female volleyballers' physical abilities, technical skills and psychophysiological properties and relate these data to their individual peculiarities of body build;
3) using the original volleyball recording system *Game* devised by the author, record the matches where the subjects participated and associate their performance with individual peculiarities of body build and tests results.

MATERIAL AND METHODS

2.1. Subjects

The principle sample consisted of 46 female volleyball players aged 13–16 years. All of them had practised volleyball regularly for the last three years and participated in young female volleyballers' championships in the age group of up to 16-year-olds. The players were informed about the essence of the studies planned, and they as well as their parents consented to voluntary testing. The study was approved by the Medical Ethics Committee of the University of Tartu.

The players were studied in teams (n = 6). The anthropometric measuring as well as the testing of physical abilities, performance of volleyball technical skills and psychophysiological properties of all players of a team were carried out at one and the same session. The same researchers participated in examining all the teams.

In addition to anthropometric measurements and tests, the proficiency of 32 players was registered by the computer program *Game* at Estonian championships in at least four matches.

Additionally, in 2004 the author studied the body build and proficiency in the game of 74 female volleyballers aged 13–15 years from eight teams who participated in Estonian championships.

Anthropometric measurements were taken by Liidia Saluste PhD; tests were carried out by Raini Stamm and Meelis Stamm; games were recorded by Raini Stamm.

The preliminary research results on the girls' physical abilities and body build were used by Meelis Stamm for writing his Master's thesis at the Faculty of Physical Education at Tallinn Pedagogical University (M. Stamm, 2002). The analysis of the study as a whole about volleyballers' performance in relation to their body build, physical abilities, technical skills and psychophysiological properties was carried out by the author of the present paper, doctoral student of the Faculty of Exercise and Sports Sciences at the University of Tartu Raini Stamm.

2.2. Measurement procedures

2.2.1. Anthropometric research

The girls were healthy, and their sexual development corresponded to Tanner's (1962) stages III-IV. The methodology of the anthropometric study relied on the long-term research carried out on many populations at the Centre for Physical Anthropology, University of Tartu (Kaarma, 1981; 1995; Kaarma et al., 1997, 2000, 2001; Peterson and Saluvere, 1998).

All anthropometric measurements were taken by the same trained anthropometrist, who had previously shown test-retest reliability of $r > 0.90$. Three complete sets of measurements were carried out and the mean of the three values was used.

The girls were measured according to the classical method of Martin (Knussmann, 1988). For measuring the skinfolds, the methodology provided in Knussmann's handbook (1988, p. 274) was followed. To measure lower extremity length, we applied the method of K. S. Jatsuta (1923) that has been widely accepted in Russia and has been the principal method used in Estonia since J. Aul's work (1977).

Body height was measured in centimetres (± 0.1 cm) using a Martin metal anthropometer and body weight in kilograms (± 0.05 kg) on medical scales. Depth and breadth measurements were measured with Martin calipers, circumferences with a metal measuring tape, skinfolds with Holtain skinfold calipers on the right side of the body. A total of 49 body measurements, including 11 skinfolds, were taken. From these basic measurements, 65 indices and body composition characteristics were calculated.

The length measurements were body height, suprasternal height, xiphoidal height, head-neck length, sternum length, abdomen length, trunk length, upper body length, lower body length, upper limb length, lower limb length. In addition to these, horizontal arms spread was measured.

The breadth-depth measurements were biacromial, chest, waist and pelvic breadths, chest and abdomen depths. To assess the thickness of limb bones, femur, ankle, humerus and wrist breadths were measured. The circumferences measured included head, neck, upper and lower chest, waist, pelvis, hip, proximal and mid-thigh, upper and lower leg, forearm and wrist, arm and arm flexed and tensed. The measured skinfolds were chin, chest, side, waist, suprailical, umbilical, subscapular, biceps, triceps, thigh and calf.

In addition to the anthropometric data of the 46 adolescent female volleyballers, the same anthropometric variables of schoolgirls of the same age who had not practised volleyball regularly (n=586) were used for comparison as representatives of the national population of ordinary girls (Veldre, 2002b).

In 74 girls who participated in Estonian championships, 14 measures were taken – weight, height, suprasternal height, xiphoidal height, wrist breadth, upper, lower chest, waist and hip circumferences, upper thigh, lower leg circumferences, arm circumference, flexed and tensed arm circumference, wrist circumference.

2.2.2. Physical ability tests

All the subjects passed nine validated tests of physical fitness. Jumping ability was measured by two vertical jump performance tests (Young et al., 1997): standing vertical jump and reach (PA_1), and running vertical jump and reach (PA_2). As the highest reach of the player's outstretched arm had been measured, then subtracting from PA_1 the highest reach of the outstretched arm, the height of standing vertical jump (PA_3) was obtained. By subtracting the highest reach of the outstretched arm from PA_2, we obtained the height of running vertical jump (PA_4).

Maximum aerobic endurance was measured by 20 m shuttle run (PA_5). The reliability and validity of this test have been checked by Leger et al. (1988). Trunk strength (PA_6) was measured using the sit-up test by Brewer and Davis (1993). The flexibility test (PA_7) measured the extent of bending forward from sitting the position (Larson, 1974). Deftness and speed of movement (PA_8) were measured by a zigzag run test (Курамшин et al., 1985). Upper body and arms strength were measured by the medicine ball throwing test (PA_9) (Viitasalo, 1988).

2.2.3. Volleyball technical skills tests

Mastery of volleyball skills was evaluated by nine tests compiled by the author of the thesis. The tests were based on the classical elements of volleyball (McGown, 1994; Viera and Ferguson, 1996). They included two overhead pass tests (T_1, T_2), a forearm pass test (T_3), two serve tests (T_7, T_8), a reception test (T_9), two spike tests (T_4, T_5) and a feint test (T_6).

2.2.4. Psychophysiological tests

The girls' psychophysiological abilities were assessed by 21 computerized tests that can be grouped into the following four types.

1) Perception of the speed of a moving object. In three series, the subject had to assess the speed of an object moving on the computer screen (eight attempts in each series). Based on this, the program calculated the average value of speed assessment correctness in points, separately for each series (A_1, A_3, A_5), and the average time needed for assessment in seconds (A_2, A_4, A_6). The test result was the better the more points the subject achieved and the less time was needed for giving the assessment.

2) Auditory reaction was studied by three different stimuli (eight attempts for each stimulus). The reaction time was recorded separately for the right and the left hand. The program calculated the average reaction time for the right (B_1, B_3, B_5) and the left hand (B_2, B_4, B_6).

3) Visual reaction was also studied by three different stimuli (eight attempts for each stimulus), separately with the right and the left hand. The program calculated the average visual reaction time for the right (C_1, C_3, C_5) and the left hand (C_2, C_4, C_6).

4) If auditory and visual tests were viewed as simple reactions, the speed perception test was evaluated as a complex reaction. Here the subjects had to assess objects moving at different speeds, adopt a decision and react only after that. Therefore, in order to compare individually the speed of processing different information, we calculated the difference in seconds between complex reaction time (A_2, A_4, A_6) and perception time of visual stimuli

as a simple reaction (C_1 – C_6). The respective test was called the test of anticipatory reflection of reality (D_1 – D_3), and its results were calculated as follows:

$$D_1 = A_2 - \frac{C_1+C_2}{2}\ ;\ D_2 = A_4 - \frac{C_3+C_4}{2}\ ;\ D_3 = A_6 - \frac{C_5+C_6}{2}\ .$$

The methodology of psychophysiological tests for volleyballers was mostly based on the well-substantiated methodologies of E. Kioumourtzoglou et al. (2000), Z. Hascelik et al. (1989) and K. Thomson (1997, 2001). The apparatus used by us for psychophysiological studies had been patented in Moscow on 8 June 1992 (No. 1766372) (Thomson, 1992) and accepted for use by the IX World Congress of Sport Psychology in Israel in 1997 (Thomson, 1997).

2.2.5. Players' proficiency

To assess players' proficiency at competitions, the original volleyball recording program *Game* was used (Nõlvak, 1995a, b). This program has been applied by the Estonian Volleyball Federation and has been introduced in the journal of the American Volleyball Federation (Stamm et al., 2000a, 2001).

The results were recorded at Estonian Championship and Cup matches for up to 16-year-olds, in which the 32 players under study participated.

All the girls played in the teams where they practise. The games were recorded within three months in different cities of Estonia where the matches took place. The assessment of each player was based on at least four matches. Technically, the assessment of players' proficiency proceeded as follows: during the game a recording assistant (a volleyball expert) fixed the performance of each technical element by each player of one team by pressing, according to the program, three keys on the computer keyboard. This enabled us to record: (1) the element of the game that was performed; (2) grade for its performance; (3) the number of the player who performed the element.

To calculate each player's proficiency in all the elements they performed the following formula was used:

$$\text{Index of proficiency} = \frac{\text{number of performances} \times \text{maximum grade} - \text{sum of grades}}{(\text{maximum grade} - 1) \times \text{number of performances}}$$

Proficiency can range from 0 to 1, where 1 means that in all the cases the element was performed excellently, and 0 – a failure in all the cases.

The 74 female volleyballers studied in 2004 participated in 28 matches, which were recorded in parallel with two computers equipped with the program *Game*.

2.2.6. Statistical analysis

The data were processed using the SAS system. For anthropometric analysis, basic anthropometric measurements and indices and body composition characteristics were used. For all anthropometric variables the basic statistics (means $\bar{x}$ and standard deviations SD), in most cases also minimum (min) and maximum (max) were calculated (see Tables 1 and 2).

To check the influence of age, the linear correlation coefficient r was calculated between age and all anthropometric variables, and its significance (using significance level α = 0.05) was tested (see Tables 1 and 2). To illustrate the dynamics of anthropometric measurements in age, the means and standard deviations of measurements were calculated in age groups (Table 1).

To prove the determining role of weight and height in the dependency structure of all anthropometric measurements for most basic measurements, linear models by age, weight and height were created (Table 4) where the description rate was measured with the help of the determination coefficient R^2.

Using the means and standard deviations of weight and height, a 5 SD weight-height classification (Fig. 1) was created according to the following rule:

Class 1 (small):

weight < $\bar{x}_w - 0.5\ SD_w$ and height < $\bar{x} - 0.5\ SD_h$

Class 2 (medium):

$\bar{x}_w - 0.5\ SD_w \leq$ weight < $\bar{x} + 0.5\ SD_w$ and $\bar{x}_h - 0.5\ SD_h \leq$ height < $0.5\ SD_h$

Class 3 (large):

weight ≥ $\bar{x}_w + 0.5\ SD_w$ and height ≥ $\bar{x}_h + 0.5\ SD_h$

Class 4 (pycnomorphic):

weight ≥ $\bar{x}_w - 0.5\ SD$ and height < $\bar{x}_h - 0.5\ SD_h$ or

weight ≥ $\bar{x}_w + 0.5\ SD$ and height < $\bar{x} + 0.5\ SD_h$

Class 5 (leptomorphic):

weight < $\bar{x}_w - 0.5\ SD$ and height ≥ $\bar{x}_h - 0.5\ SD_h$ or

weight < $\bar{x}_w + 0.5\ SD$ and height ≥ $\bar{x}_h + 0.5\ SD_h$.

		Weight classes		
Height classes		*Light*	*Medium*	*Heavy*
	Short	Small	Pycno-morphic	Pycno-morphic
	Medium	Lepto-morphic	Medium	Pycno-morphic
	Tall	Lepto-morphic	Lepto-morphic	Large

Fig. 1. Body build classes

For all anthropometric data means and standard deviations in all classes were calculated. Using Scheffe test, the class means of all anthropometric data were compared between classes 1 and 3, but also between classes 4 and 5, using the significance level $\alpha = 0.05$ (see Tables 5 and 6).

The basic statistics were calculated and correlation with age checked for physical ability tests results (Table 7), volleyball technical skills tests results (Table 12) and psychophysiological tests results (Table 16). The means of physical ability tests results were calculated also in 5 SD height-weight classes and comparisons between classes means were made (Table 10).

The means of all anthropometric measurements of young volleyballers were compared with the same characteristics of ordinary girls of the same age; for comparisons t-test with significance level 0.05 was applied (see Table 3, the last column).

To illustrate the differences between young volleyballers and ordinary girls the z-scores scale was calculated using basic statistics for ordinary girls $\overline{x}_{og}$ and SD_{og} and volleyball players; the scores were calculated by the following formula:

$$z = \frac{x - \overline{x_{og}}}{SD_{og}} ,$$

see Table 3, which gives the basic statistics of z-scores.

To check the dependencies between different variables (anthropometric measurements and test results), the following linear correlation coefficients were calculated:

- mutual correlations of physical ability tests (Table 8);
- correlations between physical ability tests and basic anthropometric variables (Table 9)
- correlations between volleyball technical skills tests and basic anthropometric variables (Table 13);
- correlations between volleyball technical skills tests and body composition characteristics (Table 14);
- correlations between psychophysiological tests and anthropometric measurements (Table 17);
- correlations between psychophysiological tests and anthropometric indices and body composition characteristics (Table 18).

In most cases only significant correlations ($\alpha = 0.05$) are given.

Linear regression models by anthropometric variables were created for physical ability tests (Table 11), volleyball technical skills (Table 15) and psychophysiological tests results (Table 19). In all cases optimal models were found using stepwise procedures. All given models are statistically significant ($\alpha = 0.05$) and their quality is characterized by determination coefficient R^2.

In the 74 players from 2004, the proficiency in the game was assessed according to body build classes.

For the efficiency of performance of different technical elements a series of linear models was created in the same way by different groups of explanatory variables:

- anthropometric measurements;
- anthropometric indices and body composition characteristics;
- physical ability tests;
- volleyball technical skills tests;
- psychophysiological properties (see Table 20).

RESULTS

3.1. Results of anthropometric research

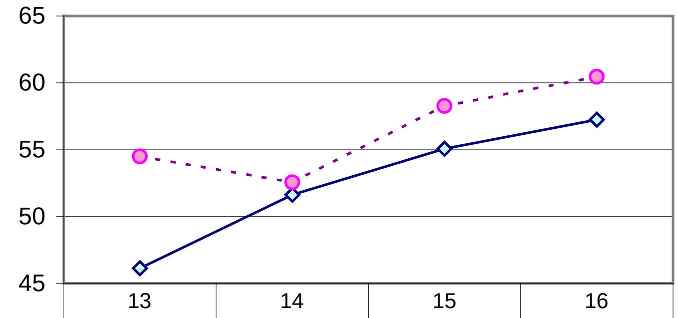
Means and standard deviations of basic anthropometric variables in age classes and their correlation with age are presented in Table 1. As the table shows, significant differences could be noticed in the case of 14 variables. Increase in age caused a significant increase in height, weight, suprasternal height, xiphoidal height, head-neck length, sternum length, upper limb length, horizontal arms spread, acromial breadth and pelvis breadth. As for circumferences, there was no increase in pelvis circumference, middle thigh, upper leg and forearm circumferences. Limb bones thicknesses – humerus, femur, ankle and wrist breadth – and lower leg and wrist circumference did not increase significantly. There was no significant difference in skinfolds.

In indices and body composition characteristics, the age-related difference was even smaller (Table 2). Only four indices out of 65 showed a statistically significant difference. Thus, increase in age caused an increase in body surface area, humerus breadth / upper limb length and bone-muscle rate of the cross-sectional area of the arm. Relative head circumference decreased.

There were no significant differences in body mass index, Rohrer index, relative thickness of limb bones and all the characteristics of body fat content.

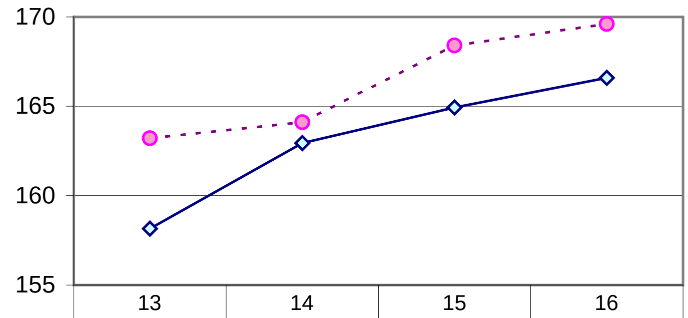
Although we did not conduct a longitudinal but a cross-sectional study, the assessment of proportions showed that despite individual variability of body characteristics in puberty, the general development of young volleyballers still followed the established proportions.

Comparing the girls' height and weight with Estonian averages in respective age groups, we found that volleyballers surpassed their peers in all age groups (Fig. 2 and 3).



	13	14	15	16
national	46,12	51,62	55,07	57,24
VB	54,48	52,55	58,26	60,46

Fig. 2. Weight of girls aged 13-16: national data and data of VB-girls



	13	14	15	16
national	158,15	162,94	164,92	166,59
VB	163,2	164,1	168,4	169,6

Fig. 3 Height of girls aged 13-16: national data and data of VB-girls

Next we compared all the basic anthropometric characteristics of our volleyballers with the national population of girls of the same age (n=586). The volleyballers' data were presented on the scale of z-scores of ordinary girls of the same age (Table 3). As we can see, out of the 39 basic anthropometric variables compared, 31 had statistically significant differences between volleyballers and the national average. All the length measurements compared, including upper limb length, were significantly greater in volleyballers; only lower limb length was greater in the control group.

Among breadth and depth measurements, volleyballers had greater biacromial breadth; the control group, however, greater chest, waist and pelvis breadth, and chest and abdominal depth.

Volleyballers had greater waist, upper and middle thigh, upper and lower leg, arm, flexed arm and wrist circumference. The control group, however, had greater pelvis and forearm circumference.

Predicting the variability of all basic measurements from height, weight and age, we managed to demonstrate (Table 4) that in 1/3 of cases height, weight and age determine the variability of other basic measurements with a description rate of up to 50%, and in 2/3 of cases the description rate (in the sense of R^2) reached 50–90%. Along with height and weight, the impact of age in regression models was essential in only four cases (lower limb length, humerus breadth, side and subscapular skinfold.

Considering the above mentioned, we placed all the girls into the unified classification according to their height and weight (Table 5). The impact of age in classes was significant. Gradual increase in height and weight (classes 1, 2, 3) caused statistically significant increase in many height, breadth and depth measurements, bone thicknesses, circumferences and skinfolds. Characteristic differences could also be noticed between the body measurements of pycnomorphs and leptomorphs (classes 4 and 5). Pycnomorphs had significantly greater chest and waist breadth and abdomen depth. Most circumferences, except head, hip, lower leg and wrist circumferences and thicknesses of all skinfolds were also greater in pycnomorphs.

Indices and body composition characteristics also revealed systematic differences between classes (Table 6). Thus, in classes 1, 2 and 3, there was a significant gradual increase in Rohrer index, body mass index and body surface area, several relative circumferences like head, waist, pelvis, upper thigh, upper leg, arm, forearm, mean skinfold, mass and relative mass of subcutaneous adipose tissue, total cross-sectional area of arm and thigh, and fat rate and bone-muscle rate of the cross-sectional area of arm and thigh. In the classes of pycnomorphs and leptomorphs, there were essential characteristic differences in relative lower limb length, in relative biacromial, chest and waist breadths, in chest and abdomen depth, in relative femur and ankle breadth, and in most relative circumferences, which were all greater in the class of pycnomorphs. Pycnomorphs also had essentially lower body density, and all indicators of body fat content were higher.

The results of the anthropometric study of adolescent female volleyballers showed that volleyballers surpassed their peers in height, weight and most other body dimensions. Age correlated significantly with 14 basic body measurements out of the studied 49 and with 4 indices and body composition characteristics out of 65. Body build as a whole proved to be a regular anthropometric structure where all the variables were in mutual correlation, and the leading characteristics were height and weight. This enabled us to systematize all basic characteristics into five SD classes of height and weight.

3.2. Results of physical ability tests

Basic statistics of physical ability tests results and their correlations with age are presented in Table 7. The table shows that two jump tests (PA_1, PA_2) and the highest reach of the player's outstretched arm were related to age. The correlation matrix of the tests (Table 8) shows that, with the exclusion of the stomach muscle strength test (PA_6), all the other tests were in weaker or stronger mutual correlation.

The tests also showed significant correlation with anthropometric variables (Table 9). The tests of vertical jump and reach (PA_1, PA_2) and the highest reach of the player's outstretched arm correlated very strongly (at the level of 0.7–0.9) with height, extremities length and horizontal arms spread; there was also an almost as strong correlation with biacromial and pelvic breadth. The jump tests also showed statistically significant correlations with nearly all the anthropometric variables, except skinfolds.

Analogously to the previous ones, although somewhat more weakly, the medicine ball throwing test (PA_9) correlated with practically all the anthropometric variables except skinfolds. The strongest correlations (at the level of 0.5–0.6) were with extremities circumferences.

The tests of jump height (PA_3 and PA_4) showed significant negative correlations with all skinfolds. The same could be said about the speed test – the thicker the skinfolds, the worse the speed test results.

The endurance test correlated negatively not only with skinfolds but also with a number of other anthropometric variables, which suggests that smaller players have greater endurance.

Flexibility and stomach muscles test showed practically no correlations with anthropometric variables.

As test results correlated closely with body build, we systematized them using the same height-weight classification, which we had already used for systematizing the girls' anthropometric data (Table 10). As we can see, the tests of highest jump and reach (PA_1, PA_2) and the highest reach of the player's outstretched hand could be well systematized into classes, showing that jumping ability gradually improved in classes small-medium-big, and leptomorphs could jump essentially higher than pycnomorphs. Consequently, the most capable in this test were girls with bigger height and weight but also tall and slender girls. The same trend was noticed in PA_9, but the differences were statistically insignificant. In speed test, leptomorphs were more successful than pycnomorphs.

The impact of body build on physical ability was also studied by regression analysis (Table 11). We predicted the results of all physical fitness tests using two models: (1) by age, height and weight; (2) by other basic anthropometric variables, chosen by stepwise regression, from the set of variables, which significantly correlated with the test under study.

The study showed that age, height and weight determined the variability of PA_1, PA_2 and PA_3 results within 60–90%. The description rate of PA_5, PA_8 and PA_9 was smaller (16–29%). By comparing the two models used for prediction, we found that in all cases the model composed of various other characteristics was more effective (in the sense of R^2) than the age-height-weight model.

The essential basic characteristics in the models were lower limb length, upper leg circumference, ankle breadth, arm circumference, biacromial breadth, upper chest circumference, horizontal arms spread. Relative mass of subcutaneous adipose tissue correlated negatively with tests results.

In conclusion, we noticed relatively great individual variability in tests results, and strong correlations between the tests results themselves and with body build. Consequently, the assessment of adolescent female volleyballers' physical abilities should take into consideration the body as a whole and, if necessary, the age. In our study, the appropriate predictive models consisted either of (1) height, weight and age; or (2) several basic anthropometric characteristics that correlated significantly with tests results. The 5 SD classification of height and weight also describes the variability of physical ability tests of young volleyballers.

3.3. Results of volleyball technical skills tests

Table 12 presents the results of three pass tests (T_1, T_2, T_3), two spike tests (T_4, T_5), feint test (T_6), two serve tests (T_7, T_8) and reception test (T_9). All results measure the number of successful repetitions. These tests had no statistically significant correlation with age. Tests results were correlated with basic anthropometric measurements (Table 13), and indices and body composition characteristics (Table 14).

From the three pass tests, the forearm pass test (T_3) showed the strongest correlations with body measurements. It had negative correlations with weight, circumferences and all the indicators of adiposity (skinfolds, mass of subcutaneous adipose tissue, body mass index, fat rate of the cross-sectional area of thigh and arm ($r = 0.3–0.4$). It revealed positive correlations with biacromial breadth / pelvis breadth and arm cross-sectional bone and muscle area (Tables 13 and 14).

Spike test (T_4) correlated positively with length measurements (height, head-neck length, sternum length and upper limb length), biacromial breadth, horizontal arms spread, upper leg and lower leg circumferences and wrist circumference. Spike test T_5 demonstrated positive correlation with indices – wrist circumference / upper limb length, humerus breadth / upper limb length and wrist breadth / upper limb length (Tables 13 and 14). All the correlations were at the level of $r = 0.3–0.4$. This suggests that better results in spike are achieved by tall and slender players with greater extremities' strength.

The results of the feint test (T_6) also depended on the breadth and strength of extremities bones. There were positive correlations ($r = 0.3–0.4$) with wrist breadth, wrist circumference, relative wrist circumference, humerus breadth, ankle breadth and relative ankle breadth (Tables 13 and 14).

Serve (T_7) had positive correlation with biacromial breadth / pelvis breadth (r = 0.377) and with bone-muscle rate of the cross-sectional area of the thigh / total cross-sectional area of the thigh (r = 0.303) and negative correlation with fat rate of the cross-sectional area of the thigh / total cross-sectional area of the thigh.

Test T_8 had positive correlation with femur breadth / lower limb length (r = 0.346) and negative correlation with relative lower limb length (r = –0.345) and calf skinfold (r = –0.295).

Test T_9 had positive correlations with head circumference (r = 0.350) and negative correlations with trunk length / upper chest circumference (r = –0.310) (Tables 13 and 14).

In conclusion, our results showed that volleyball tests were better performed by slender girls with smaller body fat content, longer upper limb length, larger biacromial breadth and strong limb bones. The same was confirmed by regression analysis results (Table 15), which revealed that most dependent on body build were the forearm pass (T_3) and spike (T_4) tests (R^2 = 0.29 and 0.32).

3.4. Results of psychophysiological tests

Table 16 presents the basic statistics of 21 computerized tests of speed perception, auditory reaction, visual reaction and anticipatory reaction to reality that were carried out on 32 girls. As in the case of the previous test types, individual differences were great, but age had no influence on test results.

We calculated the correlations of all psychophysiological tests with anthropometric data (Tables 17 and 18). The basic anthropometric characteristics that correlated positively with psychophysiological tests results were sternum length, trunk length, abdomen length, biacromial breadth, chest breadth and waist breadth.

The tests had negative correlations with weight, chest depth, abdomen depth, femur breadth, ankle breadth, upper chest circumference, hip and upper thigh circumference, upper and lower leg circumference, arm, forearm and wrist circumferences, umbilical and triceps skinfolds.

The indices that revealed only positive correlations were relative trunk length, relative abdomen length, relative upper body length, relative upper limb length, relative biacromial breadth, relative waist breadth, relative wrist circumference, lower leg circumference / lower limb length, femur breadth / lower limb length, trunk length / upper chest circumference.

The only negatively correlated indices were body mass index, relative lower body length, relative lower limb length, relative humerus breadth, relative hip and upper thigh circumference, relative upper leg circumference, relative arm circumference, forearm circumference / upper limb length, wrist circumference / upper limb length, wrist breadth / upper limb length.

We applied regression analysis, attempting to predict the results of all the tests from anthropometric data (Table 19). Five models were significant having the description rate R^2 = 0.28–0.43). In conclusion, it might be said that psychophysiological tests were performed better by slim girls with smaller extremities' measurements.

3.5. Mutual correlations between physical ability tests, volleyball technical skills tests and psychophysiological tests

Above, we analysed in detail the correlations between young volleyballers' body build and all the tests performed. In this section, we are going to observe whether the tests assessing girls' different abilities were also in mutual correlation. The respective data are presented in Fig. 4, where all statistically significant correlations are indicated.
We can see that all the nine physical ability tests were in statistically significant correlation with volleyball technical skills tests, and four physical ability tests had significant correlations with psychophysiological tests. There were also correlations between three ball handling tests and five psychophysiological tests.

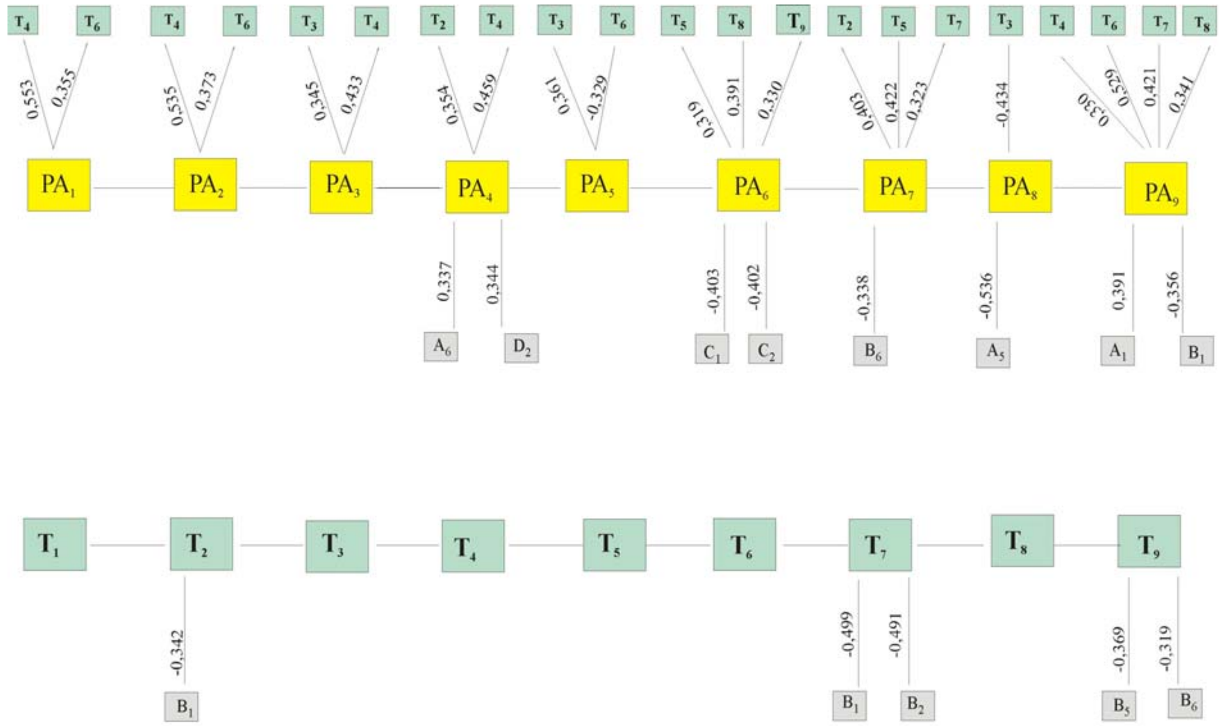


Fig.4. Mutual correlations between physical ability tests (PA), volleyball tests (T) and psychophysiological tests (A-D)

Explanation of symbols used in Fig 4

PA_1 - Test of highest jump and reach standing
PA_2 - Test of highest jump and reach running
PA_3 - Vertical jump height standing
PA_4 - Vertical jump height running
PA_5 - Endurance test
PA_6 - Stomach muscle strength test
PA_7 - Test of flexibility
PA_8 - Test of speed measuring
PA_9 - Medicine ball throwing test

T_1- Overhead pass with clap behind the back
T_2 - Overhead pass with squat
T_3 - Forearm pass into l m²
T_4 - Spike along the sideline
T_5 - Spike diagonally
T_6 - Feint into the centre of the court
T_7 - Serve straight
T_8 - Serve diagonally
T_9 - Reception into zone 2 or 3

A_1 - Average score of first time speed perception tests
A_5 - Average score of third-time speed perception tests
A_6 - Average reaction time in third time speed perception tests
B_1 - Average reaction time in first-time auditory perception tests (right hand)
B_2 - Average reaction time in first-time auditory perception tests (left hand)
B_5 - Average reaction time in third-time auditory perception tests (right hand)
B_6- Average reaction time in third time auditory perception tests (left hand)
C_1 - Average reaction time in first-time visual perception tests (right hand)
C_2 - Average reaction time in first-time visual perception tests (left hand)
D_2 - Anticipatory reflection of reality (second attempt)

The tests assessing jumping ability, like standing vertical jump and reach (PA_1) and running vertical jump and reach (PA_2) proved to be of great significance for volleyball. If we subtract the length of the outstretched arm from the results of these tests, we obtain the height of standing (PA_3) and running vertical jump (PA_4). All the subjects who were more successful in these four tests also had better results in the spike test (r=0.433–0.553). The next in its significance among the physical ability tests measured the strength of upper body and extremities (PA_9), and the subjects with better results in this test had also greater success in spike (T_4), feint (T_6) and serve tests (T_7, T_8), (r=0.330–0.529).

The following physical ability tests – stomach muscle strength test (PA_6) and flexibility test (PA_7) – correlated weakly with other physical ability tests but showed significant correlations with several ball handling tests like pass test (T_2), spike test (T_5) and serve tests (T_7, T_8) (r=0.319–0.422). The results of the speed test (PA_8) were in correlation with one of the pass tests (T_3); the negative value of the correlation follows from the fact that in speed test smaller numerical values designate better results.

One of the most significant pass tests – T_3 – was dependent on the results of three physical ability tests. These were standing vertical jump height PA_3 (r=0.345), endurance test PA_5 (r=0.361) and the above-mentioned speed test (PA_8).

In conclusion, physical ability tests and ball handling tests were connected in a number of ways, which emphasises the necessity of parallel assessment of both types of tests for successful coaching.

Psychophysiological tests also correlated with physical ability tests as well as with ball handling tests (Fig. 4).

Different psychophysiological properties that we assessed by 21 computerized tests to measure the girls' speed perception, auditory and visual reaction and anticipatory reflection of reality had, in different combinations, correlations with jump test PA_4, stomach muscle strength test PA_6, flexibility test PA_7, speed test PA_8 and medicine ball throwing test PA_9.

It is interesting to note that the results of one of the volleyball technical skills tests – reception test T_9 – depended on auditory perception tests B_5 (r=–0.369) and B_6 (r=–0.319).

Thus, psychophysiological tests, in combination with other tests, also help to measure the formation of skills necessary for a young volleyballer.

In summary, we can state that most of the tests applied were in mutual correlation. As they were also related to body build, this shows that body build and different abilities form one whole that should be taken into consideration as such.

3.6. Assessment of players' proficiency

Out of the 46 girls who were studied anthropometrically and by tests, 32 participated in competitions, where their performance was recorded by the computer program *Game*. Each player participated in at least four matches. For each player we calculated the index of proficiency for all elements of the game in all matches where she participated. For the whole group, the mean index of proficiency at serve was 0.545 (SD = 0.279), at reception 0.513 (SD = 0.183), at feint 0.657 (SD = 0.246), at block 0.523 (SD = 0.360) and at attack 0.563 (SD = 0.226). The mean value of the proficiency index was 0.539 (SD = 0.161).

For all the anthropometric variables and tests results of the girls who participated in competitions, correlations with the index of proficiency for all elements of the game were calculated. From the anthropometric variables and tests results that had significant correlations with proficiency in the game, we calculated by means of stepwise regression the best linear models for predicting proficiency in different elements of the game.

To assess independently the impact of anthropometric variables and tests results on proficiency, different models were formed by means of basic anthropometric variables, indices and test results studied. The results are presented in Table 20.

All the elements of proficiency in the game could be predicted by a model that consisted only of basic anthropometric variables. The elements of proficiency correlated significantly with 14 body measurements. These were height, weight, xiphoidal height, suprasternal height; trunk measurements: upper and lower chest, waist and hip circumferences; limb measurements: arm circumference, arm circumference flexed and tensed, upper thigh and lower leg circumference, wrist circumference and wrist breadth.

The efficiency of serve (coefficient of determination = 32%) was facilitated by greater xiphoidal height and arm circumference. Efficiency of reception (50%) was linked to a bigger weight, bigger suprasternal height and bigger wrist breadth.

Block was best performed (80%) by girls with bigger height and weight. For feint the most essential (83%) characteristics were bigger xiphoidal height, arm circumference and hip circumference. Attack was also more successful (71%) in girls with bigger weight and lower leg circumference.

For serve (17%), reception (33%), block (65%), feint (93%) and attack (41%) it was also possible to compile statistically significant regression models from anthropometric indices and body composition characteristics only. The most essential indices were Rohrer index, body mass index, relative chest breadth, relative waist breadth, relative pelvis breadth, relative humerus breadth, and the following relative circumferences: head, lower chest, upper leg and arm.

The physical ability model contained the results of four tests. Efficiency of reception depended on the positive result of the flexibility test (PA_7, 44%). Efficiency of feint was determined by the endurance test (PA_5, 18%) and efficiency of attack was determined by the medicine ball throwing test (PA_9, 22%).

Out of the nine volleyball technical tests, five correlated with proficiency in the game. In the model where only volleyball technical tests were used as arguments, their number was three (T_2, T_6, T_8).

The model of volleyball technical tests was essential for reception (39%) and feint (44%). In the first case, the pass test T_2 was essential, and in the second case the serve test T_8.
Proficiency in the game correlated surprisingly closely with seven psychophysiological tests (A_3, A_5, A_6, B_3, B_4, B_6, D_2). They determined the efficiency in four elements of the game out of five within 39–98%. The only element where they did not have any significance was serve, for the performance of which the player has enough time and

where she is not dependent on the activity of other players. On the contrary, success in psychophysiological tests was very essential for such elements as block (98%) and attack (80%), which, as a rule, are performed in the greatest deficit of time. Here, the player needs very quick reaction and correct assessment of the movement of the ball.

In addition to the above mentioned, the results of the eight teams (74 players) participating in Estonian championships in 2004 were used in order to find whether the body build classification (see Methods) could be used in assessment of proficiency in the game. The girls were taken the same 14 body measurements that proved essential in the sample of 32 girls. Girls of different ages (13–15 years) were placed into the classes of a common height-weight classification according to their individual height and weight. The average ages of girls of all classes did not differ statistically. The other variables changed in classes similarly to the sample of 46 girls.

The girls' proficiency in the game during the whole tournament was assessed in the same body build classes. For each class, the total number of serves, receptions, attacks and blocks, their mean values per player and percentage from elements performed during the whole tournament (28 games), and the mean index of proficiency were calculated (see Table 21). The means of performance of elements of the game in different classes were compared using the Scheffé test, to compare percentages z-test was used.

The most active players belonged to class 3, the least successful to class 1, and girls in classes 2, 4 and 5 achieved intermediate values.

DISCUSSION

4.1. Regularities of adolescent female volleyballers' body build

The anthropological trend of research in sports has completely justified itself. Morphological characteristics, being constant characteristics of a person's constitution, are genetically determined. They influence directly results in games, gymnastics and other sports, or indirectly by the manifestation and development of physical abilities (Loko 1996, 2002; Maiste, 1999a; Harro, 2001; Skinner, 2001; Wolfarth, 2001).

To obtain greater theoretical and practical benefit from applying body build data in different sports, we need more detailed anthropometric research than has been done until now (Stamm et al., 1998, 2000a, 2002a, 2003a; Loko et al., 1999; Fernate et al., 2001; Martirosov, 2001; Avloniti, 2001).

Considering the above-mentioned, the author undertook the task of detailed anthropometric research of adolescent female volleyballers (n=46, aged 13–16 years, 49 basic measurements and 65 indices and body composition indicators) in order to analyse the importance of age and body build for physical abilities, volleyball technical skills tests, psychophysiological tests and proficiency in the game.

To assess the significance of all the basic anthropometric measurements for volleyball, we need a concept of the anthropometric structure of the body as a whole. Our research results confirmed that the structure of the body as a whole is determined by a complex of variables that are mutually in statistically significant correlations. The leading characteristics of the system are height and weight, which correlate most strongly with all the other variables. The integrated structure of body build could be demonstrated by the fact that age, height and weight determined statistically significantly the variability of all the other characteristics within 18–90%. At that, two thirds of the variability of characteristics was determined within 50–90% and only in one third of the cases below 50%. This confirms a very essential aspect of volleyballers' body build – in parallel to all variables being in mutual correlation, each basic measurement is, to a certain extent, also able to represent the body as a whole. The existence of an integrated structure makes it possible to apply extensively not only the features that have been considered essential for volleyball but all the basic anthropometric measurements, indices and body composition characteristics that are concerned with the area studied.

Integrated body structure also makes it possible to classify all body build data by a 5 SD height-weight classification into the following classes: 1) small, 2) medium, 3) large, 4) pycnomorphous, 5) leptomorphous. Between all the classes, it is possible to demonstrate the existence of systematic changes in length, breadth and depth measurements, skinfolds, indices and body composition characteristics. This also enabled us to demonstrate systematic changes depending on classes in many indicators of body fat content – body mass index, mean skinfold, body density, relative mass of fat by Siri, mass of subcutaneous adipose tissue, fat rate and bone-muscle rate of the cross-sectional areas of arm and thigh.

In literature we have not found such a classification being used for volleyballers. Predominantly, body dimensions have been systematized according to Heath and Carter. As the Heath-Carter scheme does not make use of many extremities length measures and circumferences that are essential for volleyballers, then our classification could provide a useful addition. Our classification also makes it possible to assess simultaneously a great number of body fat indicators.

According to literature data, both elite and adolescent female volleyballers have greater height and weight (Hosler et al., 1978; Häkkinen, 1993: Viviani and Boldin, 1993). We had the opportunity of comparing the volleyballers studied by us with national average values for the same age (n=586) and found that, in addition to height and weight, 18 other basic measurements and triceps skinfold had higher values in volleyballers than in the control group. Thus, volleyballers had greater upper extremity length, biacromial breadth, breadth of extremities bones (femur, ankle, humerus and wrist), trunk and extremities circumferences (waist, upper thigh, upper leg and lower leg, arm and wrist).

We could compare our data with those of 13–15-year-old female volleyballers from Budapest (Farkas et al., 1991). Their height varied from 161.24 to 168.76 cm (our average 167.23 cm); their height varied from 51.53 to 56.17 kg (our average 56.78), their body fat percentage from 21.13 to 22.27 (our average 18.86). The data were similar, only the body fat content of our girls was lower than in those of Budapest.

The sample studied by us displayed age-related differences in 14 basic measurements but not in indices and body composition characteristics. Classification of subjects' anthropometric variables into height-weight classes revealed that average age did not differ considerably by classes. Therefore, we could treat the sample studied as relatively uniform, although in all tests, along with body dimensions, we always considered the girls' age. We did not concern ourselves with the biological age of our material, but we are of the opinion that chronological age in combination with detailed anthropometric status is also representative of biological age.

4.2. Correlation of physical ability tests results with body build

To assess young volleyballers' abilities essential for the game, we conducted three categories of tests: 9 physical ability tests, 9 volleyball technical skills tests and 21 psychophysiological tests. We chose relatively simple tests that every coach would be able to use, that could be conducted indoors, regardless of season and weather, and that would not need special equipment. We analysed the dependence of test results on body build and correlations between different categories of tests.

The programme of physical ability tests was compiled of tests that, according to literature, were most essential for volleyball: jumping tests, medicine ball throwing test, speed, endurance, flexibility and stomach muscles strength test.

Better jumping ability, according to our own data (R. Stamm et al., 2000b) as well as literature (Matsudo et al., 1987; Viitasalo, 1988), was typical of girls with greater height and weight. As we used four tests to characterize jumping ability, and in addition the highest reach of the player's outstretched hand and many basic anthropometric measurements, we could analyse the tests in detail. Thus, vertical jump and reach (PA_1, PA_2) and the highest reach of player's outstretched hand had correlations with nearly all other anthropometric characteristics except skinfolds. There were very strong correlations (r = 0.7–0.9) with height, extremities length, horizontal arms spread, biacromial and pelvis breadth. The variability of the highest reach of player's outstretched hand was 35 cm (201–236 cm), which gives taller players considerable advantage at spike and block.

The other jump tests – standing vertical jump (PA_3) and running vertical jump (PA_4) – correlated negatively with skinfolds, confirming the views from literature that better jumping ability is inversely proportional to body fat percentage (Thissen-Milder and Mayhew, 1991).

We could compare the results of the standing vertical jump test with the data of J. D. Zheleznyak (Железняк,1988). In our data, the mean height of standing vertical jump was 35.78 cm, but according to Zheleznyak the result of this test in 13-16-year-old girls should be 40–50 cm.

In our study, jumping ability also had a significant correlation with upper body muscles' explosive strength (medicine ball throwing test, PA_9). This test is also essential for successful block and spike, and better results are achieved by players with greater height and weight (Morrow et al., 1979; Hoeger et al., 1987; Häkkinen, 1989; Häkkinen et al., 1999; Smith et al., 1992). In addition, we showed that the results of this test correlated with practically all anthropometric variables except skinfolds.

Endurance is an essential component of volleyball (Wielki, 1979; Viitasalo et al., 1987; Smith et al., 1992; Bale et al., 1992; Arbeit, 1998; Wieczorek, 2001). In our data, endurance test (PA_5) showed significant negative correlations with all body measurements and skinfolds; thus, the results were better in smaller and slimmer girls. The average numerical result of our research – 6.3 min – was similar to the result obtained by A.Lopman (1995), who used the same method to test 16-year-old girls.

Most authors include speed test (PA_8) among the tests assessing 12–15-year-old adolescents' physical abilities as this is the age when speed strength and speed of movements develop most rapidly (Kantola, Rusko, 1984). Our study also confirmed its importance among other tests as it was the only test that correlated with the results of all the other tests except the flexibility test. In our study, faster girls had lower body fat content and smaller wrist and hip circumferences. Our results coincided with literature data that higher body fat content is in correlation with worse results in the speed test and other tests (Malina, 1975; Watson and O'Donovan, 1977; Raudsepp and Jürimäe, 1996).

Flexibility test (PA_7) had a negative correlation with hip circumference (r=–0.332). Girls with smaller hip circumference had greater extent of bending forward. The only positive correlation of this test was with running vertical jump height (PA_4, r=0.336). Girls with better flexibility jumped higher.

Our average result of the flexibility test (16.63 cm) was better than in 11-15-year-old girls who did not practise sports (9 cm) (Hein, 1998). Our result is in concordance with A. Saar's (1998) result of 16-year-old girls' flexibility test (17 cm) and A. Lopman's (1995) respective result (16 cm).

Stomach muscle strength test (PA_6) was the only one among our tests whose results did not correlate statistically significantly with any anthropometric variable. It only had a negative correlation with speed test(r=–0.382), which means that the girls who had a better result in stomach muscles strength test were able to run faster.

As the results of seven out of nine physical ability tests used by us correlated with many anthropometric variables, we performed regression analysis to model the dependence of physical ability test results on body build. To predict tests results, we used two types of models. In the first case we used as arguments height, weight and age, and in the second case the other anthropometric characteristics, which showed statistically significant correlations with the test studied. In all the tests age, height and weight gave somewhat worse results than the best combination of other characteristics. By using the second model, we could anthropometrically determine the variability of PA_1 within 89%, PA_2 – 78%, PA_3 – 61%, PA_4 – 42%, PA_5 – 42%, PA_8 – 63% and PA_9 – 65% (in the sense of the determination coefficient).

Literature has discussed only the correlation of tests with height, weight and fat percentage, but our results suggested that a more detailed anthropometric study combined with physical abilities tests gives, in general, a better assessment of young players' abilities and their prospects in the chosen sport.

4.3. Correlations of volleyball technical skills tests results with body build

The complex of volleyball technical tests consisted of three pass tests, two spike tests, a feint test, two serve tests and a reception test. The tests results correlated between themselves and with a number of anthropometric variables but not with age. The greatest dependence on body build was found in spike tests (R^2=0.32). Better results were achieved by tall and slender players with greater strength of extremities. Feint test also depended on the breadth of extremities bones. Significant correlations with body build could be also noticed in forearm pass test (R^2=0.29) and serve test; both of them had negative correlations with indicators of adiposity.

In conclusion, tests were best performed by girls with smaller body fat content, longer upper limb length, greater biacromial breadth and strong limb bones.

We could not directly compare our results with data from literature, as the sources available for us did not describe tests conducted on such a scale. Moreover, the methods of applying the tests were different.

4.4. Correlations of psychophysiological properties tests with body build

For a comparative study of young female volleyballers' psychophysiological abilities, we conducted 21 computerized tests of speed perception, auditory and visual reaction and tests of anticipatory reflection of reality. Like in other categories of tests, individual variability of results was great, but age did not influence tests results. Out of 21 tests, 10 had the strongest correlations with anthropometric measurements at the level of r=0.3-0.4. The best models for predicting tests results from anthropometric arguments were obtained for five tests (R^2=0.28–0.43).

Literature contains few comparative data on psychophysiological tests carried out to such an extent. Numerically, we could compare the data of Z. Hascelik et al. (1989) from Ankara, Turkey, on 22 young male volleyballers' (average age 18.5 years) auditory and visual reaction times before and after an eight-week period of physical conditioning exercises. While the average auditory reaction time in our sample of girls varied from 0.209 to 0.235 sec, the average of the male team before the training period was 0.191 and after it 0.175 sec. The average visual reaction time of the girls' group varied from 0.197 to 0.200 sec, the males' time before training was 0.215 sec and after it 0.200 sec. From this we might conclude that auditory reaction was better in boys and visual reaction in girls.

4.5. Correlations between players' proficiency, their body build and tests results

Performance in the game was recorded by the computer program *Game* in 32 girls out of 46, who participated in competitions. For all players and all elements of the game, we calculated the indices of proficiency. We calculated the correlations of all the anthropometric variables and test results with this index, and calculated the best linear models for predicting proficiency in different elements of the game.

We found that basic anthropometric measurements enabled us to predict proficiency in all the elements of the game within 32–83%; anthropometric indices within17–93%. Test results did not provide statistically significant results in the case of serve. In reception, the description rate of tests varied from 36-44%, in feint from 18-60% and in attack from 22-80%. In the case of block, only psychophysiological tests proved to be significant (R^2=0.98).

In assessment we used an original program, which had previously been approved by the Estonian Volleyball Federation and introduced in the Journal of the American Volleyball Federation (Stamm et al., 20001, 2001). Therefore, we could not compare our data with concrete data from literature.

Summing up the results of our study, we can state that our research confirmed the data provided in literature that adolescent female volleyballers' body build correlates with the results of various tests, and that body build characteristics as well as better physical abilities are a prerequisite for proficiency in the game.

Additionally, we studied in detail the possibilities of applying the anthropometric factor in assessing both tests results and proficiency in the game and introduced an original program of recording and assessing the proficiency *Game*.

The results of our study were checked again at Estonian young female volleyballers' championships in Pärnu on 14–16 May 2004 with the participation of eight best teams of Estonia. All 74 players were measured anthropometrically (14 body measurements) and the girls' proficiency in the game was assessed in 5 body build classes. The results showed that the most successful were the girls of class 3 with big height and weight. The small girls of class 1 were the least successful. The players belonging to classes 2, 4 and 5 formed an intermediate group.

The author has also compiled methodological instructions (Stamm R., 2003b) that are used by the Estonian Volleyball Federation as methodological material for volleyball coaches and sports clubs or sports schools that practise volleyball.

CONCLUSIONS

1. Multivariate statistical analysis of 49 basic anthropometric variables and 65 indices and body composition characteristics established the essence of the anthropometric structure of body build as a whole.
2. A 5 SD classification of height and weight enabled us to systematize all volleyballers' length, breadth and depth measurements, circumferences and body composition characteristics.
3. As the structure of body measurements of young female volleyballers is similar to ordinary schoolgirls, the 5-class classification of height and weight forms a handy tool for predicting the potential abilities of schoolgirls as volleyball players.
4. Seven physical ability tests out of nine were related to body measurements; two anthropometric regression models from height, weight and age or from a combination of other anthropometric variables predicted the variability of tests results within 24-95%. The tests results placed in a 5 SD classification showed essential differences in jumping ability and speed tests.
5. Volleyball technical skills tests correlated with 30 basic anthropometric variables and with 26 indices and body composition characteristics at the level of $r = 0.3 – 0.4$.
6. Psychophysiological tests correlated with 27 basic anthropometric variables and with 32 indices and body composition characteristics at the level or $r = 0.3 – 0.5$.
7. Young female volleyballers' (aged 13–16 years) performance in the game is essentially determined by all the components discussed in the present study – peculiarities of body build and results of all kinds of tests performed. The 5-class classification of height and weight (the body build classification) enables simultaneous assessment of body build and proficiency.
8. Attack, block and feint were best performed by players with greater height, weight, arm, upper thigh and lower leg circumferences, who reacted faster to the changing situation in the game (anthropometric models $R^2 = 0.71–0.83$, psychophysiological models $R^2 = 0.60–0.98$).
9. The efficiency of reception was determined by anthropometric variables and results of all tests within 39–50%. The efficiency of serve was determined by anthropometric models within 17–32%.

10. The computer program *Game* created by the author is well suited for assessment of young female volleyballers’ performance at competitions.

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Summary in Estonian

Tänapäevane võrkpall esitab mängijatele suuri nõudeid, mistõttu tavalise treeninguõpetuse kõrval vajavad arendamist ka noorte mängijate füüsiline ja psühhofüsioloogiline võimekus. Üha enam ilmub kirjanduses andmeid nende võimete seotuse kohta ealiste konstitutsionaalsete iseärasustega (Bale et al., 1992; Kiomourtzoglou et al., 2000; Avloniti et al., 2001). Kõik see mõjutas käesoleva uuringu eesmärki – analüüsida noorte naisvõrkpallurite kehaehituse iseärasuste seotust nende füüsilise, mängutehnilise, psühhofüsioloogilise võimekuse ja mänguedukusega.

Uuringute aluseks olid 46 noort naisvõrkpallurit 13–16 aasta vanuses. Mängijad pärinesid 6 naiskonnast, olid viimase 3 aasta jooksul osalenud regulaarselt treeningutel ning võistelnud vabariiklikel kuni 16-aastastele mõeldud võistlustel. Tütarlapsed olid terved ning andsid koos vanematega nõusoleku vabatahtlikuks osalemiseks uuringus. Tütarlaste bioloogiline küpsus määrati Tanneri (1962) sekundaarsete suguliste tunnuste väljakujunemise alusel. Antropomeetrilisi mõõtmisi teostati klassikalise Martini (Knussmann, 1988) metoodika alusel. Mõõdeti 49 kehamõõtu, kuhu kuulusid ka 11 nahavolti ning nende alusel arvutati 65 indeksit ja kehakoostise näitajat. Füüsilise võimekuse hindamiseks kasutati 9 valideeritud testi. Need olid paigalthüppe kõrgus, hoojooksult hüppe kõrgus, mängija ülessirutatud käe ulatus paigalasendis, paigalthüppe ulatus, hoojooksult hüppe ulatus, vastupidavuse kontrolltest (EuroFit, 20 m süstikjooks), kõhulihaste tugevuse kontrolltest (selililamangust istesse tõus), painduvustest, kiiruse mõõtmise test (siksakjooks topispallide puudutamisega) ja käte- ning seljalihaste jõutest. Võrkpallimängu tehnilisi oskusi kontrolliti 9 võrkpalli klassikalisi elemente (McGown 1994; Viera ja Ferguson, 1996) sisaldava testiga. Psühhofüsioloogiliseks uurimiseks kasutati 21 kompuutertesti, mis olid mõeldud selleks, et spetsiaalse kompuuterprogrammiga välja selgitada tütarlaste reaktsiooni kiirus tajumisele, helile ja värvile. Nende andmete alusel hinnati tegelikkust ennetava peegelduse kiirust. Kõik võistlusmängud, kus nimetatud tütarlapsed osalesid, kirjutati üles autori poolt koostatud originaalse võrkpalli ülesmärkimise arvutiprogrammiga „Mäng“.

Noorte naisvõrkpallurite antropomeetriliste tunnuste mitmemõõtmeline statistiline analüüs tõestas regulaarse antropomeetrilise süsteemi olemasolu, milline moodustus omavahel

statistiliselt oluliselt seotud üksiktunnustest juhtivate tunnustega pikkuse ja kaalu näol. Autori poolt kasutusele võetud pikkus-kaalu 5SD klassifikatsioon võimaldas süstematiseerida kõiki pikkus-laius-sügavusmõõte, ümbermõõte, nahavolte ja kehakoostise näitajaid. Võrdlus sama vanade võrkpalli mitte mänginud koolitüdrukute (n=586) kehamõõtudega (Veldre jt., 2002) näitas, et enamike üksikmõõtude osas ületavad võrkpallurid oma eakaaslasi ning et võrkpallurite kehastruktuur sarnaneb sama vanade koolitüdrukute omaga (Kaarma jt., 2004).

Käesoleva uuringu tulemused kinnitasid, et kehaehitus on oluliselt seotud kõigi kasutatud testidega, määrates 42–89% füüsilise võimekuse testide, kuni 32% võrkpallitehniliste testide ja kuni 43% psühhofüsioloogiliste testide tulemustest.

Kompuuterprogramm „Mäng“ võimaldas registreerida võistlusmängudes 32 tütarlapse kõigi mänguelementide soorituse ning arvutada välja vastavad resultatiivsuse indeksid. Viimased seostati mängijate kõigi antropomeetriliste tunnuste ja testide tulemustega ning arvutati parimad prognoosimudelid kõigi mänguelementide jaoks. Selgus, et mänguedukus sõltus nii tütarlaste kehaehitusest kui ka kõigist kasutatud testidest. Nii sooritasid rünnaku, sulustamise ja pettelöögi paremini pikemad, suurema kaalu, suurema õlavarre, reie ülemise ja sääre alumise ümbermõõduga tütarlapsed, kes reageerisid kiiremini mängu muutuvale situatsioonile (antropomeetrilised mudelid R^2 – 0,71–0,83, psühhofüsioloogilised mudelid R^2 – 0,60–0,98). Pallingu vastuvõtu resultatiivsus sõltus antropomeetrilistest tunnustest ja kõigist testidest 39–50% ulatuses. Pallingu resultatiivsuse määrasid antropomeetrilised mudelid 17–32%.

Üksikutest antropomeetrilistest tunnustest olid mänguedukuses olulised 14 kehamõõtu. Nende kasutamine pikkus-kaalu klassifikatsioonina 74 võrkpallitütarlapse juures Eesti meistrivõistlustel 2004. a. võimaldas eristada edukamaid tütarlapsi vähem edukatest.

Kokkuvõttes võib öelda, et noorte naisvõrkpallurite ja sama vanade koolitüdrukute sarnane kehaehitusstruktuur võimaldab kasutada pikkus-kaalu viieklassilist klassifikatsiooni võrkpalluritele järelkasvu otsimiseks koolitüdrukute hulgast.

Samuti võimaldab regulaarne kehaehitusstruktuur, selle seotus testitulemustega ja mänguedukusega kasutada kogu parameetrite kompleksi mängijate individuaalse arengu testimiseks.

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TABLES

List of tables:

Table 1

Means and standard deviations of basic anthropometric measurements in age groups of young female volleyballers (n=46) and their correlations with age.

No	Variable	$\bar{x}$	SD	13 years n=10		14 years n=14		15 years n=12		16 years n=10		Statistical significant correlation with age (r)
				$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
2.	Weight (kg)	56.177	9.107	54.48	13.84	52.55	6.65	58.26	4.20	60.46	9.47	0.291
3.	Height (cm)	166.22	6.02	163.19	7.23	164.08	4.41	168.43	5.30	169.60	5.50	0.429
4.	Suprasternal height (cm)	135.26	5.50	132.83	6.78	133.31	3.94	137.14	5.12	138.14	4.97	0.395
5.	Xiphoidal height (cm)	120.46	5.07	118.95	5.96	118.64	3.74	122.50	5.02	122.08	5.10	0.295
6.	Head-neck length (cm)	30.99	0.96	30.36	1.20	30.76	1.05	31.29	0.64	31.46	0.75	0.413
7.	Sternum length (cm)	14.85	1.78	13.88	1.56	14.67	2.33	14.64	1.63	16.06	1.06	0.363
8.	Abdomen length (cm)	35.44	5.37	35.68	6.66	34.69	5.97	37.39	4.60	33.92	3.72	-
9.	Trunk length (cm)	50.24	5.52	49.56	7.29	49.36	5.81	52.03	5.23	49.98	3.31	-
10.	Upper body length (cm)	66.95	5.40	64.36	4.52	67.65	7.73	68.10	3.78	67.20	3.38	-
11.	Lower body length (cm)	99.27	7.25	98.83	6.63	96.43	10.00	100.33	5.80	102.40	2.97	-
12.	Upper limb length	72.69	4.09	71.63	5.83	70.74	2.29	73.77	3.83	75.21	2.87	0.375
13.	Lower limb length	87.60	5.62	87.50	3.72	85.76	6.56	88.68	6.36	88.99	4.88	-
14.	Horizontal arms spread (cm)	167.51	8.35	164.05	9.41	163.91	5.11	169.00	8.14	174.22	7.41	0.464
15.	Biacromial breadth (cm)	35.33	1.62	34.90	2.14	34.89	0.76	35.33	1.60	36.35	1.68	0.319
16.	Chest breadth (cm)	23.88	1.50	23.80	2.11	2.43	1.37	24.13	1.26	24.30	1.21	-
17.	Waist breadth (cm)	21.90	1.73	22.15	2.16	21.32	1.61	21.58	1.12	22.85	1.81	-
18.	Pelvis breadth (cm)	25.67	1.54	24.90	1.82	25.39	1.40	26.00	1.04	26.45	1.66	0.367
19.	Chest depth (cm)	16.23	1.25	16.40	2.12	15.79	0.96	16.38	0.93	16.50	0.71	-
20.	Abdomen depth (cm)	15.48	1.31	15.15	2.11	15.36	0.93	15.25	0.94	16.25	0.98	-
21.	Femur breadth (cm)	8.69	0.57	8.54	0.76	8.64	0.50	8.78	0.52	8.83	0.53	-
22.	Ankle breadth (cm)	6.86	0.46	6.84	0.64	6.76	0.32	6.90	0.43	6.96	0.50	-

23.	Humerus breadth (cm)	6.17	0.39	6.22	0.44	6.90	0.33	6.21	0.43	6.17	0.41	-
24.	Wrist breadth (cm)	5.07	0.29	4.91	0.40	5.13	0.27	5.08	0.23	5.13	0.25	-
25.	Head circumference (cm)	34.96	1.44	54.93	1.49	55.32	1.18	54.60	1.60	54.91	1.62	-
26.	Neck circumference (cm)	31.50	1.71	31.46	2.55	31.41	1.43	31.41	1.43	31.12	1.86	-
27.	Upper chest circumference (cm)	81.23	4.97	81.64	7.53	79.52	4.04	82.10	3.69	82.16	4.47	-
28.	Lower chest circumference (cm)	73.96	5.36	74.15	7.37	72.17	4.72	74.67	3.51	75.57	5.88	-
29.	Waist circumference (cm)	67.62	5.65	67.65	7.84	65.83	3.96	67.45	2.63	70.32	7.32	-
30.	Pelvis circumference (cm)	79.49	6.30	77.50	9.53	77.26	4.73	81.48	3.50	82.20	5.88	0.324
31.	Hip circumference (cm)	85.13	9.35	85.11	10.42	81.34	10.83	88.89	3.02	85.93	10.27	-
32.	Upper thigh circumference (cm)	55.09	5.94	54.20	8.16	52.94	5.50	56.80	1.99	57.12	6.65	-
33.	Middle thigh circumference (cm)	46.49	4.79	44.72	6.31	45.26	4.05	47.87	3.14	48.34	5.21	0.308
34.	Upper leg circumference (cm)	34.16	2.68	33.26	3.39	33.26	2.64	35.27	1.77	35.01	2.44	0.304
35.	Lower leg circumference (cm)	22.04	1.58	21.63	2.39	21.63	1.19	22.33	2.23	22.70	1.37	-
36.	Arm circumference (cm)	24.87	2.41	24.17	3.59	24.22	1.74	25.65	1.54	25.55	2.50	-
37.	Arm circumference flexed and tensed (cm)	26.84	2.57	26.25	3.91	26.28	1.85	27.51	1.60	27.40	2.79	-
38.	Forearm circumference (cm)	22.45	1.60	21.92	2.15	21.91	1.39	22.89	1.14	23.18	1.48	0.328
39.	Wrist circumference (cm)	15.73	0.94	15.58	1.54	15.58	0.69	15.73	0.75	16.08	0.71	-
40.	Chin skinfold (cm)	0.64	0.23	0.70	0.31	0.57	0.19	0.63	0.18	0.68	0.25	-
41.	Chest skinfold (cm)	0.67	0.27	0.76	0.35	0.56	0.18	0.71	0.21	0.70	0.35	-
42.	Side skinfold (cm)	0.82	0.40	0.94	0.49	0.74	0.42	0.82	0.22	0.84	0.45	-
43.	Waist skinfold (cm)	1.27	0.50	1.31	0.73	1.16	0.35	1.26	0.34	1.39	0.61	-
44.	Suprailiacal skinfold (cm)	0.83	0.39	0.89	0.59	0.79	0.37	0.88	0.29	0.77	0.28	-
45.	Umbilical skinfold (cm)	1.03	0.39	1.09	0.58	0.90	0.25	1.08	0.37	1.09	0.38	-
46.	Subscapular skinfold (cm)	1.03	0.41	1.19	0.60	0.93	0.39	1.08	0.23	0.95	0.37	-
47.	Biceps skinfold (cm)	0.81	0.31	0.91	0.39	0.71	0.25	0.86	0.25	0.78	0.35	-
48.	Triceps skinfold (cm)	1.27	0.40	1.31	0.53	1.18	0.37	1.42	0.27	1.16	0.43	-
49.	Thigh skinfold (cm)	2.14	0.56	2.01	0.56	1.91	0.50	2.42	0.33	2.26	0.73	-
50.	Calf skinfold (cm)	1.34	0.34	1.28	0.35	1.20	0.24	1.44	0.38	1.48	0.34	-

Table 2

Basic statistics of indices and body composition characteristics by young female volleyballers (n=46) and their correlations with age

No	Variable	$\bar{x}$	SD	Min	Max	Statistically significant correlation with age (r)
51	Rohrer index	1.22	0.15	0.99	1.70	-
52	Body mass index	20.26	2.58	15.90	28.02	-
53	Body surface area (m^2)	1.62	0.14	1.30	2.01	0.367
54	Relat. trunk length (%)	30.22	3.15	26.85	42.08	-
55	Relat. abdomen length (%)	21.33	3.18	15.95	32.72	-
56	Relat. upper body length (%)	40.31	3.42	35.68	59.59	-
57	Relat. lower body length (%)	59.69	3.42	40.41	64.32	-
58	Realt. upper limb length (%)	43.73	1.59	39.98	47.11	-
58	Relat. lower limb length (%)	52.68	2.31	46.41	55.73	-
60	Relat horizontal arms spread (%)	100.77	3.22	95.17	115.64	-
61	Relat biacromial breadth (%)	21.26	0.87	19.28	23.09	-
62	Relat. chest breadth (%)	14.37	0.83	12.95	16.12	-
63	Relat. waist breadth (%)	13.18	0.95	11.68	17.58	-
64	Relat. pelvis breadth (%)	15.44	0.71	13.59	17.13	-
65	Relat. chest depth (%)	9.76	0.69	8.63	12.45	-
66	Relat. abdomen depth (%)	9.31	0.75	6.87	11.54	-
67	Relat. femur breadth (%)	5.23	0.31	4.65	6.05	-
68	Relat. ankle breadth (%)	4.13	0.25	3.38	4.55	-
69	Relat humerus breadth (%)	3.71	0.20	3.37	4.19	-
70	Relat. wrist breadth (%)	3.05	0.16	2.72	3.42	-
71	Relat. head circumference (%)	33.10	1.24	30.55	35.79	-0.472
72	Relat upper chest circumference (%)	48.89	2.83	43.49	57.86	-

73	Relat lower chest circumference (%)	44.54	3.06	39.93	53.01	-
74	Relat. waist circumference (%)	40.69	3.13	35.98	50.82	-
75	Relat. pelvis circumference (%)	47.81	3.25	41.45	55.62	-
76	Relat hip circumference (%)	51.21	5.29	31.19	60.90	-
77	Relat. upper thigh circumference (%)	33.12	3.15	24.63	39.59	-
78	Relat. upper leg circumference (%)	20.55	1.38	18.68	23.61	-
79	Relat. arm circumference (%)	14.96	1.31	12.10	17.79	-
80	Relat. forearm circumference (%)	13.50	0.83	12.10	15.45	-
81	Relat. wrist circumference (%)	9.46	0.49	8.68	11.11	-
82	Arm circumf./upper limb length (%)	34.25	3.14	29.27	40.87	-
83	Forearm circumf./upper limb length (%)	30.93	2.23	27.57	35.90	-
84	Wrist circumf./upper limb length (%)	21.67	1.33	19.01	25.52	-
85	Humerus breadth/upper limb length (%)	8.49	0.48	7.35	9.63	-0.380
86	Wrist breadth/upper limb length (%)	6.98	0.44	6.13	8.14	-
87	Upper thigh circumf./lower limb length (%)	63.05	7.06	45.70	75.03	-
88	Middle thigh circumf./lower limb length (%)	53.21	5.70	43.37	65.27	-
89	Upper leg circumf./lower limb length (%)	39.10	3.32	33.93	47.90	-
90	Lower leg circumf./lower limb length (%)	25.23	2.00	21.50	31.21	-
91	Femur breadth/lower limb length (%)	9.96	0.83	8.60	12.21	-
92	Ankle breadth/lower limb length (%)	7.85	0.60	6.26	9.63	-
93	Chest breadth/chest depth (%)	147.59	9.67	126.83	171.43	-
94	Chest depth/chest breadth (%)	68.04	4.40	58.33	78.85	-
95	Waist breadth/abdomen depth (%)	141.98	10.78	127.27	181.82	-
96	Abdomen depth/waist breadth (%)	70.80	4.96	55.00	78.57	-
97	Biacromial breadth/pelvis breadth (%)	137.85	6.54	125.46	154.35	-
98	Waist circumf./pelvis circumf. (%)	85.13	3.42	76.95	94.67	-
99	Biacromial breadth/upper chest circumf. (%)	40.97	2.00	34.93	46.13	-
100	Trunk length/upper chest circumf. (%)	61.93	6.52	53.41	84.79	-
101	Body density (g/cm^3)	1.06	0.01	1.04	1.08	-

102	Relat. mass of fat by Siri (%)	18.33	3.83	7.49	25.80	-
103	Mean skinfold (cm)	1.08	0.32	0.50	1.98	-
104	Mass of subcutaneous adipose tissue (kg)	7.97	2.94	3.27	16.33	-
105	Relat. mass of subcutaneous adipose tissue (%)	18.86	3.24	7.28	21.49	-
106	Total cross-sectional area of arm (cm^2)	49.68	9.57	27.83	69.25	-
107	Total cross-sectional area of thigh (cm^2)	244.27	51.20	126.05	327.31	-
108	Bone-muscle rate of the cross-sectional area of arm (cm^2)	37.42	5.85	21.67	51.23	0.385
109	Fat rate of the cross-sectional area of arm (cm^2)	12.26	4.71	4.19	23.83	-
110	Bone-muscle rate of the cross-sectional area of thigh (cm^2)	188.31	39.36	97.97	285.69	-
111	Fat rate of the cross-sectional area of thigh (cm^2)	55.95	17.66	20.02	94.90	-
112	Bone-muscle rate of the cross-sectional area of arm/total cross-sectional area of arm	0.76	0.06	0.64	0.89	-
113	Fat rate of the cross-sectional area of arm/total cross-sectional area of arm	0.24	0.06	0.11	0.37	-
114	Bone-muscle rate of the cross-sectional area of thigh/total cross-sectional area of thigh	0.77	0.05	0.64	0.88	-
115	Fat rate of the cross-sectional area of thigh/total cross-sectional area of thigh	0.23	0.05	0.12	0.36	-

Table 3

Basic characteristics of basic anthropometric measurements of young women volleyballers (VB) expressed on the scale of z-scores of national population (NP) of the same age. Comparison of means of anthropometric measurements of VB-girls (n=46) and ordinary girls (NP) (n=586, α=0,05).

No	Value	$\bar{x}$	SD	Min	Max	Statistical significant difference >means (VB) bigger <means (VB) smaller
2.	Weight (kg)	0.28	1.07	-1.19	3.05	>
3.	Height (cm)	0.45	0.94	-1.29	2.48	>
4.	Suprasternal height (cm)	0.34	0.99	-1.28	2.33	>
5.	Xiphoidal height (cm)	0.26	1.03	-1.97	2.31	>
6.	Head-neck length (cm)	0.61	0.68	-0.54	2.23	>
7.	Sternum length (cm)	0.36	1.09	-2.02	1.81	>
9.	Trunk length (cm)	0.60	2.41	-2.17	8.07	>
12.	Upper limb length (cm)	0.47	1.26	-2.39	3.50	>
13.	Lower limb length (cm)	-0.26	1.49	-4.08	2.45	<
15.	Biacromial breadth (cm)	0.67	0.88	-1.50	2.29	>
16.	Chest breadth (cm)	-0.21	1.07	-2.36	1.72	<
17.	Waist breadth (cm)	-0.24	1.08	-2.02	1.89	<
18.	Pelvis breadth (cm)	-0.56	0.98	-2.75	2.13	<
19.	Chest depth (cm)	-0.42	0.96	-1.90	2.27	<
20.	Abdomen depth (cm)	-0.43	0.94	-2.90	1.73	<
21.	Femur breadth (cm)	0.23	1.33	-2.18	3.10	>
22.	Ankle breadth (cm)	0.60	1.42	-2.18	3.15	>
23.	Humerus breadth (cm)	0.60	1.32	-1.67	3.12	>
24.	Wrist breadth (cm)	0.18	1.00	-1.76	2.28	-
25.	Head circumference (cm)	-0.24	0.96	-2.37	1.62	-

26.	Neck circumference (cm)	0.05	1.10	-1.50	3.10	-
27.	Upper chest circumference (cm)	-0.09	0.96	-1.31	2.70	-
29.	Waist circumference (cm)	0.11	0.92	-1.21	3.16	>
30.	Pelvis circumference (cm)	-1.64	1.13	-3.35	1.01	<
33.	Middle thigh circumference (cm)	-0.06	1.07	-1.67	2.37	>
34.	Upper leg circumference (cm)	0.07	0.97	-1.36	2.08	>
35.	Lower leg circumference (cm)	0.07	1.10	-2.20	2.11	>
36.	Arm circumference (cm)	0.05	0.91	-1.74	2.14	>
37.	Arm circumference flexed and tensed (cm)	0.33	1.02	-1.49	2.90	>
38.	Forearm circumference (cm)	-0.19	1.09	-2.31	2.17	<
39.	Wrist circumference (cm)	0.85	1.11	-1.5	3.67	>
41.	Chest skinfold (cm)	-1.34	0.84	-1.83	1.41	-
46.	Subscapular skinfold (cm)	-1.35	0.65	-1.88	0.81	-
47.	Biceps skinfold (cm)	-1.71	1.07	-2.71	1.30	-
48.	Triceps skinfold (cm)	-2.30	1.07	-3.37	0.48	>
49.	Thigh skinfold (cm)	-1.97	1.11	-2.93	1.80	<
50.	Calf skinfold (cm)	-2.12	1.21	-3.31	0.57	<

Table 4

Linear models for young female volleyballers (n=46) basic anthropometric measurements by age, weight and height.

No	Variable	Regression model coefficients				
		Intercept	Age	Weight	Height	R^2
6	Head-neck length (cm)	13.14	0.18	-0.01	0.09*	0.38
7	Sternum length (cm)	-13.75	0.41	-0.06	0.16*	0.26
11	Lower body length (cm)	-37.72	-0.53	-0.012	0.87*	0.47
12	Upper limb length (cm)	-13.63	0.20	0.01	0.20*	0.60
13	Lower limb length (cm)	-38.85	-1.14*	-0.07	0.88*	0.64
14	Horizontal arms spread (cm)	-22.28	1.25	0.07	1.06*	0.63
15	Biacromial breadth (cm)	21.45	0.18	0.08*	0.04	0.40
16	Chest breadth (cm)	22.99	-0.04	0.15*	-0.04	0.66
17	Waist breadth (cm)	22.57	-0.05	0.18*	-0.06	0.67
18	Pelvis breadth (cm)	4.61	0.15	0.06*	0.09*	0.51
19	Chest depth (cm)	15.43	-0.13	0.12*	-0.02	0.60
20	Abdomen depth (cm)	15.21	0.15	0.11*	-0.05	0.45
21	Femur breadth (cm)	6.39	0.05	0.04*	0.000	0.40
22	Ankle breadth (cm)	3.96	-0.04	0.03*	0.01	0.36
23	Humerus breadth (cm)	2.03	-0.10*	0.01	0.03*	0.40
24	Wrist breadth (cm)	1.99	0.004	0.005	0.01*	0.21
25	Head circumference (cm)	49.52	-0.34	0.05*	0.04	0.23
26	Neck circumference (cm)	31.67	-0.16	0.17*	-0.04	0.64
27	Upper chest circumference (cm)	99.83	-0.39	0.64*	-0.29*	0.92
28	Lower chest circumference (cm)	94.81	-0.05	0.66*	-0.34*	0.84
29	Waist circumference (cm)	76.15	0.14	0.61*	-0.27	0.68
30	Pelvis circumference (cm)	61.08	0.69	0.66*	-0.17	0.79
31	Hip circumference (cm)	74.01	-0.23	0.73*	-0.16	0.41
32	Upper thigh circumference (cm)	39.08	0.18	0.61*	-0.13	0.75
33	Middle thigh circumference (cm)	36.57	0.48	0.51*	-0.16	0.79
34	Upper leg circumference (cm)	24.86	0.22	0.27*	-0.06	0.76
35	Lower leg circumference (cm)	7.29	-0.03	0.13*	0.049	0.73
36	Arm circumference (cm)	28.12	0.18	0.29*	-0.13	0.89
37	Arm circumference flexed and tensed (cm)	29.94	0.01	0.32*	-0.13*	0.90
38	Forearm circumference (cm)	17.79	0.18	0.17	-0.04	0.80
39	Wrist circumference (cm)	11.80	-0.04	0.08*	-0.001	0.62
40	Chin skinfold (cm)	1.99	-0.02	0.02*	-0.01*	0.43
41	Chest skinfold (cm)	1.46	-0.04	0.02*	-0.01	0.63
42	Side skinfold (cm)	3.71	0.06*	0.05*	-0.02	0.73
43	Waist skinfold (cm)	4.39	-0.02	0.06*	-0.04*	0.67
44	Suprailiacal skinfold (cm)	3.87	-0.06	0.04*	-0.03*	0.57

45	Umbilical skinfold (cm)	4.28	-0.009	0.05*	-0.03*	0.70
46	Subscapular skinfold (cm)	5.40	-0.08*	0.05*	-0.03*	0.66
47	Biceps skinfold (cm)	2.49	-0.06	0.03*	-0.02	0.52
48	Triceps skinfold (cm)	5.13	0.04	0.04*	-0.03	0.55
49	Thigh skinfold (cm)	3.34	0.09	0.05*	-0.03*	0.44
50	Calf skinfold (cm)	-0.59	0.04	0.02*	0.002	0.35

* statistically significant variables in the model. All models are statistically significant on level 0.05.

Table 5

Means and standard deviations of basic anthropometric measurements in a 5SD height-weight classification of young female volleyballers (n=46) Comparison of means from different classes (α=0,05).

No	Variable	Small (n=8)		Medium (n=8)		Large (n=6)		Significance 1-3	Pycnomorphs (n=13)		Leptomorphs (n=11)		Significance 4-5
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
1	Age	13.63	1.06	14.88	0.83	15.00	1.26	-	14.54	0.97	14.45	1.04	-
2	Weight (kg)	44.56	4.02	54.22	2.63	68.58	7.16	+	60.87	7.41	53.75	5.20	+
3	Height (cm)	158.39	3.31	166.96	1.15	174.52	3.62	+	163.75	3.15	169.77	4.86	+
4	Surpasternal height (cm)	128.40	2.45	136.01	1.18	142.93	3.09	+	132.95	2.90	138.24	5.10	-
5	Xiphoidal height (cm)	114.23	2.61	121.45	2.07	126.8	3.35	+	119.04	2.49	122.47	5.59	-
6	Head-neck length (cm)	29.99	1.01	30.95	0.70	31.58	0.97	+	30.81	0.70	31.54	0.99	+
7	Sternum length (cm)	14.18	2.28	14.56	1.21	16.07	1.25	-	13.91	2.16	15.76	1.12	+
8	Abdomen length (cm)	31.15	2.52	35.05	1.73	36.10	2.91	+	38.26	6.39	35.15	6.67	-
9	Trunk length (cm)	45.33	1.32	49.61	1.90	52.17	2.34	+	52.17	7.18	50.92	6.45	-
10	Upper body length (cm)	66.15	11.92	67.23	2.09	68.98	2.98	-	66.01	4.30	67.35	3.19	-
11	Lower body length (cm)	92.24	11.92	99.74	2.49	105.53	1.90	+	97.75	3.44	102.42	6.27	+
12	Upper limb length (cm)	68.93	4.10	73.64	3.14	76.18	4.03	+	71.11	2.81	74.72	3.42	+
13	Lower limb length (cm)	83.01	4.85	88.95	2.08	93.30	1.93	+	84.19	5.64	90.87	4.25	+
14	Horizontal arms spread (cm)	162.19	11.48	169.23	4.05	175.50	5.66	+	163.32	6.38	170.74	6.89	+
15	Biacromial breadth (cm)	33.81	1.56	35.44	0.98	36.33	2.34	+	35.61	1.45	35.45	1.25	-
16	Chest breadth (cm)	22.56	1.45	23.25	0.89	25.50	0.71	+	24.77	1.24	23.36	1.16	+
17	Waist breadth (cm)	20.69	1.51	21.31	1.13	24.08	1.59	+	22.73	1.47	21.05	1.06	+
18	Pelvis breadth (cm)	24.19	1.62	25.94	0.78	27.00	2.05	+	25.69	1.38	25.82	1.05	-

19	Chest depth (cm)	15.06	1.05	16.06	0.78	17.17	1.03	+	16.85	1.38	15.95	0.91	-
20	Abdomen depth (cm)	14.31	1.67	15.63	1.03	16.75	0.69	+	15.96	1.23	14.95	0.57	+
21	Femur breadth (cm)	8.05	0.49	8.66	0.39	9.05	0.68	+	8.90	0.49	8.75	0.44	-
22	Ankle breadth (cm)	6.48	0.46	6.65	0.44	7.03	0.66	-	7.01	0.35	7.02	0.29	-
23	Humerus breadth (cm)	5.88	0.28	6.18	0.30	6.57	0.37	+	6.10	0.41	6.23	0.36	-
24	Wrist breadth (cm)	4.57	0.32	5.01	0.23	5.20	0.28	+	5.10	0.22	5.23	0.21	-
25	Head circumf. (cm)	54.68	1.31	54.31	1.79	55.77	1.18	-	55.17	1.62	54.95	1.11	-
26	Neck circumf. (cm)	29.80	0.98	30.95	1.08	33.83	1.50	+	32.31	1.47	30.91	0.94	+
27	Upper chest circumf. (cm)	76.29	2.73	79.71	2.24	86.18	3.02	+	85.29	4.50	78.42	2.72	+
28	Lower chest circumf. (cm)	70.10	4.29	72.09	2.95	79.50	5.48	+	77.62	5.05	71.26	3.07	+
29	Waist circumf. (cm)	63.05	3.23	65.59	2.40	74.88	6.70	+	70.70	5.04	64.84	2.58	+
30	Pelvis circumf. (cm)	71.79	4.46	79.55	4.13	87.45	4.99	+	82.71	4.41	76.89	3.23	+
31	Hip circumf. (cm)	75.91	11.73	86.89	3.39	88.17	13.99	-	89.01	8.58	84.31	2.64	-
32	Upper thigh circumf. (cm)	47.31	4.54	55.34	1.96	59.60	8.00	+	59.03	3.21	53.45	3.66	+
33	Middle thigh circumf. (cm)	41.11	3.74	46.50	2.74	52.02	5.46	+	49.10	3.06	44.31	2.59	+
34	Upper leg circumf. (cm)	30.88	1.03	33.79	1.84	37.20	2.34	+	35.61	2.12	33.46	1.90	+
35	Lower leg circumf. (cm)	19.94	1.12	21.30	0.60	23.95	0.84	+	22.71	1.03	22.29	1.31	-
36	Arm circumf. (cm)	22.10	1.77	24.34	1.09	27.13	2.09	+	26.88	1.52	23.67	1.35	+
37	Arm circumf. flexed and tensed (cm)	23.84	1.53	26.43	1.09	27.13	2.09	+	28.88	1.94	25.52	1.27	+
38	Forearm circumf. (cm)	20.44	0.99	21.69	0.70	24.05	1.49	+	23.67	1.07	22.14	0.87	+
39	Wrist circumf. (cm)	14.64	0.64	15.33	0.70	16.58	0.78	+	16.22	0.80	15.77	0.68	-
40	Chin skinfold (cm)	0.52	0.12	0.59	0.17	0.80	0.28	+	0.76	0.25	0.52	0.14	+

41	Chest skinfold (cm)	0.51	0.15	0.63	0.18	0.92	0.29	+	0.83	0.28	0.51	0.19	+
42	Side skinfold (cm)	0.56	0.15	0.73	0.18	1.20	0.48	+	1.10	0.40	0.55	0.16	+
43	Waist skinfold (cm)	0.91	0.32	1.09	0.30	1.73	0.43	+	1.63	0.49	0.97	0.31	+
44	Suprailiacal skinfold (cm)	0.54	0.14	0.83	0.31	1.10	0.32	+	1.13	0.39	0.55	0.20	+
45	Umbilical skinfold (cm)	0.76	0.28	0.94	0.19	1.30	0.29	+	1.32	0.42	0.80	0.30	+
46	Subscapular skinfold (cm)	0.80	0.15	1.00	0.24	1.25	0.35	+	1.35	0.51	0.77	0.28	+
47	Biceps skinfold (cm)	0.64	0.22	0.75	0.24	1.07	0.36	+	0.98	0.21	0.62	0.29	+
48	Triceps skinfold (cm)	0.98	0.30	1.15	0.27	1.45	0.31	+	1.65	0.26	1.00	0.33	+
49	Thigh skinfold (cm)	1.79	0.49	1.96	0.50	2.67	0.52	+	2.42	0.44	1.90	0.48	+
50	Calf skinfold (cm)	1.09	0.24	1.35	0.37	1.65	0.36	+	1.45	0.25	1.22	0.30	+

Table 6

Means and standard deviations of indices and body composition characteristics in a 5 SD height-weight classification of young female volleyballers (n=46). Comparison of means from different classes (α=0,05).

No	Variable	1 n=8 Small		2 n=8 Medium		3 n=6 Large		Signifi-cance 1-3	4 n=13 Pycnomorphs		5 n=11 Leptomorphs		Signifi-cance 4-5
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
51	Rohrer index	1.12	0.08	1.17	0.05	1.29	0.07	+	1.38	0.14	1.10	0.07	+
52	Body mass index	17.74	1.28	19.45	0.89	22.47	1.50	+	22.66	2.36	18.61	1.18	+
53	Body surface area (m^2)	1.42	0.07	1.60	0.04	1.83	0.11	+	1.66	0.10	1.62	0.10	-
54	Relat. trunk length (%)	28.62	0.89	29.72	1.17	29.89	0.94	-	31.88	4.53	29.97	3.48	-
55	Relat. abdomen length (%)	19.68	1.67	20.99	1.00	20.67	1.42	-	23.40	4.09	20.68	3.65	-
56	Relat. upper body length (%)	41.79	7.25	40.27	1.32	39.52	1.09	-	40.30	2.19	39.71	2.38	-
57	Relat. lower body length (%)	58.21	7.25	59.73	1.32	60.48	1.09	-	59.71	2.19	60.29	2.38	-
58	Relat. upper limb length (%)	43.50	2.09	44.11	1.97	43.65	2.05	-	43.42	1.18	44.00	1.19	-
59	Relat. lower limb length (%)	52.42	3.12	53.27	1.09	53.47	0.98	-	51.39	2.85	53.52	1.55	+
60	Relat. horizontal arms spread (%)	102.36	6.08	101.36	2.39	100.55	1.60	-	99.71	2.66	100.55	1.81	-
61	Relat. biacromial breadth (%)	21.35	0.99	21.23	0.61	20.81	1.04	-	21.75	0.67	20.90	0.89	+
62	Relat. chest breadth (%)	14.25	0.88	13.93	0.55	14.61	0.20	-	15.13	0.71	13.76	0.62	+
63	Relat. waist breadth (%)	13.06	0.85	12.76	0.66	13.79	0.71	-	13.88	0.89	12.40	0.62	+
64	Relat. pelvis breadth (%)	15.27	0.93	15.53	0.40	15.46	0.89	-	15.69	0.77	15.21	0.53	-

65	Relat. chest depth (%)	9.51	0.67	9.62	0.44	9.84	0.55	-	10.29	0.80	9.40	0.45	+
66	Relat. abdomen depth (%)	9.04	1.03	9.36	0.64	9.60	0.25	-	9.75	0.77	8.81	0.38	+
67	Relat. femur breadth (%)	5.08	0.30	5.19	0.25	5.19	0.39	-	5.44	0.31	5.51	0.26	+
68	Relat. ankle breadth (%)	4.09	0.27	3.98	0.28	4.03	0.35	-	4.28	0.20	4.13	0.12	+
69	Relat. humerus breadth (%)	3.71	0.19	3.70	0.20	3.76	0.19	-	3.73	0.24	3.67	0.18	-
70	Relat. wrist breadth (%)	3.00	0.19	3.00	0.16	2.98	0.19	-	3.12	0.13	3.08	0.15	-
71	Relat. head circumf. (%)	34.52	0.61	32.53	1.07	31.96	0.50	+	33.69	0.84	32.39	1.09	+
72	Relat. upper chest circumf. (%)	48.17	1.60	47.74	1.37	49.37	0.86	-	52.08	2.51	46.20	1.45	+
73	Relat. lower chest circumf. (%)	44.26	2.55	43.18	1.73	45.36	2.31	-	47.40	2.97	41.98	1.47	+
74	Relat. waist circumf. (%)	39.81	1.95	39.28	1.31	42.93	4.05	+	43.17	2.88	38.20	1.46	+
75	Relat. pelvis circumf. (%)	45.33	2.73	47.64	2.34	50.11	2.59	+	50.51	2.47	45.30	1.81	+
76	Relat. hip circumf. (%)	47.97	7.53	52.04	1.84	50.45	7.51	-	54.34	4.93	49.67	1.41	+
77	Relat. upper thigh circumf. (%)	29.88	2.84	33.15	1.26	34.10	4.09	+	36.04	1.73	31.47	1.71	+
78	Relat. upper leg circumf. (%)	19.50	0.66	20.24	1.09	21.31	1.22	+	21.74	1.22	19.71	0.97	+
79	Relat. arm circumf. (%)	13.95	0.98	14.58	0.64	15.54	1.00	+	16.41	0.83	13.94	0.69	+
80	Relat. forearm circumf. (%)	12.90	0.47	12.99	0.42	13.78	0.68	+	14.45	0.58	13.04	0.46	+
81	Relat. wrist circumf. (%)	9.24	0.37	9.18	0.45	9.50	0.43	-	9.90	0.43	9.29	0.39	+
82	Arm circumf./upper limb length (%)	32.08	2.04	33.11	2.11	35.63	2.14	+	37.81	1.77	31.71	1.70	+
83	Forearm circumf./upper limb length (%)	29.68	1.05	29.50	1.59	31.64	2.62	-	33.31	1.42	29.66	1.32	+
84	Wrist circumf./upper limb length (%)	21.26	0.76	20.84	1.13	21.82	1.68	-	22.82	1.03	21.14	1.13	+

85	Humerus breadth/upper limb length (%)	8.55	0.56	8.39	0.32	8.64	0.59	-	8.58	0.51	8.34	0.44	-
86	Wrist breadth/upper limb length (%)	6.90	0.44	6.81	0.39	6.85	0.67	-	7.18	0.32	7.01	0.42	-
87	Upper thigh circumf./lower limb length (%)	57.29	7.61	62.25	2.76	63.82	7.93	-	70.27	3.79	58.87	3.95	+
88	Middle thigh circumf./lower limb length (%)	49.75	6.15	52.29	2.97	55.71	5.28	-	58.46	3.98	48.82	3.07	+
89	Upper leg circumf./lower limb length (%)	37.34	3.14	38.00	2.10	39.89	2.64	-	42.38	2.54	36.87	2.28	+
90	Lower leg circumf./lower limb length (%)	24.10	2.11	23.95	0.74	25.68	1.16	-	27.06	1.79	24.56	1.62	+
91	Femur breadth/lower limb length (%)	9.73	0.85	9.74	0.49	9.70	0.64	-	10.62	0.94	9.64	0.58	+
92	Ankle breadth/lower limb length (%)	7.82	0.69	7.47	0.43	7.54	0.65	-	8.35	0.54	7.73	0.30	+
93	Chest breadth/chest depth (%)	150.27	12.42	144.93	6.68	148.92	8.39	-	147.71	11.64	146.70	8.37	-
94	Chest depth/chest breadth (%)	66.93	5.34	69.12	3.00	67.34	3.96	-	68.10	5.51	68.36	3.77	-
95	Waist breadth/ abdomen depth (%)	145.78	15.53	136.92	11.92	143.83	8.76	-	142.84	10.15	140.85	7.50	-
96	Abdomen depth/waist breadth (%)	69.18	6.27	73.47	5.75	69.73	4.05	-	70.33	4.96	71.18	3.67	-
97	Biacromial breadth/pelvis breadth (%)	140.02	4.83	136.73	5.42	134.74	5.42	+	138.91	7.88	137.53	7.37	-
98	Waist circumf./pelvis circumf. (%)	87.90	2.41	82.52	2.31	85.60	5.05	+	85.43	2.50	84.40	3.50	-

99	Biacromial breadth/chest circumf. (%)	41.55	0.86	41.56	1.26	39.79	1.38	+	39.72	2.29	42.23	1.98	+
100	Trunk length/upper chest circumf. (%)	59.49	2.95	62.31	3.58	60.53	1.82	-	61.41	9.94	64.82	6.34	+
101	Body density (g/m^3)	1.06	0.01	1.05	0.01	1.05	0.01	-	1.05	0.01	1.06	0.01	+
102	Relat. mass of fat by Siri (%)	16.73	4.78	19.58	3.55	19.57	4.09	-	19.78	3.71	16.20	2.10	+
103	Mean skinfold (cm)	0.83	0.17	1.00	0.20	1.38	0.28	+	1.33	0.28	0.86	0.21	+
104	Mass of subcutaneous adipose tissue (kg)	5.31	1.27	7.23	1.58	11.36	2.68	+	9.97	2.60	6.25	1.70	+
105	Relat. mass of subcutaneous adipose tissue (%)	11.83	2.30	13.27	2.41	16.49	3.12	+	16.21	2.48	11.54	2.55	+
106	Total cross-sectional area of arm (cm^2)	39.09	6.02	47.22	4.36	58.88	9.00	+	57.65	6.50	44.73	5.19	+
107	Total cross-sectional area of thigh (cm^2)	179.57	33.33	243.95	17.26	286.92	71.91	+	278.06	30.03	228.35	30.31	+
108	Bone-muscle rate of the cross-sectional area of arm (cm^2)	30.65	4.89	36.31	1.97	42.95	6.33	+	41.24	4.50	35.61	3.37	+
109	Fat rate of the cross-sectional area of arm (cm^2)	8.43	2.31	10.91	2.99	15.92	4.66	+	16.42	3.13	9.12	3.56	+
110	Bone-muscle rate of the cross-sectional area of thigh (cm^2)	139.27	23.17	192.77	17.92	213.38	63.15	+	211.02	24.05	180.23	24.93	+
111	Fat rate of the cross-sectional area of thigh (cm^2)	40.30	13.46	51.18	12.88	73.54	16.69	+	67.03	13.67	48.12	13.04	+

112	Bone-muscle rate of the cross-sectional area of arm/total cross-sectional area of arm	0.79	0.05	0.77	0.04	0.73	0.06	-	0.72	0.03	0.80	0.06	+
113	Fat rate of the cross-sectional area of arm/total cross-sectional area of arm	0.22	0.05	0.23	0.04	0.27	0.06	-	0.28	0.03	0.20	0.06	+
114	Bone-muscle rate of the cross-sectional area of thigh/total cross-sectional area of thigh	0.78	0.05	0.79	0.05	0.74	0.07	-	0.76	0.04	0.79	0.05	-
115	Fat rate of the cross-sectional area of thigh/total cross-sectional area of thigh	0.22	0.05	0.21	0.05	0.27	0.07	-	0.24	0.04	0.21	0.05	-

Table 7

Basic statistics of young female volleyballers' physical ability tests results and their correlation with age (n=41, α=0,05)

No	Variable	$\bar{x}$	SD	Min	Max	Statistically significant correlation with age (r)
1.	Test of highest jump and reach standing (PA_1) (cm)	252.98	10.01	237.00	275.00	0.383
2.	Test of highest jump and reach running (PA_2) (cm)	256.98	10.08	243.00	284.00	0.373
3.	Highest reach of the players outstretched hand (cm)	217.20	8.25	201.00	236.00	0.370
4.	Vertical jump height standing (PA_3) (cm)	35.78	4.14	27.00	46.00	-
5.	Vertical jump height running (PA_4) (cm)	39.78	5.21	31.00	58.00	-
6.	Endurance test (PA_5) (sec)	375.78	84.70	135.00	545.0	-
7.	Stomach muscle strength test (PA_6) (sec)	169.68	59.56	85.00	300.0	-
8.	Test of flexibility (PA_7) (cm)	16.63	6.53	4.00	32.50	-
9.	Test of speed measuring (PA_8) (sec)	27.70	1.48	24.70	33.00	-
10.	Medicine ball throwing test (PA_9) (cm)	300.37	44.35	210.00	400.0	-

Table 8

Correlation matrix of physical ability tests results of young female volleyballers (n=41)

No	Variables	Test of highest jump and reach standing (PA_1) cm	Test of highest jump and reach running (PA_2) cm	Highest reach of the players' outstretched hand (cm)	Vertical jump height standing (PA_3) cm	Vertical jump height running (PA_4) cm	Endurance test (PA_5) cm	Stomach muscle strength test (PA_6) sec	Test of flexibility (PA_7) cm	Test of speed measuring (PA_8) sec	Medicine ball throwing test (PA9) cm
1	Test of highest jump and reach standing PA_1 (cm)	1.000									
2	Test of highest jump and reach running PA_2 (cm)	0.959•	1.000								
3	Highest reach of the players outstreched hand (cm)	0.915•	0.857•	1.000							
4	Vertical jump height standing PA_3 (cm)	0.594•	0.609•	0.219	1.000						
5	Vertical jump height running PA_4 (cm)	0.406•	0.578•	0.075	0.388•	1.000					
6	Endurance test PA_5 (sec)	-0.123	-0.045	-0.300	0.301	0.388•	1.000				
7	Stomach muscle strength test PA_6 (sec)	-0.005	-0.004	-0.097	0.181	0.146	0.140	1.000			
8	Test of flexibility PA_7 (cm)	-0.024	0.084	-0.110	0.161	0.336•	0.069	0.054	1.000		
9	Test of speed measuring PA_8 (sec)	-0.397•	-0.424•	-0.162	-0.637•	-0.565•	-0.459•	-0.382•	0.103	1.000	
10	Medicine ball throwing test PA_9 (cm)	0.478•	0.539•	0.487•	0.184	0.270	-0.108	-0.031	0.008	-0.305	1.000

Table 9

Statistically significant coefficients of linear correlation between physical ability tests results and basic anthropometric variables of young female volleyballers (n=41, α=0,05).

No	Variables	$\bar{x}$	SD	Age	Test of highest jump and reach standing (PA_1) cm	Test of highest jump and reach running (PA_2) cm	Highest reach of the players' outstretched hand (cm)	Vertical jump height standing (PA_3) cm	Vertical jump height running (PA_4) cm	Endurance test (PA_5) cm	Stomach muscle strength test (PA_6) sec	Test of flexibility (PA_7) cm	Test of speed measuring (PA_8) sec	Medicine ball throwing test (PA9) cm
2	Weight (kg)	56.178	9.107	0.291	0.548	0.550	0.713	-	-	-0.473	-	-	-	0.517
3	Height (cm)	166.22	6.02	0.429	0.863	0.786	0.944	-	-	-0.343	-	-	-	-0.448
4	Suprasternal height (cm)	135.26	5.50	0.395	0.870	0.802	0.959	-	-	-0.311	-	-	-	0.456
5	Xiphoidal height (cm)	120.46	5.07	0.295	0.773	0.705	0.898	-	-	-0.334	-	-	-	0.498
6	Head-neck length (cm)	30.97	0.99	0.413	0.419	0.325	0.420	-	-	-0.355	-	-	-	-
7	Sternum length (cm)	14.79	1.87	0.363	0.507	0.491	0.440	0.350	-	-	-	-	-0.332	-
8	Abdomen length (cm)	35.44	5.37	-	-	-	-	-	-	-	-	-	-	-
9	Trunk length (cm)	50.23	5.52	-	0.320	0.328	0.435	-	-	-	-	-	-	-
10	Upper body length (cm)	66.55	5.4	-	-	-	-	-	-	-	-	-	-	-
11	Lower body length (cm)	99.27	7.25	-	0.588	0.515	-	-	-	-	-	-	-	-

12	Upper limb length (cm)	72.69	4.09	0.375	0.766	0.640	0.839	-	-	-	-	-	-	0.313
13	Lower limb length (cm)	87.6	5.62	-	0.713	0.625	0.738	-	-	-0.315	-	-	-	-
14	Horizontal arms spread (cm)	167.51	8.35	0.464	0.796	0.728	0.849	-	-	-	-	-	-	0.318
15	Biacromial breadth (cm)	35.33	1.62	0.319	0.620	0.625	0.696	-	-	-	-	-	-	0.557
16	Chest breadth (cm)	23.88	1.5	-	0.411	0.456	0.515	-	-	-	-	-	-	0.483
17	Waist breadth (cm)	21.9	1.73	-	0.412	0.419	0.571	-	-	-	-	-	-	0.377
18	Pelvis breadth (cm)	25.67	1.54	0.67	0.659	0.655	0.778	-	-	-0.310	-	-	-	0.403
19	Chest depth (cm)	16.23	1.25	-	0.310	0.321	0.507	-	-	-0.449	-	-	0.479	0.374
20	Abdomen depth (cm)	15.48	1.31	-	-	0.313	0.417	-	-	-	-	-	-	0.314
21	Femur breadth (cm)	8.69	0.54	-	0.320	-	0.425	-	-	-	-	-	-	-
22	Ankle breadth (cm)	6.86	0.46	-	0.421	0.430	0.491	-	-	-	-	-	-	0.583
23	Humerus breadth (cm)	6.17	0.39	-	0.508	0.467	0.580	-	-	-0.332	-	-	-	0.344
24	Wrist breadth (cm)	5.07	0.29	-	0.454	0.458	0.449	-	-	-	-	-	-	0.375
25	Head circumf.(cm)	54.96	1.44	-	-	-	0.356	-	-	-	-	-	-	0.356

26	Neck circumf. (cm)	31.5	1.71	-	0.374	0.386	0.535	-	-	-0.323	-	-	-	-
27	Upper chest circumf. (cm)	81.23	4.97	-	0.310	0.338	0.488	-	-	-0.400	-	-	-	0.413
28	Lower chest circumf. (cm)	73.96	5.36	-	0.326	0.358	0.513	-	-	-0.374	-	-	-	0.502
29	Waist circumf. (cm)	67.62	5.65	-	0.350	0.337	0.515	-	-	-0.346	-	-	0.324	-
30	Pelvis circumf. (cm)	79.49	6.3	0.324	0.419	0.405	0.606	-	-	-0.479	-	-	0.326	-
31	Hip circumf. (cm)	85.13	9.35	-	-	0.323	0.421	-	-	-	-	-0.310	-	0.345
32	Upper thigh circumf. (cm)	55.09	5.54	-	0.358	0.382	0.538	-	-	-0.428	-	-	-	0.467
33	Middle thigh circumf. (cm)	46.49	4.79	0.308	0.379	0.404	0.549	-	-	-0.371	-	-	-	0.542
34	Upper leg circumf. (cm)	34.16	2.68	0.304	0.494	0.537	0.564	-	-	-0.320	-	-	-	0.638
35	Lower leg circumf. (cm)	22.04	2.41	-	0.586	0.580	0.690	-	-	-0.328	-	-	-	0.595

36	Arm circumf.(cm)	24.87	2.41	-	0.320	0.313	0.505	-	-	-0.445	-	-	-	0.533
37	Arm circumf. flexed and tensed (cm)	26.84	2.567	-	0.342	0.343	0.522	-	-	-0.444	-	-	-	0.503
38	Forearm circumf. (cm)	22.45	1.6	0.328	0.432	0.462	0.578	-	-	-0.342	-	-	-	0.607
39	Wrist circumf. (cm)	15.73	0.94	-	0.495	0.524	0.601	-	-	-	-	-	-	0.516
40	Chin skinfold (cm)	0.64	0.23	-	-	-	-	-0.331	-	-0.363	-	-	0.352	-
41	Chest skinfold(cm)	0.67	0.27	-	-	-	0.334	-0.520	-0.425	-0.498	-	-	0.483	-
42	Side skinfold (cm)	0.82	0.39	-	-	-	0.407	-0.386	-0.331	-0.472	-	-	0.384	-
43	Waist skinfold (cm)	1.27	0.5	-	-	-	-0.317	-0.455	-0.421	-0.437	-	-	0.498	-
44	Suprailiacal skinfold (cm)	0.84	0.39	-	-	-	-	-0.464	-0.372	-0.454	-	-	0.565	-
45	Umbilical skinfold (cm)	1.03	0.39	-	-	-	-	-0.474	-0.379	-0.412	-	-	0.493	-

46	Subscapular skinfold (cm)	1.03	0.41	-	-	-	-	-0.411	-0.345	-0.339	-	-	0.516	-
47	Biceps skinfold (cm)	0.81	0.31	-	-	-	-	-0.418	-0.376	-0.450	-	-	0.406	-
48	Triceps skinfold (cm)	1.27	0.4	-	-	-	-	-0.374	-0.314	0.452	-	-	0.506	-
49	Thigh skinfold (cm)	2.14	0.56	-	-	-	-	-0.330	-0.335	-0.435	-	-	-	-
50	Calf skinfold (cm)	1.34	0.34	-	-	-	-	-	-0.327	-0.438	-	-	0.316	-

Table 10

Means and standard deviations of physical ability tests results in 5 SD height-weight classification of young female volleyballers (n=46). Comparison of means from different classes (α=0,05).

No	Variable	1 n=8 Small		2 n=8 Medium		3 n=6 Large		Signifi- cance 1-3	4 n=13 Pycnomorphs		5 n=11 Leptomorphs		Signifi- cance 4-5
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
1	Test of highest jump and reach standing (PA_1) cm	246.33	9.40	254.00	6.00	266.00	3.32	+	248.27	9.26	258.64	7.51	+
2	Test of highest jump and reach running (PA_2) cm	251.08	10.04	257.25	7.09	270.00	8.22	+	253.27	9.24	261.18	7.22	+
3	Highest reach of the players outstreched hand cm	211.42	8.22	218.65	4.03	229.40	4.39	+	214.00	5.48	220.55	7.13	+
4	Vertical jump height standing (PA_3) cm	34.92	6.05	35.38	2.39	36.60	5.32	-	34.27	5.59	38.09	2.17	+
5	Vertical jump height running (PA_4) cm	39.67	6.39	38.63	3.66	40.60	1.30	-	39.27	5.31	40.64	2.91	-
6	Endurance test (PA_5) sec	427.08	68.94	356.63	78.03	337.40	129.22	-	369.27	87.59	386.55	65.33	-
7	Stomach muscle strength test (PA_6) sec	154.42	31.49	169.13	60.41	160.60	47.74	-	160.64	79.03	189.73	65.28	-
8	Test of flexibility (PA_7) cm	15.92	6.00	19.50	5.58	16.80	10.69	-	16.91	6.32	13.14	3.96	-
9	Test of speed measuring (PA_8) sec	28.09	1.03	27.80	1.59	27.94	1.36	-	28.36	1.89	26.97	1.03	+
10.	Medicine ball throwing test (PA_9) cm	272.50	37.45	295.00	35.76	326.00	63.48	-	309.09	38.07	300.46	46.01	-

Table 11

Linear regression formulae for predicting physical ability tests results from young female volleyballers' (n=41) anthropometric measurements.

No	Predicted variables	Explanatory variables	Coefficients	R^2
1.	Test of highest jump and reach standing PA_1	Intercept Age Weight Height*	-1.31 0.18 -0.14 1.53	0.75
2.	PA_1	Intercept Lower limb length Horizontal arms spread Upper leg circumference Chest skinfold	46.60 0.72 0.60 1.52 -12.69	0.89
3.	Test of highest jump and reach running PA_2	Intercept Age Weight Height*	37.37 0.43 -0.018 1.29	0.62
4.	PA_2	Intercept Horizontal arms spread Upper leg circumference Umbilical skinfold	77.26 0.62 2.62 12.79	0.78
5.	Highest reach of the players' outstretched hand	Intercept Age Weight Height*	13.80 -0.30 0.07 1.23	0.90
6.	Highest reach of the players' outstretched hand	Intercept Trunk length Lower limb length Horizontal arms spread Neck circumference	29.05 0.27 0.65 0.51 1.03	0.95
7.	Vertical jump height standing PA_3	Intercept Weight Height*	-14.30 -0.21 0.37	0.16
8.	PA_3	Intercept Upper leg circumference Chest skinfold Biceps skinfold Relat. mass of subcutaneous adipose tissue	14.75 1.02 11.68 7.13 -0.85	0.61
9.	Vertical jump height running PA_4	Intercept Age Weight Height	-	-

10.	PA_4	Intercept Ankle breadth Upper leg circumference Chin skinfold Relat. mass of Subcutaneous adipose tissue	37.28 -5.72 1.84 13.60 -2.14	0.63
11.	Endurance test PA_5	Intercept Age Weight* Height	617.36 14.98 4.14 1.36	0.26
12.	PA_5	Intercept Upper chest circumference Subscapular skinfold Relat. mass of subcut. adipose tissue	-6.06 22.84 -134.64 -38.19	0.42
13.	Test of speed measuring PA_8	Intercept Age Weight* Height*	45.51 -0.31 0.09 -0.11	0.24
14.	PA_8	Intercept Biacromial breadth Chest depth Ankle breadth Suprailiacal skinfold	34.70 -0.31 0.85 -1.53 1.11	0.63
15.	Medicine ball throwing test PA_9	Intercept Age Weight* Height	-11.08 5.20 1.86 0.80	0.29
16.	PA_9	Intercept Upper leg circumference Arm circumference Suprailiacal skinfold Mass of subcutaneous adipose tissue (kg)	-274.32 5.32 20.49 -41.51 -10.26	0.65

* statistically significant variables in the model.
All models are statistically significant (on level 0.05)

Table 12

Basic statistics of young female volleyballers (n=45) volleyball technical skills tests*.

No	Variable	$\bar{x}$	SD	Min	Max	Statistically significant correlation with age (r)
1.	Overhead pass with a clap behind the back T_1	16.58	5.56	2.00	20.00	-
2.	Overhead pass with squat T_2	7.31	4.89	2.00	20.00	-
3.	Forearm pass into 1 m^2 T_3	21.40	11.69	1.00	30.00	-
4.	Spike along the sideline T_4	4.49	2.04	0.00	8.00	-
5.	Spike diagonally T_5	3.93	1.50	0.00	7.00	-
6.	Feint into the centre of the court T_6	4.11	1.82	0.00	8.00	-
7.	Serve straight T_7	5.33	1.85	0.00	8.00	-
8.	Serve diagonally T_8	5.20	1.63	2.00	8.00	-
9.	Reception into zone 2 or 3 T_9	5.02	1.71	2.00	8.00	-

* The tests measured the number of successful repetitions

Table 13

Statistically significant correlation coefficients between volleyball technical skills tests and basic anthropometric variables in young female volleyballers (n=45, α=0,05).

No	Variable	Overhead pass with squat (T_2) in points	Forearm pass into 1 m^2 (T_3) in points	Spike along the sideline (T_4) in points	Spike diagonally (T_5) in points	Feint into the centre of the court (T_6) in points	Serve diagonally (T_8) in points	Reception into zone 2 or 3 (T_9) in points
2	Weight (kg)		-0.297					
3	Height (cm)			0.424				
6	Head-neck length (cm)			0.412				
7	Sternum length (cm)			0.419				
12	Upper limb length (cm)			0.313				
14	Horizontal arms spread (cm)			0.436				
15	Biacromial breadth (cm)			0.313				
20	Abdomen depth (cm)		-0.295					
21	Femur breadth (cm)		-0.304					
22	Ankle breadth (cm)					0.429		
23	Humerus breadth (cm)					0.351		
24	Wrist breadth (cm)					0.315		
25	Head circumf. (cm)							0.350
26	Neck circumf. (cm)		-0.373					
27	Upper chest circumf. (cm)		-0.316					
28	Lower chest circumf. (cm)		-0.299					
29	Waist circumf. (cm)		-0.359					
30	Pelvis circumf. (cm)		-0.327					
34	Upper leg circumf. (cm)			0.342				
35	Lower leg circumf. (cm)			0.377				
39	Wrist circumf. (cm)			0.386		0.386		

40	Chin skinfold (cm)		-0.489					
41	Chest skinfold (cm)		-0.314					
42	Side skinfold (cm)		-0.325					
43	Waist skinfold (cm)	-0.319	-0.323					
44	Suprailiacal skinfold (cm)		-0.360					
45	Umbilical skinfold (cm)		-0.351					
46	Subscapular skinfold (cm)		-0.395					
48	Triceps skinfold (cm)		-0.411					
49	Thigh skinfold (cm)		-0.331					
50	Calf skinfold (cm)	-0.448			-0.295		-0.295	

The following tests had no significant correlations with any anthropometric variabls:

- Overhead pass with a clap behind the back (T_1)
- Serve straight (T_7)

Table 14

Statistically significant correlation coefficients between volleyball technical skills tests and body composition characteristics in young female volleyballers (n=45, n=0,05).

No	Variable	Overhead pass with a clap behind the back (T_1) in points	Overhead pass with squat (T_2) in points	Forearm pass into 1 m² (T_3) in points	Spike along the sideline (T_4) in points	Spike diagonally (T_5) in points	Feint into the centre of the court (T_6) in points	Serve straight (T_7) in points	Serve diagonally (T_8) in points	Reception into zone 2 or 3 (T_9) in points
52	Body mass index			-0.346						
53	Body surface area (m^2)				0.340					
55	Relat. abdomen length (%)	-0.295								
58	Relat. lower limb length (%)								-0.345	
67	Relat. femur breadth (%)			-0.296						
68	Realt. ankle breadth (%)						0.366			
74	Relat. waist circumf. (%)			-0.354						
75	Relat. pelvis circumf. (%)			-0.344						
79	Relat. arm circumf. (%)			-0.311						
81	Relat. wrist circumf. (%)						0.310			
82	Arm circumf./upper limb length (%)			-0.367						
84	Wrist circumf./upper limb length (%)					0.333				
85	Humerus breadth/upper limb length (%)					0.323				
86	Wrist breadth/upper limb length (%)					0.322				

91	Femur breadth/lower limb length (%)			-0.312					0.346	
92	Ankle breadth/lower limb length (%)									
97	Biacromial breadth/pelvis breadth (%)		0.409	0.322				0.377		
100	Trunk length/upper chest circumf. (%)									-0.310
103	Mean skinfold (cm)			-0.401						
104	Mass of subcutaneous adipose tissue (kg)			-0.391						
105	Relat. mass of subcutaneous adipose tissue (%)			-0.387						
106	Total cross-sectional area of arm (cm^2)			-0.312						
109	Fat rate of the cross-sectional area of arm (cm^2)									
110	Bone-muscle rate of the cross-sectional area of thigh (cm^2)									
111	Fat rate of the cross-sectional area of thigh (cm^2)			-0.336						
112	Bone-muscle rate of the cross-sectional area of arm/total cross-sectional area of arm			0.349						

113	Fat rate of the cross-sectional area of arm/total cross-sectional area of arm			-0.349						
114	Fat rate of the cross-sectional area of thigh/total cross-sectional area of thigh							0.303		
115	Fat rate of the cross-sectional area of thigh/total cross-sectional area of thigh							-0.303		

Table 15

Linear models for young female volleyballers technical skills tests by basic anthropometric measurements, indices and body composition characteristics.

No	Predicted variable	Explanatory variables	Coefficients	R^2
1.	Overhead pass with squat T_2 (in points)	Intercept Biacromial breadth/pelvis breadth (%) Relat. mass of subcut. adipose tissue (%)	-24.78 0.27 -0.40	0.24
2.	Forearm pass into 1 m^2 T_3 (in points)	Intercept Femur breadth/lower limb length (%) Biacromial breadth/pelvis breadth (%) Mean skinfold (cm)	-9.13 -3.94 0.58 -9.106	0.29
3.	Spike along the sideline T_4 (in points)	Intercept Horizontal arms spread (cm) Wrist breadth (cm)	-20.08 0.08 2.08	0.27
		Intercept Upper limb length (cm) Horizontal arms spread (cm) Wrist breadth (cm)	-21.08 0.23 0.18 2.54	0.32
4.	Feint into the centre of the court T_6 (in points)	Intercept Ankle breadth (cm)	-7.77 1.73	0.18
5.	Serve straight T_7 (in points)	Intercept Biacromial breadth/pelvis breadth (%) Bone muscle rate of the cross sectional area of thigh/total cross sectional area of thigh	-16.75 0.10 10.62	0.22

Table 16
Basic statistics of young female volleyballers' psychophysiological tests results (n=32).

No	Variable n=32	$\bar{x}$	SD	Min	Max
1.	Average score of first- time speed perception tests (in points) A_1	4.341	4.072	-8.000	10.000
2.	Average reaction time in first-time speed perception tests (sec) A_2	0.697	0.240	0.210	1.880
3.	Average score of second- time speed perception tests (in points) A_3	6.049	2.881	0.000	12.000
4.	Average reaction time in second-time speed perception tests (sec) A_4	0.691	0.160	0.500	1.270
5.	Average score of third- time speed perception tests (in points) A_5	2.878	2.685	-2.000	12.000
6.	Average reaction time in third-time speed perception tests (sec) A_6	0.790	0.142	0.580	1.440
7.	Average reaction time in first-time auditory perception tests (right hand) (sec) B_1	0.235	0.064	0.169	0.447
8	Average reaction time in first-time auditory perception tests (left hand) (sec) B_2	0.229	0.061	0.175	0.452
9.	Average reaction time in second-time auditory perception tests (right hand) (sec) B_3	0.209	0.053	0.119	0.387
10.	Average reaction time in second-time auditory perception tests (left hand) (sec) B_4	0.213	0.057	0.125	0.429
11.	Average reaction time in third-time auditory perception tests (right hand) (sec) B_5	0.216	0.043	0.160	0.368
12.	Average reaction time in third-time auditory perception tests (left hand) (sec) B_6	0.212	0.047	0.110	0.374
13.	Average reaction time in first-time visual perception tests (right hand) (sec) C_1	0.199	0.060	0.129	0.364
14.	Average reaction time in first-time visual perception tests (left hand) (sec) C_2	0.200	0.060	0.121	0.369
15.	Average reaction time in second-time visual perception tests (right hand) (sec) C_3	0.200	0.076	0.101	0.495
16.	Average reaction time in second-time visual perception tests (left hand) (sec) C_4	0.197	0.078	0.069	0.501
17.	Average reaction time in third-time visual perception tests (right hand) (sec) C_5	0.197	0.050	0.107	0.326
18.	Average reaction time in third-time visual perception tests (left hand) (sec) C_6	0.197	0.048	0.100	0.319
19.	Anticipatory reflection of reality, first attempt (sec) D_1	0.494	0.228	0.002	1.541
20.	Anticipatory reflection of reality, second attempt (sec) D_2	0.483	0.182	0.103	1.059
21.	Anticipatory reflection of reality, third attempt (sec) D_3	0.586	0.155	0.281	1.237

Table 17

Statistically significant correlation coefficients between psychophysiological tests and basic anthropometric measurements in young female volleyballers (n=32, α=0,05).

No	Variable	Psychophysiological tests											
		A1	A2	A3	A4	B5	B6	C3	C4	C5	C6	D1	D2
2.	Weight (kg)			-0,319				-0,368					
5.	Xiphoidal height (cm)							-0,402	-0,42				0,318
6.	Head-neck length (cm)	0,351		-0,321									
7.	Sternum length (cm)							0,43	0,381				
8.	Abdomen length (cm)		0,405		0,447	0,364	0,3					0,414	0,383
9.	Trunk length (cm)		0,438		0,439	0,444						0,44	0,334
12.	Upper limb length (cm)												0,367
15.	Biacromial breadth (cm)												0,33
16.	Chest breadth (cm)				0,332								0,392
17.	Waist breadth (cm)				0,333								0,363
19.	Chest depth (cm)			-0,357									
20.	Abdomen depth (cm)			-0,373				-0,399					
21.	Femur breadth (cm)			-0,353				-0,511	-0,521	-0,41	-0,409		0,434
22.	Ankle breadth (cm)			-0,342									
23.	Humerus breadth (cm)							-0,472	-0,495				
27.	Upper chest circumf. (cm)							-0,368					
31.	Hip circumference (cm)			-0,369									
32.	Upper thigh circumf. (cm)			-0,354				-0,388					
34.	Upper leg circumf. (cm)			-0,381									
35.	Lower leg circumf. (cm)			-0,314									
36.	Arm circumf. (cm)			-0,379									
37.	Arm circumf. flexed and tensed (cm)			-0,362				-0,364					

38.	Forearm circumf. (cm)							-0,352					
39.	Wrist circumf. (cm)			-0,312									
45.	Umbilical skinfold (cm)			-0,322									
46.	Subscapular skinfold (cm)												0,334
48.	Triceps skinfold (cm)			-0,396									

Tests $A_{5,}$ A_6, B_1, B_2, C_1, C_2 and D_3 had no significant correlations with any anthropometric measurements.

Table 18.

Statistically significant correlation coefficients between psychophysiological tests and indices and body composition characteristics in young female volleyballers (n=32, α=0,05).

	Variable	Psychophysiological tests														
		A2	A3	A4	A5	A6	B1	B2	B5	B6	C2	C3	C4	D1	D2	D3
52.	Body mass index		-0,313													
53.	Body surface area		-0,313									-0,364				
54.	Relat. trunk length (%)	0,451		0,432					0,433	0,384				0,453		
55.	Relat. abdomen length (%)	0,39		0,426					0,331						0,338	
56.	Relat. upper body length (%)						0,339	0,377								
57.	Relat.lower body length (%)						-0,339	-0,377								
58.	Relat. upper limb length (%)														0,361	
59.	Relat. lower limb length (%)			-0,334												
61.	Relat. biacromial breadth (%)										0,38					
63.	Relat. waist breadth (%)			0,319												
67.	Relat. femur breadth (%)											-0,452	-0,442		0,367	
69.	Relat. humerus breadth (%)											-0,394	-0,393			
70.	Relat. wrist breadth (%)					0,331										0,387
76.	Relat. hip circumf. (%)		-0,327		-0,343											
77.	Relat. upper thigh circumf. (%)		-0,332													
78.	Relat. upper leg circumf. (%)		-0,346		-0,314											
79.	Relat. arm circumf. (%)		-0,348													
81.	Relat. wrist circumf. (%)					0,331										
82.	Arm circumf/upper limb length (%)	0,332												-0,323		

83.	Forearm circumf./upper limb length (%)				-0,335											
84.	Wrist circumf./upper limb length (%)				-0,308				-0,338							
86.	Wrist breadth/upper limb length (%)								-0,325							
90.	Lower leg circumf./lower limb length (%)			0,405											0,343	
91.	Femur breadth/lower limb length (%)			0,371											0,362	
100.	Trunk length/upper chest circumf. (%)	0,516		0,348					0,401	0,311				0,515		
104.	Mass of subcut. adipose tissue (kg)		-0,309													
106.	Total cross-sectional area of arm (cm²)		-0,382													
107.	Total cross-sectional area of thigh (cm²)		-0,35									-0,387				
108.	Bone muscle rate of the cross-sectional area of arm (cm²)		0,317													
109.	Fat rate of the cross-sectional area of arm (cm²)		-0,384													
110.	Bone muscle rate of the cross-sectional area of thigh (cm²)		-0,312													
111.	Fat rate of the cross-sectional area of thigh (cm²)		-3,284													

Tests A_1, $B_{3,}$ B_4, C_1, C_5, C_6 had no significant correlations with any basic anthropometric measurements

Table 19

Linear models for young female volleyballers' psychophysiological tests results by basic anthropometric measurements, indices and body composition characteristics (n=32)

No	Predicted variable	Explanatory variables	Coefficients	R^2
1.	Average reaction time in first-time speed perception tests A_2 (sec)	Intercept Relat. trunk length (%) Arm circumference/upper limb length (%)	0.45 0.05 0.03	0.37
2.	Average reaction time in second-time speed perception tests A_4 (sec)	Intercept Relat. trunk length (%) Relat. waist breadth (%) Lower leg circumf./lower limb length (%) Trunk length/upper chest circumf. (%)	-2.09 -0.04 0.11 0.03 0.03	0.40
3.	Average reaction time in third-time auditory perception tests (right hand) B_5 (sec)	Intercept Relat. trunk length (%) Wrist circumf./upper limb length (%)	0.26 0.01 -0.01	0.34
4.	Average reaction time in second-time visual perception tests (right hand) C_3 (sec)	Intercept Sternum length (cm) Femur breadth (cm)	0.46 0.02 -0.06	0.43
5.	Anticipatory reflection of reality, second attempt D_2 (sec)	Intercept Relat. abdomen length (%) Relat. upper limb length (%)	-2.02 0.02 0.05	0.28

Table 20

Linear models for young female volleyballers' efficiency of performance different technical elements by anthropometric measurements and results of tests of physical, psychophysiological and volleyball technical abilities (n=32).

No	Predicted variable	Regression equations and coefficients of determination				
		Anthropometric basic measurements	Anthropometric indices and body composition characteristics	Physical ability tests	Volleyball technical skills tests	Psychophysiological properties
1.	Efficiency of serve	$-0.99-0.02X_2-$ $-0.03X_3+0.06X_5+$ $+0.09X_{36}$ $R^2=0.32$	$1.76-0.33X_{69}$ $R^2=0.17$	none	none	none
2.	Efficiency of reception	$3.36+0.03X_2-0.09X_5+$ $+0.08X_4+0.55X_{24}-$ $-0.02X_{27}-0.13X_{39}$ $R^2=0.50$	$0.23-1.84X_{64}+0.08X_{52}$ $R^2=0.33$	$2.10-0.0008PA_5+$ $+0.009PA_7-$ $-0.05PA_8$ $R^2=0.44$	$-0.24+0.01T_2+0.03T_6$ $R^2=0.39$	$0.76+0.03A_3-$ $-2.24B_6$ $R^2=0.39$
3.	Efficiency of block	$-3.48+0.07X_2+$ $+0.06X_3-0.16X_{32}$ $R^2=0.80$	$2.09-0.48X_{64}+0.13X_{73}$ $R^2=0.65$	none	none	$0.79+0.15A_3+$ $+0.08A_5-12.27B_3+$ $+4.94B_6$ $R^2=0.98$
4.	Efficiency of feint	$-3.22-0.05X_2-$ $-0.06X_3+0.11X_5-$ $-0.07X_{29}+0.03X_{31}+$ $+0.19X_{36}$ $R^2=0.83$	$8.80-0.25X_{62}-3.03X_{51}-$ $-0.10X_{99}-0.22X_{63}-$ $0.15X_{71}+0.22X_{79}+$ $+0.01X_{97}$ $R^2=0.93$	$0.34+0.0009PA_5$ $R^2=0.18$	$0.20+0.09T_8$ $R^2=0.44$	$1.33+0.04A_5-3.74B_6$ $R^2=0.60$
5.	Efficiency of attack	$6.44+0.05X_2-0.03X_3-$ $-0.04X_{28}+0.12X_{35}-$ $-0.12X_{37}$ $R^2=0.71$	$1.26+0.06X_{78}-0.06X_{71}$ $R^2=0.41$	$0.06+0.002PA_9$ $R^2=0.22$	none	$1.07+1.61A_6-$ $-7.27B_4-0.68D_2$ $R^2=0.80$

Explonatory variables of models:

X_2 – Weight (kg)
X_3 – Height (cm)
X_4 – Suprasternal height (cm)
X_5 – Xiphoidal height (cm)
X_{24} – Wrist breadth (cm)
X_{29} – Waist circumference (cm)
X_{27} - Upper chest circumference (cm)
X_{28} – Lower chest circumference (cm)
X_{31} – Hip circumference (cm)
X_{32}– Upper thigh circumference (cm)
X_{35} – Lower leg circumference (cm)
X_{36} – Arm circumference (cm)
X_{37} – Arm circumference flexed and tensed (cm)
X_{39} – Wrist circumference (cm)
X_{51} – Rohrer index
X_{52} – Body mass index
X_{62} – Relat. chest breadth (%)
X_{63}- Relat. Waist breadth (%)
X_{64} – Relat. pelvis breadth (%)
X_{69} – Relat. humerus breadth (%)
X_{71} – Relat. head circumference (%)
X_{73} – Relat. lower chest circumference (%)
X_{78} – Relat. upper leg circumference (%)
X_{79} – Relat. arm circumference (%)
X_{97} – Biacromial breadth/pelvis breadth (%)
X_{99} - Biacromial breadth/upper chest circumference (%)
PA_5 – Endurance shuttle run test (sec)
PA_7 – Flexibility test (sit and reach) (cm)
PA_8 – Speed test (shuttle run) (sec)
PA_9 – Medicine ball throwing test (cm)
A_3 – Average score of second-time speed perception tests (in points)
A_5 – Average score of third-time speed perception tests (in points)
A_6 – Average reaction time in third-time speed perception tests (sec)
B_3 – Average reaction time in second-time auditory perception tests (right hand) (sec)
B_4 – Average reaction time in second-time auditory perception tests (left hand) (sec)
B_6 – Average reaction time in third-time auditory perception tests (left hand) (sec)
D_2 - Anticipatory reflection of reality second attempt (sec)
T_2 – Overhead pass with squat (in points)
T_6 – Feint into the centre of the court (in points)
T_8 – Serve diagonally (in points)

Table 21

Adolescent female volleyballer's (aged 13 - 15 years, n = 74) proficiency in the game according to body build.

No	Variable	Body build classes															
		Total			Class I (small) n=10				Class II (medium) n=18				Class III (large) n=12				Statistically significant differences between classes
		n	$\bar{x}$	total	n	$\bar{x}$	total	%	n	$\bar{x}$	total	%	n	$\bar{x}$	total		
1.	Points scored	55	33.15	1823.0	3	31.0	93.0	5.10	13	32.23	419.0	22.98	12	54.08	64.90	35.60	1+4,2+4,3+4.1+5, 3+5
2.	Serves Point-winning serves	50	7.48	374.0	3	10.33	31.0	8.29	12	7.83	94.0	25.13	12	8.50	102.0	27.27	1+4,2+4,3+4,1+5
	Total serves	50	50.38	2519.0	3	56.00	168.0	6.67	12	53.17	638.0	25.33	12	55.17	662.0	26.28	1+4, 2+4, 3+4, 1+5, 4+5
3.	Receptions Total	41	52.12	2137.0	1	26.00	26.0	1.22	11	58.91	648.0.	30.32	11	52.64	579.0	27.09	1+4, 2+4,1+5,2+5, 3+5, 4+5
4.	Attacks Point-winning attacks	27	37.30	1007.0	1	47.00	47.00	4.67	7	30.0	210.0	20.85	10	41.90	419.0	41.61	1+4, 2+4, 3+4, 2+5, 3+5
	Total of attacks	27	87.07	2351.0	1	99.0	99.0	4.21	7	76.29	534.0	22.71	10	92.70	927.0	39.43	1+4, 2+4, 3+4, 1+5, 2+5, 3+5
5.	Blocks Point-winning blocks	29	7.66	222.0	1	0.00	0.00	0.00	8	6.00	48.0	21.62	10	10.70	107.0	48.20	1+4, 2+4, 3+4, 1+5, 3+5
	Total of blocks	29	26.52	769.0	1	13.00	13.00	1.69	8	18.38	147.0	19.12	10	35.20	352.0	45.77	1+4, 2+4, 3+4, 1+5, 3+5
6.	Index of proficiency serve	50	0.44		3	0.47			12	0.46			12	0.42			-
	reception	41	0.52		1	0.59			11	0.53			11	0.52			-
	attack	27	0.64		1	0.70			7	0.62			10	0.64			-
	block	29	0.52		1	0.32			8	0.53			10	0.54			-

No	Variable	Body build classes								
		Class IV (pyknomorphs) n=16				Class V (leptomorphs) n=18				Statistically significant differences between classes
		n	$\bar{x}$	total	%	n	$\bar{x}$	total	%	
	Points scored	12	25.83	310.0	17.0	15	23.47	352.0	19.31	1+4, 2+4, 3+4, 1+5, 3+5
	Serves Point-winning serves	10	7.16	71.0	18.98	13	5.85	76.0	20.32	1+4, 2+4, 3+4, 1+5
	Total serves	10	44.9	449.0	17.82	13	46.31	602.0	23.90	1+4, 2+4, 3+4, 1+5, 4+5
	Receptions Total	10	53.7	537.0	25.13	8	43.38	347.0	16.24	1+4, 2+4, 1+5, 2+5, 3+5, 4+5
	Attacks Point-winning attacks	4	38.75	155.0	15.35	5	35.20	176.0	17.48	1+4, 2+4, 3+4, 2+5, 3+5
	Total of attacks	4	89.50	358.0	15.23	5	86.60	433.0	18.42	1+4, 2+4, 3+4, 1+5, 2+5, 3+5
	Blocks Point-winning blocks	5	4.40	22.0	9.91	5	9.0	45.0	20.27	1+4, 2+4, 3+4, 1+5, 3+5
	Total of blocks	5	20.60	103.0	13.39	5	30.80	154.0	20.03	1+4, 2+4, 3+4, 1+5, 3+5
	Index of proficiency serve	10	0.44			13	0.41			-
	reception	10	0.50			8	0.52			-
	attack	4	0.65			5	0.62			-
	block	5	0.49			5	0.53			-

PUBLICATIONS

Dependence of young female volleyballers' performance on their body build, physical abilities, and psycho-physiological properties

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Aim. **The aim of the study was to establish which anthropometric characteristics, physical abilities and psycho-physiological properties determine the success of adolescent female volleyballers at competitions.**
Methods. **For this purpose we studied 32 female volleyballers aged 13-16 years. The anthropometric examination included 43 measurements, 7 tests of physical fitness, and 4 series of computerised psycho-physiological tests (n=21). The performance of game elements was measured empirically during championship games using the original computer program "Game".**
Results. **The proficiency of performing volleyball elements — serve, reception, feint, block and spike — was calculated by regression models from the 14 anthropometric measurements, 4 physical fitness and 7 psychophysiological test results, which showed significant correlation with proficiency in the game. The predictive power of the models was at least 32% and in average 56%. The anthropometric factor was significant in the performance of all the elements of the game, being most essential (71-83%) for attack, block and feint. Good results in physical ability tests granted success in serve, attack and reception.**
Conclusion. **It was possible to predict the efficiency of reception (44%) by endurance, flexibility and speed measuring tests. Medicine ball throwing test was essential for attack (22%). Psycho-physiological tests were significant for the performance of block (98%), attack (80%), feint (60%) and reception (39%).**

KEY WORDS: Volleyball - Female - Anthropometry - Physical fitness - Psycho-physiology - Neuropsychological tests.

The paper has been presented at the following conferences:
1) Raini Stamm, Meelis Stamm, Kaivo Thomson. Prediction of volleyballers' performance on the basis of their physical fitness, anthropometry, technical skills and psychophysiological properties. Proceedings of the 3rd International Scientific Congress of Modern Olympic Sport. Warszawa 1999.p.192-3.
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A number of authors have studied the body build, physical fitness, ability profile and motor skills of adult volleyballers.[1-3] A great amount of papers on volleyball have compared the players of elite teams with adult players performing at lower levels. The physical abilities of the latter have been found to be lower; they are smaller, and their motor skills are lower than those of elite players.[4-6] Fewer studies have been carried out on adolescent volleyballers.[7, 8] Only very few authors have paid attention to the players' psychophysiological properties [9] and have tried to assess them in combination with anthropometric measurements and technical skills.[10] In the literature we have not found any studies recording the technical abilities of players in competition situation and analysing their anthropometric dimensions, physical fitness and psychophysiological properties on this basis. Neither is there any clarity in the literature which characteristics should be used in volleyball research. Thus, Malina [7] has studied mainly height and weight, Häkkinen [4] has analysed weight and proximal, mean and distal thigh circumferences, Thissen-Milder and Mayhew,[5] Smith *et al.*[6] and Häkkinen [4] have assessed the total mass of adipose tissue by means of skinfolds. As yet, there is no clarity about the significance of other anthropometric characteristics and the relations between separate anthropometric variables and the structure of the body as a whole.

Therefore, the aim of the present study was to analyse the role of a possibly great amount of anthropometric characteristics, physical abilities and psychophysiological properties in the success of female volleyballers of the up to 16-year age group at competitions.

Materials and methods

Subjects

The sample consisted of 32 female volleyball players aged 13-16 years (average age 14.61). All of them practised volleyball regularly and participated in young female volleyballers' championships in the age group of up to 16-year-olds. The players were informed about the essence of the studies planned, and they as well as their parents consented to voluntary testing. The study was approved by the Medical Ethics Committee of the University of Tartu.

The players were studied in teams (n=6). The anthropometric measuring as well as the testing of physical abilities and psychophysiological properties of a team were carried out at 1 and the same session. The same researchers participated in examining all the teams.

Variables and measurement procedures

Anthropometric research

The girls were healthy, and their sexual development corresponded to Tanner's [11] stages III-IV. The methodology of the anthropometric study relied on the long-term research carried out on many populations at the Centre for Physical Anthropology, University of Tartu.[12-16]

Anthropometric measurements were taken by a trained anthropometrist, who had previously shown test-retest reliability of $r>0.90$.

The girls were measured according to the classical method of Martin.[17] For measuring the skinfolds, the methodology provided in Knussmann's handbook [17] was followed. To measure lower extremity length, we applied the method of K. S. Jatsuta [18] that has been widely accepted in Russia and has been the principal method used in Estonia since J. Aul's work.[19]

Body height was measured in centimeters (±0.1 cm) using a Martin metal anthropometer and body weight in kilograms (±0.05 kg) on medical scales. Depth and breadth measurements were measured with Martin calipers, circumferences with a metal measuring tape, skinfolds with Holtain skinfold calipers. A total of 43 body measurements, including 11 skinfolds, were taken.

To determine length measurements (n=10), body stature and the height from the ground of a number of classical anthropometrical points (suprasternale, processus xiphoideus, symphysion, spina iliaca anterior superior, acromion, dactylion) were measured with an anthropometer. From the differences between the heights of these points the following projected segment lengths were calculated: sternum length (the difference between suprasternal height and xiphoidal height); abdomen length (the difference between xiphoidal height and symphyseal height); upper limb length (the difference between acromial height and dactylion height). Lower limb length was calculated by the method of K. Jatsuta,[18] where half of the difference between iliospinal height and symphyseal height is added to symphyseal height.

The breadth-depth measurements taken (n=6) were biacromial, chest, waist and pelvic breadths, chest and abdomen depths. To assess the thickness of limb bones, femur, ankle, humerus and wrist breadth were measured. The circumferences measured (n=15) included head, neck, upper and lower chest, waist, pelvis, hip, proximal and mid-thigh, upper and lower leg, forearm and wrist, arm relaxed and arm flexed and tensed. The measured skinfolds (n=11) were chin, chest, side, abdominal, subscapular, triceps, biceps, waist, suprailical, thigh and calf.

In addition to the anthropometric data of the 32 adolescent female volleyballers the same variables of anthropometric measurements (n=43) of ordinary schoolgirls (n=586) of the same age were used for comparison. These schoolgirls had not practised volleyball.

Physical fitness tests

All the subjects passed the following 7 validated tests of physical fitness. Jumping ability was measured by 2 vertical jump performance tests:[20] standing vertical jump and reach (PA_1) and running vertical jump and reach (PA_2). Maximum aerobic endurance was measured by 20 m shuttle run (PA_3). The reliability and validity of this test have been checked by Leger *et al.*[21] Trunk strength (PA_4) was measured using a sit-up test by Brewer and Davis.[22] The flexibility test (PA_5) measured the extent of bending forward from sitting position.[23] Deftness and speed of movement was measured by a zigzag run test (PA_6).[24] Upper body and arms strength were measured by the medicine ball throwing test (PA_7).[25]

Psycho-physiological tests

The girls' psycho-physiological abilities were assessed by the following 4 kinds of computerised tests (n=21).

1) Perception of the speed of a moving object. In 3 series the subject had to assess the speed of an object moving on the computer screen (8 attempts in each series). Based on this, the program calculated the average value of speed assessment correctness in points, separately for each series (A_1, A_3, A_5), and the average time needed for assessment in seconds (A_2, A_4, A_6). The test result was the better the more points the subject achieved and the less time was needed for giving the assessment.

2) Auditory reaction was studied by 3 different stimuli (8 attempts for each stimulus). The reaction time was recorded separately for the right and the left hand. The program calculated the average reaction time for the right (B_1-B_3) and the left hand (B_4-B_6).

3) Visual reaction was also studied by 3 different stimuli (8 attempts for each stimulus), separately with the right and the left hand. The program calculated the average visual reaction time for the right (C_1-C_3) and the left hand (C_4-C_6).

4) If auditory and visual tests were viewed as simple reactions, the speed perception test was evaluated as a complex reaction. Here the subjects had to assess objects moving at different speeds, adopt a decision and react only after that. Therefore, in order to compare individually the speed of processing different information, we calculated the difference in seconds between complex reaction time (A2, A4, A6) and perception time of visual stimuli as a simple reaction (C_1-C_6).

The respective test was called the test of anticipatory reflection of reality (D_1-D_3), and its results were calculated in the following way:

$$D_1=A_2-\frac{C1+C2}{2};\ D_2=A_4-\frac{C3+C4}{2};\ D_3=\frac{C5+C6}{2}.$$

The methodology of psychophysiological tests for volleyballers was mostly based on the well-substantiated methodologies of Kioumountzoglou *et al.*[9] and Hascelik *et al.*[10] The apparatus used by us for psychophysiological studies had been patented in Moscow on 8 June 1992 (no. 1766372)[26] and accepted for use by the 9th World Congress of Sport Psychology in Israel in 1997.[26]

Players' proficiency

To assess the players' proficiency at competitions, an original volleyball recording program, Game, devised by the authors was used .[28] This program has been applied by the Estonian Volleyball Federation and has been introduced in the journal of the American Volleyball Federation.[29]

The results were recorded at Estonian Championship and Cup matches for up to 16-year-olds, in which the 32 players under study participated.

All the girls played in the teams where they practice. The games were recorded within 3 months in

TABLE I.—*Means and standard deviations of anthropometric data in age groups (n=32) and their average z-scores compared with national*

No. Variable	$\bar{X}$	SD	13 years (n=5)		14 years (n=9)		15 years (n=10)		16 years (n=8)	
			$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
1. Weight (kg)	56.778	9.504	56.930	17.132	51.76	6.69	58.28	4.57	60.45	10.16
2. Height (cm)	167.23	6.09	165.46	8.57	164.20	4.89	168.03	5.55	170.74	1.15
3. Xiphoidal height	121.38	5.26	121.36	7.33	118.72	4.73	121.95	5.08	123.69	4.19
4. Suprasternal height (cm)	136.24	5.36	135.30	8.37	133.68	4.59	136.60	5.28	139.25	4.59
5. Upper chest circumf. (cm)	81.33	5.32	82.52	9.75	78.84	3.72	81.94	3.97	82.63	4.84
6. Lower chest circumf. (cm)	73.94	5.70	73.86	10.07	71.70	3.90	74.65	3.83	75.61	6.29
7. Waist circumf. (cm)	67.41	4.98	68.42	10.31	65.73	2.71	67.44	2.90	68.64	4.87
8. Hip circumf. (cm)	86.30	7.21	85.74	13.15	82.30	6.96	88.70	3.04	88.15	5.62
9. Arm circumf. relaxed (cm)	24.93	2.40	24.42	4.31	23.83	1.36	25.67	1.61	25.56	2.55
10. Arm circumf. flexed and tensed (cm)	26.94	2.59	26.60	4.79	25.94	1.50	27.57	1.68	27.48	2.86
11. Wrist circumf. (cm)	15.91	0.98	15.76	2.03	15.69	0.78	15.92	0.66	16.25	0.68
12. Upper thigh circumf. (cm)	55.88	5.50	55.28	10.41	52.82	4.11	56.83	2.11	58.50	5.08
13. Lower leg circumf. (cm)	22.26	1.61	21.96	2.83	21.64	1.40	22.54	1.24	22.80	1.30
14. Wrist breadth (cm)	5.12	0.26	4.94	0.35	5.14	0.30	5.12	0.22	5.21	0.20

different cities of Estonia where the matches took place. All the players were assessed on the basis of at least 4 matches. Technically, the assessment of players' proficiency proceeded as follows: during the game a recording assistant (a volleyball expert) fixed the performance of each technical element by each player of one team by pressing, according to the program, 3 keys on the computer keyboard. This enabled us to record: 1) the element of the game that was performed; 2) grade for its performance on a 5-point scale (1 — excellent ... 5 — failed); 3) the number of the player who performed the element.

Each player's proficiency in all the elements they performed was calculated after the following formula:

$$\text{Index of proficiency} = \frac{\text{no. of performances} \times \text{maximum grade-sum of grade}}{(\text{maximum grade-1}) \times \text{no. of performances}}.$$

Proficiency can range from 0 to 1, where 1 means that in all the cases the element was performed excellently, and 0 — a failure in all the cases.

Statistical analysis

The data were processed using the SAS-system. Anthropometric data were first submitted to primary statistical analysis where their $\bar{x}$, SD, minimum and maximum values were computed in age classes and the correlation of anthropometric characteristics to age was found. The anthropometric data of the adolescent female volleyballers were also compared with the same characteristics of schoolgirls who did not practise volleyball (n=586). The volleyballers' data were expressed on the scale of z-scores of ordinary girls of the same age.

Thereafter the anthropometric variables were correlated between themselves and, together with the players' age and degree of maturity, they were correlated with different elements of proficiency in the game.

All the results of physical fitness and psychophysiological properties tests were also correlated with the indicators of proficiency in the game.

For predicting the proficiency of different elements of the game, by means of stepwise procedure, the best models of linear regression were calculated from the anthropometric variables and test results in significant correlation with proficiency in the game. To assess the independent impact of anthropometric variables and test results on game proficiency, separate models were formed from anthropometric characteristics and results of physical abilities' and psychophysiological tests.

Results

Players' proficiency

The present study attempted to link the analysis of proficiency in game with the players' individual anthropometric characteristics and test results. The mean index of proficiency at serve was 0.545 (SD=0.279), *average values of the same age (n=586).*

Statistical connection with age r	Values of z-scores				Statistical significant difference *versus* control group
	$\bar{X}$	SD	Min	Max	
0.27	0.28	1.07	–1.19	3.05	—
0.13	0.45	0.94	–1.29	2.48	p<0.05
0.27	0.26	1.03	–1.97	2.31	—
0.23	0.34	0.99	–1.28	2.33	—
0.44	–0.09	0.96	–1.31	2.70	—
0.54	–0.33	1.05	–1.93	2.41	—
0.65	0.11	0.92	–1.20	3.16	—
0.22	–0.71	1.09	–3.93	1.80	p<0.05
0.32	0.05	0.91	–1.74	2.14	—
0.52	0.33	1.02	–1.49	2.90	—
0.69	0.85	1.11	–1.50	3.67	p<0.05
0.18	0.39	1.08	–1.70	2.72	p<0.05
0.46	—	—	—	—	—
0.35	0.18	1.00	–1.76	2.28	—

at reception 0.513 (SD=0.183), at feint 0.657 (SD=0.246), at block 0.523 (SD=0.360), and at attack 0.563 (SD=0.226). The mean value of the proficiency index was 0.539 (SD=0.161).

Results of anthropometric research

There were 14 anthropometric variables that correlated significantly with game proficiency. A list of these characteristics with their values in different age groups is presented in Table I. As could be expected, the values of these variables depended significantly on age. Proficiency in game, however, did not reveal any significant correlation with age or maturation.

The anthropometric variables correlating with game proficiency were intercorrelated. All the variables were found to be in statistically significant mutual correlation. The characteristics that showed the strongest correlations with other variables were height and weight. The variables correlating with game proficiency were compared with the same variables in the control group, which consisted of schoolgirls (n=586) who did not practise volleyball.

The volleyballers' data were expressed on the scale of z-scores of ordinary girls of the same age (Table I). As the table shows, the average z-scores of volleyballers' anthropometric measurements differed considerably from the average z-score of the control group (which is 0) in 4 cases: height, wrist circumference and proximal thigh circumference were larger; hip circumference was smaller.

The anthropometric regression models used for predicting game proficiency are presented in Tables II, III. Here we can see that bodily characteristics are important for all the main elements of the game, determining the efficiency of their performance within 32-83%.

As weight and height are the most often used anthropometric variables, we started compiling regressions from models relying only on height and weight. In our study, however, these models did not prove statistically significant for predicting the performance of any of the game elements. Then we added other body measurements that were also in significant correlation with the respective element of the game.

As far as the prediction of individual elements of the game from anthropometric data is concerned (Tables II, III), we can see that the efficiency of serve was explained by the anthropometric model for 32% if it included the positive values of xiphoidal height and relaxed arm circumference, and the negative values of weight and height.

The efficiency of reception was determined within 50% by 6 anthropometric variables. These were the positive values of body weight, suprasternal height and wrist breadth and the negative values of upper chest circumference, xiphoidal height and wrist circumference.

The efficiency of block was determined in 80% of cases by the positive values of height and weight and the negative value of upper thigh circumference.

With the greatest precision — within 83% — the anthropometric model determined the efficiency of feint. Six body measurements were essential in the model: the positive values of xiphoidal height, hip and arm circumference, and the negative values of weight, height and waist circumference.

The efficiency of attack (71%) also related significantly to body measurements. Weight and lower leg circumference had a positive value, and height, lower chest circumference and flexed and tensed arm circumferences a negative value.

Physical ability test results

Out of the 7 tests used in the study, 4 showed significant correlation with game proficiency (Table IV). These were endurance test (PA_3), flexibility test (PA_5), speed test (PA_6) and medicine ball throwing test (PA_7). The regression models formed from them to predict the efficiency in different ele-

TABLE II.—*The test models containing anthropometric measurements and results of tests of psychophysiological and physical abilities.*

No.	Predicted variable	Regression equations		
		Anthropometric models	Psychophysiological models	Physical ability models
1.	Efficiency of serve	$-0.99-0.02X_1-$ $-0.03X_2+0.06X_3+$ $+0.09X_9$ $R^2=0.32$	None	None
2.	Efficiency of reception	$3.36+0.03X_1-0.09X_3+$ $+0.08X_4+0.55X_{14}-$ $-0.02X_5-0.13X_{11}$ $R^2=0.50$	$0.76+0.03A_3-$ $-2.24B_6$ $R^2=0.39$	$2.10-0.0008PA_3+$ $+0.009PA_5-0.05PA_6$ $R^2=0.44$
3.	Efficiency of block	$-3.48+0.07X_1+$ $+0.06X_2-0.16X_{12}$ $R^2=0.80$	$0.79+0.15A_3+$ $+0.08A_5-12.27B_3+$ $+4.94B_6$ $R^2=0.98$	None
4.	Efficiency of feint	$-3.22-0.05X_1-$ $-0.06X_2+0.11X_3-$ $-0.07X_7+0.03X_8+$ $+0.19X_9$ $R^2=0.83$	$1.33+0.04A_5-3.74B_6$ $R^2=0.60$	$0.34+0.0009PA_3$ $R^2=0.18$
5.	Efficiency of attack	$6.44+0.05X^1-0.03X_2-$ $-0.04X_6+0.12X_{13}-$ $-0.12X_{10}$ $R^2=0.71$	$1.07+1.61A_6-$ $-7.27B_4-0.68D_2$ $R^2=0.80$	$0.06+0.002PA_7$ $R^2=0.22$

TABLE III.—*Exploratory variables of models.*

Variables	Description
X_1	Weight (kg)
X_2	Height (cm)
X_3	Xiphoidal height (cm)
X_4	Suprasternal height (cm)
X_5	Upper chest circumference (cm)
X_6	Lower chest circumference (cm)
X_7	Waist circumference (cm)
X_8	Hip circumference (cm)
X_9	Arm circumference relaxed (cm)
X_{10}	Arm circumference flexed and tensed (cm)
X_{11}	Wrist circumference (cm)
X_{12}	Upper thigh circumference (cm)
X_{13}	Lower leg circumference (cm)
X_{14}	Wrist breadth (cm)
A_3	Average score of 2nd-time speed perception tests (in points)
A_5	Average score of 3rd-time speed perception tests (in points)
A_6	Average reaction time in 3rd-time speed perception tests (sec)
B_3	Average reaction time in 2nd-time auditory perception tests (right hand) (sec)
B_4	Average reaction time in 2nd-time auditory perception tests (left hand) (sec)
B_6	Average reaction time in 3rd-time auditory perception tests (left hand) (sec)
D_2	Anticipatory reflection of reality 2nd attempt (sec)
PA_3	Endurance shuttle run test (sec)
PA_5	Flexibility test (sit and reach) (cm)
PA_6	Speed shuttle run test (sec)
PA_7	Medicine ball throwing test (cm)

ments of the game (Tables II, III, 39-98%) proved to be significant for 3 elements. Thus, reception depended (44%) on the players' flexibility (PA_5) speed (PA_6) and endurance (PA_3). The efficiency of attack was determined within 22% by arms and upper body strength (medicine ball throwing test, PA_7). The efficiency of feint was influenced by the results of the endurance test (PA_3), but the correlation was very weak (18%).

Psycho-physiological tests results

Out of the 21 psycho-physiological tests used in the study, 7 proved to be significant for proficiency in the game (Table V). They predicted the performance efficiency of 4 elements of the game within 39-98%. The only element not essentially determined by the results of these tests was serve.

Thus, the efficiency of reception depended on the average score in points for speed perception in the second series (A_3). Another test result that correlated with the efficiency of reception was reaction time in the auditory perception test (the 3rd series with the left hand, B_6).

The efficiency of block depended on the average score in points of the 2nd and the 3rd series of speed

TABLE IV.—*Physical ability tests significantly correlated with proficiency in the game.*

No.	Variable (n=32)	$\bar{X}$	SD	Min	Max	Partial corr. coeff. with efficiency of game elements		
						Reception r	Feint r	Attack r
1.	Endurance shuttle run test (sec) PA_3	386.34	86.71	135.00	515.00	-0.526	0.426	
2.	Flexibility test (sit and reach) (cm) PA_5	16.28	6.16	5.00	32.50	0.457		
3.	Speed shuttle run test (sec) PA_6	27.77	1.64	24.70	33.00	-0.587		
4.	Medicine ball throwing test (cm) PA_7	304.53	48.28	210.00	400.00			0.468

1) In the table the partial correlation coefficients are given, where the influence of other variables is eliminated. 2) All partial correlations are significant, $p<0,05$.

TABLE V.—*Psychophysiological tests significantly correlated with proficiences in the game.*

No.	Variable (n=32)	$\bar{X}$	SD	Min	Max	Partial corr. coeff. with efficiency of game elements			
						Reception r	Block r	Feint r	Attack r
1.	Average score of 2nd-time speed perception tests (in points) A_3	5.81	2.94	0	12.00	0.528	0.991		
2.	Average score of 3rd-time speed perception tests (in points) A_5	2.77	2.81	-2.00	12.00		0.986	0.566	
3.	Average reaction time in 3rd-time speed perception tests (sec) A_6	0.79	0.15	0.58	1.44				0.838
4.	Average reaction time in 2nd-time auditory perception tests (right hand) (sec) B_3	0.20	0.04	0.13	0.32		-0.973		
5.	Average reaction time in 2nd-time auditory perception tests (left hand) (sec) B_4	0.20	0.04	0.16	0.33				0.873
6.	Average reaction time in 3rd-time auditory perception tests (left hand) (sec) B_6	0.20	0.05	0.11	0.37	-0.532	0.878	-0.691	
7.	Anticipatory reflection of reality, 2nd attempt (sec) D_2	0.50	0.19	0.15	1.06				-0.633

1) In the table the partial correlation coefficients are given, where the influence of other variables is eliminated. 2) All partial correlations are significant, $p<0,05$.

perception tests (A_3, A_5) and the average reaction time in the 2nd series of the auditory perception test with the right hand (B_3) and the 3rd series of the auditory perception test with the left hand (B_6).

The efficiency of feint was the better the greater was the average score for the speed of moving object in points (in the 3rd series, A_5) and the shorter the average reaction time in the 3rd series of auditory perception tests (with the left hand, B_6).

The efficiency of attack was determined by the average reaction time in the 3rd series of speed perception tests (A_6), the 2nd series of auditory perception tests (with the left hand, B_4) and anticipatory reflection of reality (D_2).

Discussion

The results of our study indicated that, besides all other factors, the players' morphological constitution has an essential role in game proficiency. Correlating 43 body measurements with the index of proficiency in all the 5 main elements of the game, we found 14 body measurements that significantly correlated with proficiency in the game. These were height, weight, xiphoidal height, suprasternal height; the following trunk measurements: chest, waist and hip circumferences; the following limbs measurements: relaxed arm circumference, flexed and tensed arm circumference, upper thigh and lower leg circumference, wrist circumference and wrist breadth.

The regression models formed from these were essential for all the 5 elements of the game. So, the efficiency of serve (32%) was influenced by greater xiphoidal height and relaxed arm circumference. In the case of reception (50%) the essential measurements were greater weight, suprasternal height and wrist breadth.

Most proficient at the performance of block were the girls with big height and weight (80%). The measurements essential for feint (83%) were xiphoidal height, relaxed arm circumference and hip circumference. Success at attack (71%) was also supported by greater weight and greater lower leg circumference. Comparison of volleyballers with the girls of the control group (n=583) produced a similar result: volleyballers had significantly greater height, wrist circumference and upper thigh circumference.

Our results concerning the players' greater height and weight, the results of our study conformed to literature data.[7, 30] In addition, our data suggested that the bone and muscle strength of the extremities, necessary for successful performance in the game, could be revealed by the thickness of wrist and lower leg bones and by greater circumferences of the arm and the thigh.

We are of the opinion that one of the reasons why good anthropometric predictions of proficiency in the game can be obtained is that schoolchildren's body build (of the ages studied) forms a regular whole [12-14] where all the separate variables, height and weight are in statistically significant correlation. The existence of such a regular system means that all the separate significant variables do not represent only the girls' concrete body measurements, but they also represent the peculiarities of the body build as a whole. This shows the potential of the anthropometric method.

The girls' higher physical abilities were also conducive to the quality of performance. Out of the four tests of physical abilities, the efficiency of reception was determined within 44% by the players' greater flexibility and speed. The efficiency of attack (22%) was enhanced by greater strength of arms and upper body. The efficiency of feint correlated with better results in the endurance test (18%).

These results of our study were in full concordance with literature data on the qualities necessary for a successful volleyballer, such as greater speed and endurance, arms and upper body strength and sit and reach flexibility.[4, 5, 31-33]

Psycho-physiological tests proved to be surprisingly significant for game proficiency. They determined the efficiency of 4 game elements out of 5 within 39-98%. The only element for which they were not essential was serve as there is sufficient time for its performance, and the player is not dependent on the activity of other players.

On the other hand, success in psycho-physiological tests was most essential in the case of such elements as block (98%) and attack (80%) which, as a rule, are performed in the greatest deficit of time and need very quick reaction by the player and correct assessment of the ball's speed.

The efficiency of reception (39%) also depends on assessment of the direction and speed of the opponent's serve. Successful performance of feint (60%) also depends on the skill of anticipating the spiker's motions.

In the literature we could not find any data on using psycho-physiological tests for assessing adolescent female volleyballers performance. However, other studies have shown that elite male volleyballers essentially surpassed physical culture students of the same age in psychological tests of reaction speed,[9] and that an 8-week physical training period of a junior male volleyball team had a positive effect on their physical fitness, and their auditory and visual reaction times shortened.[3]

Conclusions

In summary, two conclusions might be drawn from our research. First, the anthropometric characteristics and tests of physical fitness and psycho-physiological properties that proved essential for volleyball proficiency could be included into the programs of testing adolescent female volleyballers. Second, we would get the best overview of adolescent female volleyballers abilities and performance if we used the game recording system devised by us together with testing, for example at the championship games, once a year.

Entering the data into a database that is being created would enable us to carry out regular complex longitudinal assessment of young players' performance.

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ОСОБЕННОСТИ ТЕЛОСЛОЖЕНИЯ У ЭСТОНСКИХ ДЕВУШЕК И ЮНОШЕЙ

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Конституциональный подход в современной биологии и медицине требует более детальных данных об антропометрической структуре тела, чтобы на основании ее систематизировать многомерную вариабельность антропометрических признаков.

Наряду с уже давно известными соматотипическими классификациями [3–6, 8–10, 14, 15, 18] ведутся поиски новых.

Данная статья дает краткий обзор результатов в этой области, полученных в ходе длительных исследований [11–13, 16, 17, 19, 20].

Материал и методика. Данная работа основана на антропометрических исследованиях 670 студенток Тартуского университета в возрасте от 18 до 22 лет, 1114 школьниц (15–18 лет) и 253 школьников (17–18 лет) тартуских средних школ. Для сравнения проведены измерения у 33 волейболистои 13–16 лет. У всех были измерены 36 параметров тела, 12 кожно-жировых складок и, на основании этих измерений, были вычислены 64 индекса и показателя состава тела.

Измерения выполняли в основном по методике Р. Мартина. Все данные обработаны статистически в Институте математической статистики ТУ при помощи системы SAS.

Результаты исследования и их обсуждение. В первую очередь были проанализированы данные молодых эстонских женщин-студенток. Корреляционный анализ показал, что здесь имеется система из сравнительно сильно коррелированных между собой признаков, где длина и масса тела имеют самые высокие корреляции с остальными признаками. Это дало основание предполагать, что длина и масса тела являются ведущими признаками этой системы. Такое предположение проверено при помощи анализа частных корреляций. После элиминирования линейного влияния длины и массы тела из всех коэффициентов корреляций между антропометрическими признаками 70% оказались статистически незначимыми. Факторный анализ также подтвердил ведущую роль массы и длины тела. Выяснилось, что в двух первых факторах, описывающих около 50% из общей вариабельности всех измеренных признаков, определяющими были именно длина и масса тела.

Выяснилось, что ни один другой признак, кроме массы и длины тела, не может дать столь существенного описания целостного телосложения.

Далее изучали поведение остальных признаков в зависимости от массы и длины тела. Оказалось, что практически все антропометрические признаки положительно коррелировали как с длиной, так и массой тела, при этом линейная зависимость существенна при уровне значимости 0,05. Двумерное распределение признаков (масса—длина тела, масса—остальные признаки, длина тела—остальные признаки) характеризовалось принципом относительного несоответствия, которое увеличивалось в сторону крайних вариантов и может служить основой для формирования там чистых соматотипов — пикнических и лептосомных женщин.

С целью исследования зависимости размеров тела одновременно от длины и массы тела (трехмерный анализ) образовали классификацию, пользуясь сигма-классами как длины, так и массы тела (5x5) (таблица), и нашли средние значения показателей исследуемых в каждом классе. Изменения в соотношениях массы и длины тела вели к системным изменениям всех

Классификация женщин по длине и массе тела

Ростовые классы				
I	II	III	IV	V
Очень низкий	Низкий	Средний	Высокий	Очень высокий
−2,5σ—−1,5σ	−1,5σ—−0,5σ	−0,5σ—+0,5σ	+0,5σ—+1,5σ	+1,5σ—+2,5σ
I_1	II_1	III_1	IV_1	V_1
I_2	II_2	III_2	IV_2	V_2
I_3	II_3	III_3	IV_3	V_3
I_4	II_4	III_4	IV_4	V_4
I_5	II_5	III_5	IV_5	V_5

Примечание. Весовые классы: 1-й — очень легкий (−2,5σ—−1,5σ); 2-й — легкий (−1,5σ—−0,5σ); 3-й — средний (−0,5σ—+0,5σ); 4-й — тяжелый (+0,5σ—+1,5σ); 5-й — очень тяжелый (+1,5σ—+2,5σ).

остальных признаков. Во всех ростовых классах (столбцах) при увеличении массы увеличивались постепенно все широтно-глубинные и обхватные размеры, а длиннотные размеры оставались без существенных изменений.

Наоборот, во всех весовых классах (рядах) по мере увеличения длины тела постепенно увеличивались все длиннотные размеры и уменьшались все широтно-глубинные и обхватные размеры.

Пропорциональность телосложения изучали при помощи 124 индексов в той же росто-весовой классификации. Выяснили закономерности в изменениях длиннотных, широтно-глубинных и обхватных размеров.

По классификации длины и массы тела можно было установить и систематические изменения в составе массы тела. Так, в одних и тех же ростовых классах в зависимости от увеличения массы увеличивалась постепенно и доля общего жира (%), уменьшалась плотность тела. И наоборот, в одних и тех же весовых классах, по мере увеличения длины тела, доля общего жира уменьшалась, а плотность тела увеличивалась. Наряду с изменениями в общем составе массы тела происходили и соответствующие изменения составных компонентов отдельных участков тела.

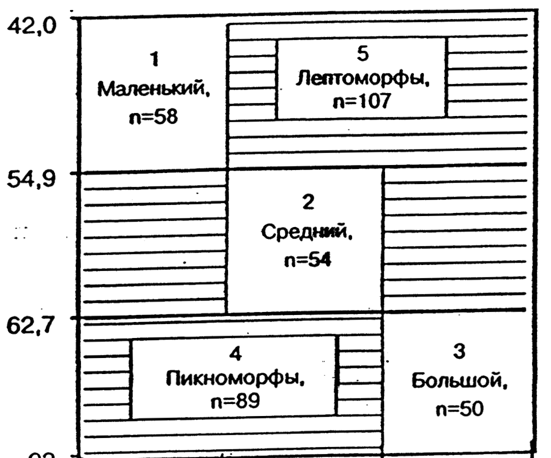
Ввиду тесной корреляционной структуры антропометрических признаков возможно методом множественного регрессивного анализа прогнозировать значение каждого признака по известным значениям остальных, притом R^2 варьирует от 0,5 до 0,83 (т. е. прогностическая сила модели не менее 50%).

Параллельно с общим контингентом женщин изучали особенности телосложения чистых пикнических (n=32) и лептосомных типов женщин (n=39), определенных соматоскопическим методом Кречмера. Выявлено, что структура пикников и лептосомов базируется на соответствующих соотношениях между массой и длиной тела, как это было в общем контингенте.

Таким образом, в общей многомерной вариабельности антропометрических признаков не существует дискретных групп отдельных соматотипов, а вся система размеров тела имеет общие тенденции варьирования, которые в краях вариабельного ряда ведут к формированию экстремальных вариантов — к чистым пикническим и лептосомным типам, как называет их Кречмер. Основой всех изменений являются соответствующие соотношения длины и массы тела.

При изучении структуры тела отдельных возрастных групп школьниц и школьников обнаружена такая же структура тела, что и при исследовании молодых женщин. В основу структуры тела легла система тесных связей антропометрических признаков, где опять ведущую роль играли масса и длина тела. Любой размер тела возможно прогнозировать по массе, длине и возрасту в пределах 20—70%. Для систематизации размеров тела юношей и девочек отдельных возрастных групп применяли упрощенный 5-классный вариант классификации по длине и массе тела [13, 16, 17], исходящий из 3×3 классификации (рисунок), где крайние сигма-классы объединены. Характеристика полученных классов следующая: 1-й — маленькие длина и масса тела, 2-й — средние длина и масса тела, 3-й — большие длина и масса тела. Классы 1—3 характеризуются соответствием массы и длины тела. Прибавляются два класса несоответствия: 4-й — большая масса, маленькая длина, 5-й — маленькая масса, большая длина. Последние классы названы классами пикноморфов и лептоморфов, поскольку основой для представителей этих классов являлось также несоответствие длины и массы тела, как это было у чистых пикнических и лептосомных женщин. Такая классификация оправдала себя и дала возможность систематизировать исследуемых с различным телосложением.

Похожая структура размеров тела выявилась также у школьниц-волейболисток в возрасте от 13 до 16 лет. Оказалось, что хотя эти девушки были немногим выше и больше их сверстниц, не занимающихся активно спортом, их размеры подчинялись тем же общим закономерностям. В случае подростков можно было прогнозировать все отдельные размеры тела на основании длины, массы тела и возраста в пределах 20—80%.



Классификация 17-летних девушек по росто-весовым классам.

По оси абсцисс — длина тела (см); по оси ординат — масса тела (кг). Объяснения в тексте.

Distribution of 17-year-old girls according to height-weight classes.

Abscissa — body length (cm); ordinate — body mass (kg). See text for explanations.

Это значит, что для изучения роли антропометрического фактора можно использовать широкий выбор различных размеров тела. Все они характеризуют одновременно и общее телосложение обследуемых.

Полученные результаты подтвердили точку зрения многих предыдущих исследователей о коррелятивных связях антропометрических признаков и об упорядоченности телосложения [1, 2, 7]. При помощи предложенных нами весо-ростовых классификаций возможно систематизировать одиночные признаки, индексы и показатели состава тела. В будущем аналогичным образом можно параллельно с антропометрическими данными изучать клинические, физиологические, биохимические показатели изучаемых контингентов.

Таким образом, создается первичная модель целостного телосложения и при помощи ее можно продолжать исследования конституциональных типов.

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REGULARITIES OF BODY BUILD STRUCTURE OF ESTONIAN GIRLS AND YOUTHS

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Anthropometric investigation of 670 female students (aged 18–22), 1114 schoolgirls (aged 15–18) and 253 schoolboys (aged 17–18) has demonstrated that the body structure in these samples formed a distinctive system of significantly intercorrelated variables with the body mass and length being the major characteristics. By means of a mass-length (height-weight) classification it is possible to systematize all the single parameters, indices and body composition characteristics. Body mass and length are also assumed as a basis for the formation of extreme pure somatotypes — pycnic and leptosomatic females.

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The Anthropometric Factor in Assessment of Physical Abilities of Young Female Volleyballers (aged 13–16)

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The study discusses the relations between the body build of 46 young female volleyballers (age 13–16 years, 51 characteristics including 11 skinfolds) and the results of nine physical ability tests. The tests included four jump tests, endurance, trunk strength, flexibility, speed and medicine ball throwing tests. Correlation of basic anthropometric characteristics with test results showed that all the tests except the trunk strength test and the flexibility test were to a greater or smaller extent related to body measurements. Body fat content had a negative impact on jump tests, and on endurance and speed tests. The endurance test correlated negatively with body measurements; smaller players had greater endurance. In regression analysis, to show the dependence of physical ability test results on body build, two models were used: 1) height, weight and age; 2) other anthropometric characteristics. The second model predicted the variability of tests results within 48–89%. In all cases the model of height, weight and age yielded somewhat less significant results. The tests results were placed in a 5 SD classification of weight and height. The classification showed that jumping ability improved gradually from the small to the medium to the big class; leptomorphs could jump higher than pycnomorphs. In speed tests leptomorphs were more successful than pycnomorphs.

Key Words: Anthropometry; Young female volleyballers; Physical ability tests.

Introduction

Volleyball belongs among the sport events which are primarily characterised by explosive movements (Viitasalo 1988; Heimer, Misigoj, Medved 1988; Häkkinen, Mero, Kauhanen 1999). Volleyballers' fundamental abilities include jumping

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skills, speed, upper body muscles explosive strength and endurance (Häkkinen 1989, 1993; Thissen-Milder, Mayhew 1991; Viitasalo, Rusko, Pajalo, Rahkile, Ahilo, Moutonen 1987; Young, MacDonald, Hegger, Fitzpatrick 1997). The level of motor abilities in volleyball is known to be influenced by peculiarities of body build (Thissen-Milder, Mayhew, 1991; Farkas, Mészarós, Mohácsi, Petrakanits, Batowski 1991). Unfortunately, the number of body dimensions studied in volleyball research has been very limited, being usually restricted to height, weight and body fat percentage. Practically no attention has been paid to the length of the extremities' and circumferences of the extremities and the trunk, which could be essential for proficiency in the game, particularly in the period of adolescence. The situation has been changing only in the recent years, and measurement of the full range of anthropometric characteristics in the adolescent period has been recommended in many sports, including volleyball (Avloniti, Douda, Pilianidis, Tokmakidis 2001).

In light of the above, the authors set themselves to conduct a detailed anthropometric study of young female volleyballers in order to find how the great number of adolescent female volleyballers' body measurements could be applied for assessment of physical ability tests results.

The authors proceeded from the results of their earlier studies of young female volleyballers' body structure. Thus, they had already established that the girls' whole body anthropometric structure consists of a regular system of bodily characteristics that are in statistically significant mutual correlation. The leading characteristics of the system are height and weight, which significantly determine the variability of all the other characteristics within 20–90%. Each basic anthropometric variable that belongs to this system represents not only a concrete body measurement but also essentially represents the body as a whole (Stamm R., Stamm M., Nurmekivi, Loko, Koskel 2000; Stamm R., Veldre, Stamm M., Kaarma, Koskel 2001; Kaarma, Veldre, Stamm, Lintsi, Kasmel, Maiste, Koskel 2001; Stamm R., Stamm M., Koskel 2002; Stamm R., Veldre, Stamm M., Thomson, Kaarma, Loko, Koskel 2003).

Proceeding from this basis, the authors analyse how basic anthropometric measurements, their different combinations and the height-weight classification that characterizes the body as a whole can be applied for comparative assessment of physical ability tests results.

Material and Methods

The sample consisted of 46 female volleyball players aged 13–16 years. All of them had practised volleyball regularly for the last three years and participated in young female volleyballers' championships in the age group of up to 16-year-olds.

The players were studied in six teams. The anthropometric measuring as well as the testing of physical abilities were carried out at one and the same session. The same researchers participated in examining all the teams.

The players were informed about the essence of the studies planned, and they as well as their parents consented to voluntary testing. The study was approved by the Medical Ethics Committee of the University of Tartu.

Measurement Procedures

Anthropometric Research

The girls were healthy, and their sexual development corresponded to Tanner's (Tanner 1962) stages III–IV. All anthropometric measurements were taken by the same trained anthropometrist, who had previously shown test-retest reliability of $r>0.90$. The girls were measured according to the classical method of Martin (Knussmann 1988). The measuring of skinfolds followed the methodology provided in Knussmann's handbook (Knussmann 1988, p. 274). To measure lower extremity length, we applied the method of K. S. Jatsuta (Jatsuta 1923) that has been widely accepted in Russia and has been the principal method used in Estonia since J. Aul's work (Aul 1977).

Forty-nine body measurements were taken, including 11 skinfolds. The skinfolds were also used to calculate the mass and relative mass of subcutaneous adipose tissue. Thus, in total, the analysis included 51 bodily characteristics.

The length measurements were body height, suprasternal height, xiphoidal height, head-neck length, sternum length, abdomen length, trunk length, upper body length, lower body length, upper limb length, lower limb length. In addition to these, horizontal arms spread was measured.

The breadth-depth measurements were biacromial, chest, waist and pelvis breadths, and chest and abdomen depths. To assess the thickness of limb bones, femur, ankle, humerus and wrist breadths were measured. The circumferences included head, neck, upper and lower chest, waist, pelvis, hip, proximal and mid-thigh, upper and lower leg, forearm and wrist, arm and arm flexed and tensed. The measured skinfolds were chin, chest, side, waist, suprailical, umbilical, subscapular, biceps, triceps, thigh and calf.

Physical Ability Tests

All the subjects passed the following nine validated tests of physical fitness. Jumping ability was measured by two vertical jump performance tests (Young, MacDonald, Hegger, Fitzpatrick 1997): standing vertical jump and reach (PA_1) and running vertical jump and reach (PA_2). As the highest reach of the players' outstretched hand had been measured, then subtracting from PA_1 the length of the outstretched arm, the height of standing vertical jump (PA_3) was obtained. By subtracting the length of the outstretched arm from PA_2, we obtained the height of running vertical jump (PA_4).

Maximum aerobic endurance was measured by 20 m shuttle run (PA_5) (Leger, Mercier, Gadoury, Lambert 1988). Trunk strength (PA_6) was measured by using the sit-up test (Brewer, Davis 1993). The flexibility test (PA_7) measured the extent of bending forward from sitting position (Larson 1974). Deftness and speed of movement (PA_8) were measured by the zigzag run test (Kuramshin, Persin, Popkovskii 1985). Upper body and arms strength were measured by the medicine ball throwing test (PA_9) (Viitasalo 1988).

Results

To start the analysis, we present the basic statistics of physical ability tests results (Table 1). We can observe a great variability of results, which is partly related to age.

To assess how the tests results depend on body build, we correlated all the physical ability tests one by one with all the anthropometric variables (Table 2). We can see that the highest jump and reach standing (PA_1) and running (PA_2), the highest reach of the player's outstretched hand and the medicine ball throwing test (PA_9) correlated with nearly all basic anthropometric characteristics except skinfolds.

The negative impact of greater body fat content was revealed in the height of standing (PA_3) and running (PA_4) vertical jump.

The greater value of skinfolds was contrary to jump height results. A similar negative impact of greater fat content was revealed in the results of the speed test (PA_8). The girls who showed longer times in the speed test also had thicker skinfolds. The endurance test (PA_5), however, revealed negative correlations with a great number of body measurements. This suggests that smaller players have greater endurance. Flexibility and stomach muscle tests showed practically no correlations with anthropometric variables.

As the results of seven out of nine physical ability tests used by us correlated with many anthropometric variables, we performed regression analysis to model the dependence of physical ability tests results on body build (Table 3). To predict tests results, we used two types of models. In the first case, the arguments used were height, weight and age, in the second case, all other anthropometric characteristics which showed statistically significant correlations with the test studied. In all the tests, age, height and weight gave somewhat less significant results than the best combination of other characteristics. By using the second model we could anthropometrically determine the variability of PA_1 within 89%, PA_2 – 78%, PA_3 – 61%, PA_4 – 42%, PA_5 – 42%, PA_8 – 63% and PA_9 – 65% (in the sense of determination coefficient).

The essential other basic anthropometric characteristics in the models were lower limb length, upper leg circumference, ankle breadth, arm circumference, biacromial breadth, upper chest circumference, horizontal arms spread. Relative mass of subcutaneous adipose tissue correlated negatively with tests results.

As the tests results correlated closely with body build, we systematised them using the same height-weight classification, which we had already used for systematizing the girls anthropometric data (Stamm R., Stamm M., Koskel 2002) (Table 4).

As we can see, the tests of highest jump and reach (PA_1, PA_2) and the highest reach of the player's outstretched hand could be well systematized into classes, showing that jumping ability gradually improved in classes small-medium-big, and leptomorphs could jump essentially higher than pycnomorphs. Consequently, the most capable in this test were girls with bigger height and weight but also tall and slender girls. The same trend was noticed in PA_9, but the differences were statistically insignificant. In the speed test leptomorphs were more successful than pycnomorphs.

Discussion

To assess the physical abilities of young female volleyballers we applied tests that literature has regarded most essential for volleyball: jump tests, medicine ball throwing test, speed, endurance, flexibility and stomach muscles strength tests.

According to our data as well as literature (Matsudo, Rivet, Pereira 1987; Viitasalo 1988) better jumping ability was typical of girls with greater height and weight. In addition, we showed that vertical jump and reach (PA_1, PA_2) and the highest reach of player's outstretched hand correlated with nearly all other anthropometric characteristics except a few skinfolds. There were very strong correlations with height, extremities length, horizontal arms spread, biacromial and pelvis breadth. Our data revealed that the variability of the highest reach of the player's outstretched hand was 35 cm 201–236 cm), which gives taller players considerable advantage at spike and block.

The results of other jump tests – standing vertical jump (PA_3) and running vertical jump (PA_4) – correlated negatively with skinfolds, confirming the views from literature that better jumping ability is inversely proportional to body fat percentage (Thissen-Milder and Mayhew 1991).

Besides jumping ability tests, another important test is that of upper body muscles' explosive strength (medicine ball throwing test, PA_9). This test is also essential for successful block and spike, and better results are achieved by players with greater height and weight (Morrow, Andrew, Jackson, Hosler, Kachwik 1979; Häkkinen 1989; Roberts, Watson 1992). In addition, we showed that the results of this test correlated with practically all anthropometric variables except a few skinfolds.

An essential ability component of volleyball is endurance (Viitasalo, Rusko, Pajalo, Rahkila, Ahilo, Montonen 1987; Smith, Roberts, Watson 1992; Bale, Mayhew, Piper, Ball, Willman 1992; Arbeit 1998; Wieczorek 2001). In our data, the endurance test (PA_5) showed significant negative correlations with all body measurements and skinfolds; the results were more significant in smaller and slimmer girls.

The speed test (PA_8) is especially significant for 12–15-year-old girls as this is the age when speed strength and speed of movements develop most rapidly (Kantola, Rusko 1984). In our study faster girls had lower body fat content, and, in this respect, our results coincided with those of other researchers (Malina, Shoup 1985; Raudsepp, Jürimäe 1996).

In conclusion, we might say that the close correlations we found between young female volleyballers' physical abilities and body build suggest that for this age group methods of detailed anthropometric measurements, in addition to height, weight and age, should be taken in order to permit a better assessment of young players' abilities and prospects in their chosen sport.

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Table 1

Basic statistics of young female volleyballers' physical ability tests results and their correlation with age ($n = 41$, $\bar{} = 0.05$)

No	*Variable*	$\bar{x}$	*SD*	*Min*	*Max*	*Statistically significant correlation with age (r)*
1	Test of highest jump and reach standing (PA_1) (cm)	252.98	10.01	237.00	275.00.	0.383
2	Test of highest jump and reach running (PA_2) (cm)	256.98	10.08	243.00	284.00	0.373
3	Highest reach of the players outstretched hand (cm)	217.20	8.25	201.00	236.00	0.370
4	Vertical jump height standing (PA_3) (cm)	35.78	4.14	27.00	46.00	-
5	Vertical jump height running (PA_4) (cm)	39.78	5.21	31.00	58.00	-
6	Endurance test (PA_5) (sec)	375.78	84.70	135.00	545.0	-
7	Stomach muscle strength test (PA_6) (sec)	169.68	59.56	85.00	300.0	-
8	Test of flexibility (PA_7) (cm)	16.63	6.53	4.00	32.50	-
9	Test of speed measuring (PA_8) (sec)	27.70	1.48	24.70	33.00	-
10	Medicine ball throwing test (PA_9) (cm)	300.37	44.35	210.00	400.0	-

Table 2

Statistically significant correlation coefficients between physical ability tests results and basic anthropometric variables of young female volleyballers (n=41, α = 0.05)

	Variables	x	SD	Age	Test of highest jump and reach standing (PA_1)	Test of highest jump and reach running (PA_2)	Highest reach of the players' outstretched hand	Vertical jump height standing (PA_3)	Vertical jump height running (PA_4)	Endurance test (PA_5)	Stomach muscle strength test (PA_6)	Test of flexibility (PA_7)	Test of speed measuring (PA_8)	Medicine ball throwing test (PA_9)
1	Weight (kg)	56.178	9.107	0.291	0.548	0.550	0.713	-	-	-0.473	-	-	-	0.517
2	Height (cm)	166.22	6.02	0.429	0.863	0.786	0.944	-	-	-0.343	-	-	-	-0.448
3	Suprasternal height (cm)	135.26	5.50	0.395	0.870	0.802	0.959	-	-	-0.311	-	-	-	0.456
4	Xiphoidal height (cm)	120.46	5.07	0.295	0.773	0.705	0.898	-	-	-0.334	-	-	-	0.498
5	Head-neck length (cm)	30.97	0.99	0.413	0.419	0.325	0.420	-	-	-0.355	-	-	-	-
6	Sternum length (cm)	14.79	1.87	0.363	0.507	0.491	0.440	0.350	-	-	-	-	-0.332	-
7	Abdomen length (cm)	35.44	5.37	-	-	-	-	-	-	-	-	-	-	-
8	Trunk length (cm)	50.23	5.52	-	0.320	0.328	0.435	-	-	-	-	-	-	-
9	Upper body length (cm)	66.55	5.4	-	-	-	-	-	-	-	-	-	-	-
10	Lower body length (cm)	99.27	7.25	-	0.588	0.515	-	-	-	-	-	-	-	-
11	Upper limb length (cm)	72.69	4.09	0.375	0.766	0.640	0.839	-	-	-	-	-	-	0.313
12	Lower limb length (cm)	87.6	5.62	-	0.713	0.625	0.738	-	-	-0.315	-	-	-	-

13	Horizontal arms spread (cm)	167.51	8.35	0.464	0.796	0.728	0.849	-	-	-	-	-	-	0.318
14	Biacromial breadth (cm)	35.33	1.62	0.319	0.620	0.625	0.696	-	-	-	-	-	-	0.557
15	Chest breadth (cm)	23.88	1.5	-	0.411	0.456	0.515	-	-	-	-	-	-	0.483
16	Waist breadth (cm)	21.9	1.73	-	0.412	0.419	0.571	-	-	-	-	-	-	0.377
17	Pelvis breadth (cm)	25.67	1.54	0.67	0.659	0.655	0.778	-	-	-0.310	-	-	-	0.403
18	Chest depth (cm)	16.23	1.25	-	0.310	0.321	0.507	-	-	-0.449	-	-	0.479	0.374
19	Abdomen depth (cm)	15.48	1.31	-	-	0.313	0.417	-	-	-	-	-	-	0.314
20	Femur breadth (cm)	8.69	0.54	-	0.320	-	0.425	-	-	-	-	-	-	-
21	Ankle breadth (cm)	6.86	0.46	-	0.421	0.430	0.491	-	-	-	-	-	-	0.583
22	Humerus breadth (cm)	6.17	0.39	-	0.508	0.467	0.580	-	-	-0.332	-	-	-	0.344
23	Wrist breadth (cm)	5.07	0.29	-	0.454	0.458	0.449	-	-	-	-	-	-	0.375
24	Head circumf. (cm)	54.96	1.44	-	-	-	0.356	-	-	-	-	-	-	0.356
25	Neck circumf. (cm)	31.5	1.71	-	0.374	0.386	0.535	-	-	-0.323	-	-	-	- -
26	Upper chest circumf. (cm)	81.23	4.97	-	0.310	0.338	0.488	-	-	-0.400	-	-	-	0.413
27	Lower chest circumf. (cm)	73.96	5.36	-	0.326	0.358	0.513	-	-	-0.374	-	-	-	0.502
28	Waist circumf. (cm)	67.62	5.65	-	0.350	0.337	0.515	-	-	-0.346	-	-	0.324	-
29	Pelvis circumf. (cm)	79.49	6.3	0.324	0.419	0.405	0.606	-	-	-0.479	-	-	0.326	-
30	Hip circumf. (cm)	85.13	9.35	-	-	0.323	0.421	-	-	-	-	-0.310	-	0.345

31	Upper thigh circumf. (cm)	55.09	5.54	-	0.358	0.382	0.538	-	-	-0.428	-	-	-	0.467
32	Middle thigh circumf. (cm)	46.49	4.79	0.308	0.379	0.404	0.549	-	-	-0.371	-	-	-	0.542
33	Upper leg circumf. (cm)	34.16	2.68	0.304	0.494	0.537	0.564	-	-	-0.320	-	-	-	0.638
34	Lower leg circumf. (cm)	22.04	2.41	-	0.586	0.580	0.690	-	-	-0.328	-	-	-	0.595
35	Arm circumf. (cm)	24.87	2.41	-	0.320	0.313	0.505	-	-	-0.445	-	-	-	0.533
36	Arm circumf. flexed and tensed (cm)	26.84	2.567	-	0.342	0.343	0.522	-	-	-0.444	-	-	-	0.503
37	Forearm circumf. (cm)	22.45	1.6	0.328	0.432	0.462	0.578	-	-	-0.342	-	-	-	0.607
38	Wrist circumf. (cm)	15.73	0.94	-	0.495	0.524	0.601	-	-	-	-	-	-	0.516
39	Chin skinfold (cm)	0.64	0.23	-	-	-	-	-0.331	-	-0.363	-	-	0.352	-
40	Chest skinfold (cm)	0.67	0.27	-	-	-	0.334	-0.520	-0.425	-0.498	-	-	0.483	-
41	Side skinfold (cm)	0.82	0.39	-	-	-	0.407	-0.386	-0.331	-0.472	-	-	0.384	-
42	Waist skinfold (cm)	1.27	0.5	-	-	-	-0.317	-0.455	-0.421	-0.437	-	-	0.498	-
43	Suprailiacal skinfold (cm)	0.84	0.39	-	-	-	-	-0.464	-0.372	-0.454	-	-	0.565	-
44	Umbilical skinfold (cm)	1.03	0.39	-	-	-	-	-0.474	-0.379	-0.412	-	-	0.493	-
45	Subscapular skinfold (cm)	1.03	0.41	-	-	-	-	-0.411	-0.345	-0.339	-	-	0.516	-
46	Biceps skinfold (cm)	0.81	0.31	-	-	-	-	-0.418	-0.376	-0.450	-	-	0.406	-
47	Triceps skinfold (cm)	1.27	0.4	-	-	-	-	-0.374	-0.314	0.452	-	-	0.506	-
48	Thigh skinfold (cm)	2.14	0.56	-	-	-	-	-0.330	-0.335	-0.435	-	-	-	-

49	Calf skinfold (cm)	1.34	0.34	-	-	-	-	-	-0.327	-0.438	-	-	0.316	-
50	Mass of subcutaneous adipose tissue (kg)	7.98	2.94		0.445	0.205	0.183	-0.524	-0.089	0.067	-	-	0.392	-0.351
51	Relat. mass of subcutaneous adipose tissue (%)	13.85	3.24		0.222	-0.032	-0.070	-0.485	-0.074	0.036	-	-	0.520	-0.487

Table 3

Linear models for young female volleyballers ($n = 41$) physical ability tests by anthropometric measurements

No	*Predicted variables*	*Explanatory variables*	*Coefficients*	R^2
1	Test of highest jump and reach standing PA_1	Intercept	-1.31	
		Age	0.18	0.75
		Weight	-0.14	
		Height*	1.53	
2	PA_1	Intercept	46.60	
		Lower limb length	0.72	0.89
		Horizontal arms spread	0.60	
		Upper leg circumference	1.52	
		Chest skinfold	-12.69	
3	Test of highest jump and reach running PA_2	Intercept	37.37	
		Age	0.43	0.62
		Weight	-0.018	
		Height*	1.29	
4	PA_2	Intercept	77.26	
		Horizontal arms spread	0.62	0.78
		Upper leg circumference	2.62	
		Umbilical skinfold	12.79	
5	Highest reach of the players' outstretched hand	Intercept	13.80	
		Age	-0.30	0.90
		Weight	0.07	
		Height*	1.23	

6	Highest reach of the players' outstretched hand	Intercept	29.05	0.95
		Trunk length	0.27	
		Lower limb length	0.65	
		Horizontal arms spread	0.51	
		Neck circumference	1.03	
7	Vertical jump height standing PA_3	Intercept	-14.30	
		Weight	-0.21	0.16
		Height*	0.37	
8	PA_3	Intercept	14.75	
		Upper leg circumference	1.02	0.61
		Chest skinfold	11.68	
		Biceps skinfold	7.13	
		Relat. mass of subcutaneous adipose tissue	-0.85	
9	PA_4	Intercept	37.28	
		Ankle breadth	-5.72	0.63
		Upper leg circumference	+1.84	
		Chin skinfold	+13.60	
		Relat. mass of cubcutaneous adipose tissue	-2.14	
10	Endurance test PA_5	Intercept	617.36	
		Age	14.98	0.26
		Weight*	4.14	
		Height	1.36	
11	PA_5	Intercept	-6.06	
		Upper chest circumference	22.84	0.42
		Subscapular skinfold	-134.64	
		Relat. mass of subcut. adipose tissue	-38.19	

12	Test of speed measuring PA_8	Intercept	45.51	
		Age	-0.31	0.24
		Weight*	0.09	
		Height*	-0.11	
13	PA_8	Intercept	34.70	
		Biacromial breadth	-0.31	0.63
		Chest depth	0.85	
		Ankle breadth	-1.53	
		Suprailiacal skinfold	1.11	
14	Medicine ball throwing test PA_9	Intercept	-11.08	
		Age	5.20	0.29
		Weight*	1.86	
		Height	0.80	
15	PA_9	Intercept	-274.32	
		Upper leg circumference	5.32	0.65
		Arm circumference	20.49	
		Suprailiacal skinfold	-41.51	
		Mass of subcutaneous adipose tissue (kg)	-10.26	

* statistically significant variables in the model.
All models are statistically significant (on level 0.05)
For PA_4 no significant model by age, weight and height exists

Table 4

Means and standard deviations of physical ability tests results in 5 SD height-weight classification of young female volleyballers (n=46). Comparison of means from different classes (= 0.05)

No	Variable	1. Small (n=8)		2. Medium (n=8)		3. Large (n=6)		Signifi-cance	4. Pycnomorphs (n=13)		5. Leptomorphs (n=11)		Signifi-cance
		$\bar{x}$	SD	$\bar{x}$	SD	x	SD	1-3	x	SD	x	SD	4-5
1	Test of highest jump and reach standing (PA_1) cm	246.33	9.40	254.00	6.00	266.00	3.32	+	248.27	9.26	258.64	7.51	+
2	Test of highest jump and reach running (PA_2) cm	251.08	10.04	257.25	7.09	270.00	8.22	+	253.27	9.24	261.18	7.22	+
3	Highest reach of the players outstreched hand cm	211.42	8.22	218.65	4.03	229.40	4.39	+	214.00	5.48	220.55	7.13	+

4	Vertical jump height standing (PA_3) cm	34.92	6.05	35.38	2.39	36.60	5.32	-	34.27	5.59	38.09	2.17	+
5	Vertical jump height running (PA_4) cm	39.67	6.39	38.63	3.66	40.60	1.30	-	39.27	5.31	40.64	2.91	-
6	Endurance test (PA_5) sec	427.08	68.94	356.63	78.03	337.40	129.22	-	369.27	87.59	386.55	65.33	-
7	Stomach muscle strength test (PA_6) sec	154.42	31.49	169.13	60.41	160.60	47.74	-	160.64	79.03	189.73	65.28	-
8	Test of flexibility (PA_7) cm	15.92	6.00	19.50	5.58	16.80	10.69	-	16.91	6.32	13.14	3.96	-
9	Test of speed measuring (PA_8) sec	28.09	1.03	27.80	1.59	27.94	1.36	-	28.36	1.89	26.97	1.03	+
10.	Medicine ball throwing test (PA_9) cm	272.50	37.45	295.00	35.76	326.00	63.48	-	309.09	38.07	300.46	46.01	-

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Body build classification for ordinary schoolgirls (aged 7–18 years) and volleyball girls (aged 13–16 years)

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With 1 figure and 3 tables

Summary: The article describes two Estonian anthropometric cross-sectional studies of 1549 ordinary schoolgirls (aged 7–18) and 46 girls, who regularly practised volleyball (aged 13–16). Data are presented on 22 basic anthropometric measurements and 6 body composition characteristics (body mass index, mean skinfold, body density, relative mass of fat by Siri, absolute mass and relative mass of subcutaneous adipose tissue). All anthropometric variables were classified into five height-weight SD classes. Schoolgirls were divided into six age groups (7–8, 9–10, 11–12, 13–14, 15–16, 17–18). Volleyballers were observed as one group as their age in SD classes did not differ significantly. The classification consisted of five categories: three height-weight concordant categories: I – small (small height, small weight), II – medium (medium height, medium weight), III large – (big height, big weight) and two height/weight discordant categories: IV – so-called pyknomorphs, V – so-called leptomorphs. To assess the differences between classes the Scheffé-test was used ($\alpha = 0.05$). It proved likewise possible to comparatively systematize length, breadth and depth measurements, circumferences and body composition characteristics in all six age groups (7–18 years) of ordinary schoolgirls and in 13–16-year-old volleyballers as in their case the average age did not differ significantly between the classes.

Key words: Girls' anthropometric measurements, height-weight classes, volleyballers' anthropometric classification.

Zusammenfassung: Diese Abhandlung beschreibt zwei estnische anthropometrische Querschnittsuntersuchungen an 1539 regulären Schulmädchen im Alter von 7–18 Jahren und an 46 Mädchen im Alter zwischen 13–16 Jahren, die regelmäßig Volleyball spielen. Die Untersuchungsdaten umfassen 22 anthropometrische Maße und 6 Charakteristika der Body Composition (Body Mass Index, mittlere Hautfaltendicke, Körperdichte, relative Fettmasse nach Siri, absolute und relative Masse des subkutanen Fettgewebes). Alle anthropometrischen Variablen wurden in fünf Körperhöhen-Körpergewicht-SD-Klassen klassifiziert. Die Schulmädchen wurden in sechs Altersgruppen eingeteilt (7–8, 9–10, 11–12, 13–14, 15–16 und 17–18 Jahre). Die Volleyballspielerinnen wurden als eine Gruppe betrachtet, da ihr Alter in den SD-Klassen nicht signifikant differierte. Die Klassifikation umfaßt fünf Kategorien: drei in Bezug auf Körperhöhe und Körpergewicht konkordante Kategorien: I – klein (geringe Körperhöhe und geringes Körpergewicht), II – mittel (mittlere Körperhöhe und mittleres Körpergewicht), III – groß (große Körperhöhe, großes Körpergewicht) und zwei in Bezug auf Körperhöhe und Körpergewicht diskordante Kategorien: IV – sogenannte Pyknomorphe und V – sogenannte Leptomorphe. Um die Differenzen zwischen diesen Klassen zu überprüfen, wurde der Scheffé-Test herangezogen ($\alpha = 0.05$). Es erwies

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sich als möglich, Längen-, Breiten- und Tiefenmaße, Umfänge und Charakteristika der Body Composition in allen sechs Altersgruppen (7–18 Jahre) der regulären Schulmädchen und der 13–16 Jahre alten Volleyballspielerinnen vergleichend zu systematisieren, da bei ihnen das mittlere Alter nicht signifikant zwischen den einzelnen Klassen differierte.

Schlüsselwörter: Anthropometrische Messungen an Mädchen, Körperhöhe-Körpergewicht-Klassen, anthropometrische Klassifikation von Volleyballspielerinnen.

Introduction

Anthropometric studies of girls in their growth years have proved very great individual variability depending on age.

Despite the detailed studies of many authors (Tanner 1962, Tutkuviene 1986, Prokopec 1988, Ducquet & Carter 1996, Claessens et al. 2001, Eiben & Nemeth 2001) no universal classification has been developed that would satisfy all the requirements and enable us to systematize and compare a large number of body measurements of schoolgirls with different age and body build. There are even fewer studies describing adolescent girls who practise volleyball. The studies are usually limited to a few body measurements (Thissen-Milder & Mayhew 1991, Häkkinen 1993, Malina 1994), and sometimes somatotyping according to Heath-Carter has been applied (Mészarós & Mohácsi 1982).

For a longer time, the Centre for Physical Anthropology at the University of Tartu has been engaged in research of young women's, schoolgirls' and schoolboys' body structure and classification of their body measurements (Kaarma 1981, 1995, Kaarma et al. 2000, 2001, Thetloff 1992, Polina et al. 1992, Peterson & Saluvere 1998, Saluvere et al. 1998, Maiste et al. 1999, Lintsi et al. 2002, Veldre et al. 2002). The centre has also participated in studying and classifying the body measurements of volleyball girls (Stamm et al. 2002, 2003).

All these studies have confirmed that the anthropometric structure of the body as a whole consists of a system of statistically significantly related characteristics, where the leading characteristics are height and weight, which significantly determine the variability of all the other characteristics. This has justified the application of a height-weight classification on all the abovementioned populations.

In this paper, we present the results of classifying the body measurements of 7–18-year-old ordinary schoolgirls as well as volleyball girls (aged 13–16 years).

Material and methods

Subjects

Ordinary schoolgirls (henceforth schoolgirls) were 7–18-year-old girls (n = 1549) from several schools of South Estonia. Volleyball girls (aged 13–16 years, n = 46, henceforth volleyballers) came from six adolescent female teams of Estonia. They had practised volleyball regularly for the last three years and participated in young female volleyballers' championships in the age group of up to 16-year-olds. All the girls from both samples were healthy and they as well as their parents had consented to anthropometric measuring. The study was approved by the Medical Ethics Committee of the University of Tartu.

Anthropometric research

The methodology of the anthropometric study of these samples relied on the long-term research carried out on many populations at the Centre for Physical Anthropology at the University of Tartu (Kaarma 1981, 1995, Kaarma et al. 1997, Peterson & Saluvere 1998).

Anthropometric measurements were taken by two trained anthropometrists (one of them measured the schoolgirls, the other the volleyballers). Both had previously shown test-retest reliability of r > 0.90.

The girls were measured according to the classical method of Martin (Knussmann 1988). For measuring the skinfolds the methodology provided in Knussmann's handbook (1988, p. 274) was followed. To measure lower extremity length we applied the method of Jatsuta (1923) that has been widely accepted in Russia and has been the principal method used in Estonia since J. Aul's work (Aul 1977).

Body height was measured in centimetres (± 0.1 cm) using a Martin metal anthropometer and body weight in kilograms (± 0.05 kg) on medical scales. Depth and breadth measurements were measured with Martin callipers, circumferences with a metal measuring tape and skinfolds with the Holtain skinfold calipers on the right side of the body.

In total, 22 basic measurements were measured on both samples of this study. These were weight, height, trunk length, upper and lower limb length, biacromial and pelvis breadth, chest and abdomen depth, femur, ankle, humerus and wrist breadth, upper chest, waist, hip, upper thigh, upper and lower leg, arm, forearm and wrist circumferences. In addition to these, 10 skinfolds were measured in schoolgirls (chin, chest, side, waist, umbilical, subscapular, biceps, triceps, thigh, calf skinfolds). In volleyballers 11 skinfolds were measured (suprailical skinfold in addition to those mentioned above).

From the measured variables, six body composition characteristics were calculated: body mass index, mean skinfold, body density (Wilmore & Behnke 1970), relative mass of fat by Siri (quoted after Wilmore & Behnke 1970), mass of subcutaneous adipose tissue (kg) and relative mass of subcutaneous adipose tissue (%).

Statistical analysis

The data were processed using the SAS system. Schoolgirls' data (n = 1549) were analyzed separately in six age groups (7–8, 9–10, 11–12, 13–14, 15–16, 17–18 years). First, the mean values ($\bar{x}$) and standard deviations of all variables were calculated for age groups. The basis for creating the classification for the respective age group was the mean height, weight and their standard deviations. Then all the other variables were placed into the classification. To create the 5 SD classification for each age group, 3 × 3 = 9 SD classes of height and weight were formed. From there, we took three concordance classes of height and weight (small height – small weight; medium height – medium weight; big height – big weight). The remaining six classes were united into two classes of discordant height and weight (big weight and small height – pyknomorphs; small weight and big height – leptomorphs; see Fig. 1).

		Weight classes		
Height classes		*Light*	*Medium*	*Heavy*
	Short	Small	Pycnomorphic	Pycnomorphic
	Medium	Leptomorphic	Medium	Pycnomorphic
	Tall	Leptomorphic	Leptomorphic	Large

Fig. 1. Body build classes.

Thus, the five height-weight SD classes were created according to the following rules:

Class 1 (small):
weight < $\bar{x}_w - 0.5\ SD_w$ and height < $\bar{x} - 0.5\ SD_h$

Class 2 (medium):
$\bar{x}_w - 0.5\ SD_w \leq$ weight < $\bar{x} + 0.5\ SD_w$ and $\bar{x}_h - 0.5\ SD_h \leq$ height < $0.5\ SD_h$

Class 3 (large):
weight $\geq \bar{x}_w + 0.5\ SD_w$ and height $\geq \bar{x}_h + 0.5\ SD_h$

Class 4 (pyknomorphs):
weight $\geq \bar{x}_w - 0.5$ SD and height < $\bar{x}_h - 0.5\ SD_h$ or
weight $\geq \bar{x}_w + 0.5$ SD and height < $\bar{x} + 0.5\ SD_h$

Class 5 (leptomorphs):
weight < $\bar{x}_w - 0.5$ SD and height $\geq \bar{x}_h - 0.5\ SD_h$ or
weight < $\bar{x}_w + 0.5$ SD and height $\geq \bar{x}_h + 0.5\ SD_h$ (see Fig. 1).

For all anthropometric variables, their means and standard deviations were calculated in all classes. Using the Scheffé-test, the class means of all anthropometric data were compared between classes 1 and 3, but also between classes 4 and 5, using the significance level $\alpha = 0.05$ (Table 1).

For volleyballers (n = 46) the mean values of the anthropometric variables were calculated in age groups and the variables' relations with age were found (Table 2). A common 5 SD classification of height and weight was formed for girls of different age using the medium height, weight and the respective standard deviations of the whole sample. Girls of different ages (13–16 years) were placed into the classes of the common height-weight classification according to their individual heights and weights. Thereafter, the average ages of girls of all classes were compared, and as there were no statistically significant differences between the classes, the application of such a common classification was found to be justified.

The statistical analysis was performed by Säde Koskel, M.Sc., from the Institute of Mathematical Statistics, University of Tartu, Estonia.

Results

Table 1 presents the anthropometric data of 7–18-year-old schoolgirls (n = 1549) – 22 basic measurements and 6 body composition characteristics – as the average values of the six age groups and, thereafter, as classified into height-weight classes. From here we can see that the average data of all age groups showed a gradual increase of basic measurements as well as indicators of body fat content. The height-weight classes of separate age groups also revealed systematic changes in mean values of anthropometric variables.

Thus, in all age groups, height and weight showed a gradual increase in classes 1–3. This was accompanied by a statistically significant increase in length, breadth and depth measurements, some of the limb thicknesses, circumferences, body mass index and body fat content.

Classes 4 and 5 of all age groups also revealed several characteristic differences between pyknic and leptosomic girls. Thus, in the classes of pyknics, the breadth and depth measurements and trunk and limbs circumferences, femur breadth and humerus breadth, body mass index and indicators of body fat content were statistically significantly greater. In the classes of leptosomic girls in all six age groups, the upper and lower limbs were statistically significantly longer and body density greater.

Table 1. Means and standard deviations of basic anthropometric measurements and body composition characteristics in body build classes of 7–18 year-old schoolgirls.

No	Variable	7–8 (n = 205) Body build classes (x̄, SD) x̄ / SD	1. Small	2. Medium	3. Large	Statis-tics	4. Pycno-morphs	5. Lepto-morphs	Statis-tics	9–10 (n = 276) Body build classes (x̄, SD) x̄ / SD	1. Small	2. Medium	3. Large	Statis-tics	4. Pycno-morphs	5. Lepto-morphs	Statis-tics
1.	Weight (kg)	25.315 4.41	n = 58 20.898 1.352	n = 44 25.068 1.306	n = 39 31.785 3.194	+	n = 21 28.433 3.717	n = 43 24.133 1.893	+	30.608 5.073	n = 66 25.400 1.549	n = 46 29.857 1.380	n = 48 37.642 3.827	+	n = 49 33.663 4.479	n = 67 28.981 2.336	+
2.	Height (cm)	126.71 6.20	119.46 3.36	126.84 1.81	134.70 3.07	+	125.86 3.47	129.51 3.67	+	137.46 6.21	130.34 3.17	137.53 1.76	145.70 3.30	+	134.34 3.57	140.80 3.61	+
3.	Trunk length (cm)	36.56 2.35	34.78 1.75	36.56 1.79	38.99 2.13	+	36.30 2.23	36.89 1.69	–	38.66 2.61	36.50 2.78	38.84 1.86	40.69 2.08	+	38.39 2.11	39.41 1.96	+
4.	Upper limb length (cm)	55.40 3.65	52.30 2.91	56.01 2.21	58.24 4.09	+	55.80 2.39	56.20 2.92	–	60.49 3.38	57.22 2.61	60.29 1.93	64.22 2.46	+	59.54 2.58	61.88 2.41	+
5.	Lower limb length (cm)	67.63 4.29	63.01 2.36	67.71 2.80	72.84 2.43	+	67.28 2.64	69.22 2.82	+	75.30 4.20	71.03 2.72	75.27 1.79	80.61 2.60	+	73.10 2.56	77.33 2.83	+
6.	Biacromial breadth (cm)	27.42 1.76	25.82 1.18	27.66 1.16	29.29 1.71	+	27.69 1.38	27.50 1.13	–	29.46 1.46	28.01 1.10	29.41 0.97	31.45 1.44	+	29.70 1.25	29.33 1.33	–
7.	Pelvis breadth (cm)	19.98 1.38	18.70 0.83	19.90 0.91	21.49 1.12	+	20.22 1.39	20.31 0.95	–	21.66 1.48	20.38 0.88	21.71 0.95	23.24 1.40	+	22.01 1.38	21.49 1.52	+
8.	Chest depth (cm)	13.68 1.28	12.91 0.73	13.70 1.63	14.72 1.02	+	14.15 1.34	13.54 0.89	–	14.24 1.30	13.31 0.68	14.04 0.88	15.47 1.30	+	15.12 1.33	13.77 0.87	+
9.	Abdomen depth (cm)	13.37 1.46	12.67 1.06	12.99 1.26	14.84 1.23	1+3 2+3	14.30 1.57	12.92 1.11	+	13.95 1.56	13.10 1.13	13.40 1.09	15.14 1.38	1+3 2+3	15.18 1.70	13.43 1.14	+
10.	Femur breadth (cm)	7.57 0.56	7.15 0.35	7.40 0.40	8.21 0.44	+	7.74 0.62	7.67 0.42	–	7.96 0.52	7.50 0.41	7.58 0.34	8.46 0.43	+	8.18 0.52	7.89 0.37	+
11.	Ankle breadth (cm)	5.79 0.44	5.57 0.35	5.79 0.43	6.10 0.43	+	5.63 0.35	5.87 0.44	+	6.05 0.44	5.83 0.37	6.04 0.36	6.34 0.40	+	6.09 0.39	6.03 0.48	–
12.	Humerus breadth (cm)	5.08 0.40	4.86 0.28	5.02 0.34	5.46 0.45	1+3 2+3	5.12 0.38	5.07 0.28	–	5.38 0.49	5.15 0.40	5.28 0.51	5.76 0.45	1+3 2+3	5.55 0.46	5.27 0.41	+
13.	Wrist breadth (cm)	4.19 0.32	3.96 0.22	4.21 0.29	4.47 0.35	+	4.16 0.27	4.23 0.25	–	4.53 0.35	4.34 0.33	4.50 0.30	4.80 0.33	+	4.56 0.29	4.54 0.32	–
14.	Upper chest circumf. (cm)	60.17 4.08	56.77 2.04	60.01 2.35	65.36 3.85	+	62.52 3.68	59.04 2.19	+	64.26 4.88	60.15 1.96	63.59 2.69	69.94 4.52	+	67.29 5.01	62.47 2.71	+
15.	Waist circumf. (cm)	52.53 4.40	49.91 2.53	52.09 3.14	57.26 4.64	+	54.83 5.02	51.11 2.90	+	55.01 5.14	51.38 2.81	54.12 2.54	59.88 4.71	+	59.48 5.52	52.42 2.67	+

Table 1. (continued).

No	Variable	7–8 (n = 205) Body build classes ($\bar{x}$, SD)								9–10 (n = 276) Body build classes ($\bar{x}$, SD)							
		$\bar{x}$ / SD	1. Small	2. Medium	3. Large	Statistics	4. Pycnomorphs	5. Leptomorphs	Statistics	$\bar{x}$ / SD	1. Small	2. Medium	3. Large	Statistics	4. Pycnomorphs	5. Leptomorphs	Statistics
16.	Hip circumf. (cm)	67.07 5.19	62.86 2.20	66.43 2.82	73.80 4.69	+	70.32 5.23	65.71 3.00	+	72.53 5.61	67.47 2.70	71.78 2.29	79.01 4.40	+	76.31 6.31	70.61 2.63	+
17.	Upper thigh circumf. (cm)	38.86 3.89	35.94 2.07	38.58 3.01	43.26 3.25	+	41.63 4.42	37.74 2.12	+	41.98 4.24	38.76 2.25	41.63 2.15	46.36 3.84	+	45.13 4.40	39.94 2.51	+
18.	Upper leg circumf. (cm)	25.96 2.30	24.22 1.19	25.66 1.87	28.77 1.65	+	27.15 2.44	25.48 1.35	+	27.86 2.40	25.92 1.35	27.57 1.17	30.24 2.59	+	29.11 2.63	27.37 1.45	+
19.	Lower leg circumf. (cm)	17.74 1.41	16.61 0.86	17.58 1.18	19.40 1.01	+	18.31 1.30	17.63 1.00	+	19.05 1.52	17.81 0.98	18.93 0.87	20.74 1.32	+	19.80 1.43	18.60 1.08	+
20.	Arm circumf. (cm)	17.94 1.82	16.67 0.94	17.82 1.16	19.93 1.67	+	19.47 2.23	17.22 1.03	+	19.49 1.96	18.09 0.94	19.15 1.07	21.40 1.97	+	21.11 1.96	18.57 1.12	+
21.	Forearm circumf. (cm)	17.26 1.40	16.24 0.79	17.23 0.88	18.75 1.04	+	17.91 2.14	17.01 0.98	–	18.61 1.53	17.52 0.92	18.50 1.06	20.07 1.33	+	19.75 1.38	17.89 1.12	+
22.	Wrist circumf. (cm)	12.80 1.03	12.16 0.94	12.71 0.75	13.80 0.68	+	13.26 1.16	12.63 0.85	+	13.51 0.96	12.87 0.67	13.35 0.59	14.51 0.87	+	14.06 0.92	13.14 0.71	+
23.	Body mass index	15.68 1.81	14.66 0.99	15.59 0.91	17.53 1.78	+	17.90 1.77	14.38 0.78	+	16.14 2.05	14.96 0.82	15.80 0.88	17.73 1.73	+	18.62 2.11	14.60 0.78	+
24.	Mean skinfold (cm)	0.84 0.26	0.700 0.09	0.79 0.16	1.10 0.36	1+3 2+3	1.01 0.28	0.74 0.16	+	0.95 0.32	0.81 0.14	0.90 0.18	1.13 0.43	1+3 2+3	1.21 0.38	0.79 0.14	+
25.	Body density (g/cm^3)	1.061 0.000	1.061 0.000	1.061 0.000	1.061 0.001	1+3 2+3	1.061 0.000	1.061 0.000	+	1.061 0.000	1.061 0.000	1.061 0.000	1.061 0.001	1+3 2+3	1.61 0.001	1.061 0.000	+
26.	Relat. mass of fat by Siri (%)	16.48 0.16	16.40 0.06	16.46 0.09	16.64 0.23	1+3 2+3	16.58 0.17	16.42 0.09	+	16.52 0.21	16.45 0.10	16.49 0.12	16.63 0.28	1+3 2+3	16.68 0.26	16.42 0.10	+
27.	Mass of subcutaneous adipose tissue (kg)	3.64 1.53	2.64 0.37	3.38 0.72	5.48 1.99	+	4.59 1.60	3.14 0.71	+	4.73 1.97	3.56 0.63	4.37 0.94	6.41 2.71	+	6.16 2.25	3.87 0.75	+
28.	Relat. mass of subcutaneous adipose tissue (%)	14.02 3.43	12.61 1.52	13.43 2.52	16.90 4.73	1+3 2+3	15.82 3.56	13.02 2.88	+	15.09 3.90	13.98 2.16	14.57 2.73	16.64 5.34	1+3 2+3	17.95 4.72	13.32 2.19	+

Table 1. (continued).

No	Variable	11–12 (n = 312) Body build classes ($\bar{x}$, SD)								13–14 (n = 240) Body build classes ($\bar{x}$, SD)							
		$\bar{x}$ / SD	1. Small	2. Medium	3. Large	Statistics	4. Pycnomorphs	5. Leptomorphs	Statistics	$\bar{x}$ / SD	1. Small	2. Medium	3. Large	Statistics	4. Pycnomorphs	5. Leptomorphs	Statistics
1.	Weight (kg)	38.804 7.512	n = 78 30.377 2.727	n = 61 38.280 1.929	n = 65 48.763 5.051	+	n = 45 42.640 5.229	n = 63 36.732 3.984	+	49.345 9.698	n = 55 38.207 3.027	n = 58 48.881 2.973	n = 48 61.615 8.240	+	n = 38 53.895 7.778	n = 41 46.654 4.759	+
2.	Height (cm)	149.02 8.23	138.83 4.78	149.33 2.39	158.78 3.93	+	146.73 4.75	152.90 4.93	+	160.17 6.69	151.58 3.99	160.60 1.77	167.89 3.58	+	157.39 3.31	164.64 4.00	+
3.	Trunk length (cm)	41.93 3.25	38.95 3.07	41.62 2.11	44.93 2.17	+	42.22 3.04	42.64 2.10	–	45.39 3.65	42.06 3.73	45.17 2.80	48.18 2.95	+	45.20 1.98	47.08 2.87	+
4.	Upper limb length (cm)	65.61 4.26	61.00 2.69	65.88 2.51	70.34 2.83	+	64.46 2.41	67.00 3.22	+	70.95 3.55	66.80 2.03	71.63 1.76	74.39 2.06	+	69.43 2.77	72.94 2.95	+
5.	Lower limb length (cm)	82.47 5.36	76.25 3.53	82.86 2.49	88.36 3.02	+	80.67 3.33	84.98 3.41	+	88.49 4.41	83.77 3.34	88.96 2.14	92.93 3.31	+	86.52 2.95	90.79 3.13	+
6.	Biacromial breadth (cm)	31.75 2.03	29.76 1.51	31.82 1.24	33.84 1.63	+	32.07 1.65	31.78 1.43	–	34.07 1.96	32.04 1.22	34.18 1.39	36.09 1.48	+	34.35 1.62	34.00 1.56	–
7.	Pelvis breadth (cm)	23.78 1.82	21.99 1.19	23.64 0.96	25.69 1.40	+	24.28 1.77	23.81 1.28	–	26.03 1.71	24.09 1.05	26.21 1.20	27.54 1.25	+	26.55 1.42	26.10 1.40	+
8.	Chest depth (cm)	15.20 1.51	13.84 0.90	15.00 0.81	16.85 1.10	+	16.08 1.39	14.73 1.10	+	16.44 1.41	15.16 1.00	16.62 0.99	17.45 1.42	+	17.09 1.13	16.14 1.22	+
9.	Abdomen depth (cm)	14.66 1.58	13.64 1.24	14.29 1.05	15.93 1.57	+	15.75 1.66	14.20 0.92	+	15.33 1.65	13.92 1.10	15.20 1.11	16.58 1.74	+	16.13 1.44	15.24 1.48	+
10.	Femur breadth (cm)	8.43 0.63	7.89 0.45	8.43 0.47	8.93 0.60	+	8.75 0.58	8.34 0.48	+	8.62 0.63	8.09 0.40	8.66 0.52	9.11 0.58	+	8.90 0.46	8.44 0.61	+
11.	Ankle breadth (cm)	6.31 0.42	6.10 0.43	6.35 0.39	6.51 0.40	1+3 1+2	6.30 0.32	6.32 0.41	–	6.53 0.46	6.33 0.37	6.47 0.42	6.84 0.50	1+3 2+3	6.54 0.47	6.50 0.39	–
12.	Humerus breadth (cm)	5.70 0.52	5.35 0.47	5.71 0.37	5.99 0.55	+	5.94 0.39	5.64 0.47	+	5.98 0.49	5.72 0.43	5.88 0.44	6.34 0.53	1+3 2+3	6.17 0.41	5.85 0.35	+
13.	Wrist breadth (cm)	4.80 0.35	4.58 0.28	4.82 0.32	5.06 0.32	+	4.80 0.26	4.80 0.37	–	4.99 0.37	4.82 0.30	5.09 0.46	5.12 0.34	1+3 1+2	4.95 0.36	5.01 0.25	–
14.	Upper chest circumf. (cm)	71.59 6.18	65.39 2.75	71.16 3.23	78.99 4.35	+	74.99 4.92	69.63 4.11	+	80.25 6.38	72.60 2.76	80.85 3.38	86.53 5.31	+	83.88 5.18	78.95 4.01	+
15.	Waist circumf. (cm)	59.25 5.59	54.50 3.21	58.11 2.85	64.71 4.65	+	64.13 5.44	57.12 3.11	+	63.35 5.89	57.80 3.15	63.15 3.45	68.48 6.27	+	66.86 5.41	61.80 3.98	+

Table 1. (continued).

No	Variable	11–12 (n = 312) Body build classes ($\bar{x}$, SD)								13–14 (n = 240) Body build classes ($\bar{x}$, SD)							
		$\bar{x}$ / SD	1. Small	2. Medium	3. Large	Statis-tics	4. Pycno-morphs	5. Lepto-morphs	Statis-tics	$\bar{x}$ / SD	1. Small	2. Medium	3. Large	Statis-tics	4. Pycno-morphs	5. Lepto-morphs	Statis-tics
16.	Hip circumf. (cm)	80.55 6.80	73.60 3.42	79.88 2.99	88.28 5.03	+	85.12 5.86	78.58 3.94	+	88.47 7.72	79.48 5.66	89.01 3.85	96.14 5.68	+	92.21 5.78	87.32 5.09	+
17.	Upper thigh circumf. (cm)	46.79 5.29	41.60 2.60	46.70 3.33	52.18 4.19	+	50.10 5.02	45.39 3.30	+	51.69 6.21	45.68 3.17	51.18 4.63	57.56 5.16	+	55.67 4.64	49.91 5.02	+
18.	Upper leg circumf. (cm)	30.82 2.77	28.25 1.74	30.76 1.83	33.77 1.95	+	32.07 2.76	30.13 1.73	+	33.33 3.33	30.01 2.16	33.38 2.63	36.40 2.78	+	35.25 2.42	32.36 2.14	+
19.	Lower leg circumf. (cm)	20.40 1.68	18.84 1.34	20.48 1.06	21.97 1.34	+	21.16 1.41	20.11 1.18	+	21.73 1.71	20.19 1.37	21.99 1.33	23.09 1.39	+	22.19 1.49	21.39 1.50	+
20.	Arm circumf. (cm)	21.45 2.38	19.40 1.43	21.39 1.17	23.73 2.02	+	23.46 2.11	20.28 1.43	+	23.36 2.75	20.87 1.77	23.41 1.81	25.78 2.70	+	25.13 22.14	2.22 1.72	+
21.	Forearm circumf. (cm)	19.82 1.70	18.39 1.14	19.91 1.24	21.41 1.43	+	20.93 1.45	19.05 1.07	+	21.41 1.85	19.73 1.16	21.48 1.48	23.25 1.73	+	22.18 1.22	20.72 1.24	+
22.	Wrist circumf. (cm)	14.54 1.13	13.56 0.77	14.59 0.86	15.50 0.95	+	15.34 1.02	14.15 0.68	+	15.36 1.05	14.44 0.78	15.35 0.81	16.33 0.95	+	15.76 0.79	15.08 0.79	+
23.	Body mass index	17.34 2.22	15.76 1.20	17.18 0.96	19.34 1.90	+	19.77 1.93	15.67 1.04	+	19.14 2.93	16.63 1.18	18.96 1.22	21.90 3.14	+	21.69 2.52	17.18 1.33	+
24.	Mean skinfold (cm)	1.08 0.35	0.92 0.18	1.02 0.20	1.22 0.37	1+3 2+3	1.45 0.48	0.90 0.15	+	1.21 0.31	0.98 0.16	1.22 0.27	1.38 0.34	+	1.43 0.26	1.08 0.22	+
25.	Body density (g/cm^3)	1.061 0.000	1.061 0.000	1.061 0.000	1.061 0.000	1+3 2+3	1.060 0.000	1.061 0.000	+	1.061 0.000	1.061 0.000	1.061 0.000	1.061 0.001	1+2 1+3	1.060 0.000	1.061 0.000	+
26.	Relat. mass of fat by Siri (%)	16.60 0.22	16.54 0.12	16.57 0.15	16.65 0.23	1+3 2+3	16.83 0.32	16.51 0.13	+	16.67 0.18	16.56 0.11	16.69 0.17	16.76 0.22	1+2 1+3	16.79 0.15	16.60 0.12	+
27.	Mass of subcutaneous adipose tissue (kg)	6.28 2.53	4.56 0.98	5.85 1.21	8.17 2.78	+	8.69 3.24	5.16 1.01	+	8.23 2.80	5.68 1.03	8.21 1.90	10.62 3.27	all	9.94 2.35	7.28 1.73	+
28.	Relat. mass of subcutaneous adipose tissue (%)	15.89 4.05	14.97 2.65	15.25 2.81	16.51 4.30	1+3	20.05 5.87	14.03 2.11	+	16.40 3.07	14.85 2.23	16.73 3.42	17.01 3.08	1+2 1+3	18.34 2.69	15.49 2.64	+

Table 1. (continued).

No	Variable	15–16 (n = 259) Body build classes ($\bar{x}$, SD)								17–18 (n = 257) Body build classes ($\bar{x}$, SD)							
		$\bar{x}$ / SD	1. Small	2. Medium	3. Large	Statis-tics	4. Pycno-morphs	5. Lepto-morphs	Statis-tics	$\bar{x}$ / SD	1. Small	2. Medium	3. Large	Statis-tics	4. Pycno-morphs	5. Lepto-morphs	Statis-tics
1.	Weight (kg)	57.698 9.646	n = 43 47.095 4.356	n = 42 57.719 2.993	n = 41 70.441 6.444	+	n = 57 63.154 8.033	n = 76 52.720 5.769	+	61.511 9.619	n = 52 52.050 3.547	n = 43 60.093 2.247	n = 24 74.325 7.810	+	n = 64 70.472 7.967	n = 74 57.076 5.432	+
2.	Height (cm)	166.54 6.08	158.12 4.15	166.63 1.70	173.81 2.84	+	163.35 3.26	169.74 3.98	+	167.90 5.58	160.36 3.28	168.47 1.29	174.89 3.26	+	166.30 3.11	171.96 3.58	+
3.	Trunk length (cm)	48.03 2.83	45.30 2.94	47.96 1.45	50.50 2.09	+	47.45 2.53	48.72 2.45	+	48.92 2.56	46.86 2.18	48.86 1.84	51.01 3.11	+	49.35 2.14	49.59 2.15	–
4.	Upper limb length (cm)	73.19 3.34	69.53 2.53	73.24 1.99	76.62 2.34	+	71.61 2.76	74.55 2.47	+	73.83 3.12	70.66 2.58	73.86 1.90	77.21 2.46	+	73.27 2.46	75.44 2.54	+
5.	Lower limb length (cm)	91.29 4.33	86.25 2.76	91.69 2.11	96.04 2.87	+	88.94 3.00	93.12 3.46	+	91.51 4.19	86.38 2.92	92.20 2.01	96.12 2.87	+	90.14 2.74	94.39 2.85	+
6.	Biacromial breadth (cm)	35.68 1.80	34.09 1.32	35.71 1.31	37.57 2.15	+	35.80 1.36	35.45 1.40	–	36.36 1.67	35.12 1.43	36.65 1.11	37.73 1.36	+	36.78 1.47	36.24 1.77	–
7.	Pelvis breadth (cm)	27.62 1.73	26.08 1.31	27.31 1.43	29.02 1.38	+	28.11 1.86	27.52 1.39	+	28.17 1.67	26.79 1.16	27.96 1.57	29.58 1.95	+	28.95 1.38	28.14 1.42	+
8.	Chest depth (cm)	17.32 1.50	16.24 0.96	17.24 0.96	18.59 1.63	+	18.20 1.40	16.65 1.10	+	17.64 1.34	16.95 0.97	17.36 1.17	19.03 1.38	1+3 2+3	18.47 1.27	17.12 0.99	+
9.	Abdomen depth (cm)	16.18 1.70	15.31 0.81	16.21 1.08	17.43 1.66	+	17.10 2.02	15.28 1.32	+	16.36 1.69	15.41 1.18	16.19 1.03	17.98 1.79	+	17.75 1.68	15.41 0.95	+
10.	Femur breadth (cm)	8.76 0.69	8.22 0.59	8.87 0.54	9.37 0.59	+	8.99 0.67	8.50 0.55	+	8.96 0.68	8.51 0.48	8.84 0.46	9.63 0.71	+	9.39 0.72	8.77 0.46	+
11.	Ankle breadth (cm)	6.66 0.45	6.52 0.46	6.62 0.40	6.90 0.50	1+3 2+3	6.70 0.39	6.59 0.42	–	6.78 0.67	6.54 0.35	6.85 0.90	6.95 0.45	+	6.96 0.47	6.78 0.49	+
12.	Humerus breadth (cm)	6.25 0.46	5.91 0.36	6.23 0.36	6.62 0.41	+	6.39 0.57	6.16 0.31	+	6.35 0.53	6.14 0.41	6.28 0.42	6.80 0.68	1+3 2+3	6.61 0.50	6.18 0.46	+
13.	Wrist breadth (cm)	5.18 0.33	4.94 0.31	5.25 0.29	5.37 0.32	1+3 1+2	5.14 0.30	5.21 0.30	–	5.18 0.35	4.98 0.29	5.27 0.33	5.46 0.44	1+2 1+3	5.23 0.31	5.14 0.30	–
14.	Upper chest circumf. (cm)	87.63 5.74	81.94 3.33	87.95 3.12	92.85 4.27	+	91.69 5.88	84.80 3.47	+	90.15 5.91	85.96 3.14	88.92 2.75	96.18 5.34	+	96.26 4.91	86.58 3.22	+
15.	Waist circumf. (cm)	67.54 6.05	62.78 2.59	88.55 3.93	72.91 4.87	+	71.78 6.70	64.27 4.12	+	69.08 5.99	64.82 3.58	68.45 2.16	74.80 5.19	+	75.10 5.35	65.30 3.41	+

Table 1. (continued).

No	Variable	15–16 (n = 259) Body build classes ($\bar{x}$, SD)								17–18 (n = 257) Body build classes ($\bar{x}$, SD)							
		$\bar{x}$ SD	1. Small	2. Medium	3. Large	Statis-tics	4. Pycno-morphs	5. Lepto-morphs	Statis-tics	$\bar{x}$ SD	1. Small	2. Medium	3. Large	Statis-tics	4. Pycno-morphs	5. Lepto-morphs	Statis-tics
16.	Hip circumf. (cm)	95.13 7.06	88.49 3.59	93.97 3.40	102.47 5.45	+	99.69 7.45	92.17 4.54	+	97.84 6.87	91.96 3.47	97.30 3.42	105.66 6.28	+	104.07 6.10	94.34 3.78	+
17.	Upper thigh circumf. (cm)	56.39 5.41	51.57 4.01	56.07 3.03	62.02 4.76	+	59.71 4.50	53.78 3.66	+	58.52 5.61	54.39 3.14	58.02 1.96	63.25 6.58	+	64.13 5.00	55.34 2.89	+
18.	Upper leg circumf. (cm)	35.78 2.84	32.91 1.80	36.22 1.70	38.54 2.25	+	37.40 2.52	34.44 2.02	+	36.49 2.93	34.97 1.84	36.12 1.39	38.57 3.96	+	39.11 2.73	34.81 1.82	+
19.	Lower leg circumf. (cm)	22.52 1.49	21.25 1.52	22.75 0.74	23.99 1.29	+	22.84 1.36	22.09 1.16	+	22.72 1.47	21.81 0.97	22.36 0.89	23.91 1.70	1+3 2+3	23.75 1.41	22.28 1.28	+
20.	Arm circumf. (cm)	25.83 2.70	21.47 1.01	25.88 1.33	28.39 1.88	+	27.83 2.57	24.22 1.78	+	26.74 2.78	25.11 1.30	26.52 1.40	29.75 1.54	+	29.48 2.61	24.67 1.54	+
21.	Forearm circumf. (cm)	22.92 1.70	21.47 1.01	23.38 1.17	24.62 1.31	+	23.55 1.62	22.10 1.38	+	23.71 1.86	22.60 1.19	23.54 0.87	25.17 1.55	+	25.40 1.77	22.65 1.42	+
22.	Wrist circumf. (cm)	15.77 1.02	14.78 0.76	15.98 0.57	16.79 0.73	+	16.10 0.82	15.43 0.96	+	15.99 0.98	20.24 1.28	16.08 0.46	16.88 1.02	+	16.78 0.76	15.49 0.73	+
23.	Body mass index	20.76 3.07	18.82 1.48	20.79 1.10	23.35 2.41	+	23.66 2.84	18.29 1.76	+	21.80 3.08	20.24 1.28	21.17 0.73	24.30 2.73	+	25.45 2.44	19.28 1.46	+
24.	Mean skinfold (cm)	1.44 0.33	1.28 0.26	1.46 0.19	1.64 0.34	+	1.65 0.36	1.25 0.21	+	1.65 0.32	1.50 0.20	1.62 0.19	1.88 0.30	+	1.95 0.28	1.45 0.23	+
25.	Body density (g/cm^3)	1.060 0.000	1.061 0.000	1.060 0.000	1.060 0.000	+	1.060 0.000	1.061 0.000	+	1.060 0.000	1.060 0.000	1.060 0.000	1.060 0.001	1+3 2+3	1.059 0.000	1.060 0.000	+
26.	Relat. mass of fat by Siri (%)	16.80 0.20	16.71 0.15	16.80 0.12	16.92 0.21	+	16.93 0.22	16.69 0.12	+	16.93 0.21	16.84 0.13	16.88 0.10	17.06 0.24	1+3 2+3	17.13 0.20	16.80 0.13	+
27.	Mass of subcutaneous adipose tissue (kg)	10.72 3.12	8.35 1.81	10.78 1.54	13.68 3.25	+	12.63 3.39	9.01 1.58	+	12.73 3.24	10.33 1.63	12.30 1.54	16.08 3.16	+	15.74 2.87	10.98 2.09	+
28.	Relat. mass of subcutaneous adipose tissue (%)	18.41 3.28	17.66 3.13	18.64 2.17	19.28 3.30	1+3	19.77 3.38	17.21 3.32	+	20.50 2.80	19.77 2.27	20.46 2.38	21.52 2.49	1+3	22.27 2.63	19.18 2.75	+

Table 2. Means and standard deviations of basic anthropometric measurements and body composition characteristics in age groups of volleyballers (n = 46, age 13–16) and their correlation with age.

No	Variable	$\bar{x}$	SD	13 years n = 10		14 years n = 14		15 years n = 12		16 years n = 10		Statistically significant correlation with age (r)
				$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
1.	Weight (kg)	56.778	9.504	54.48	13.84	52.55	6.55	58.26	4.20	60.46	9.47	0.291
2.	Height (cm)	167.23	6.09	163.19	7.23	164.08	4.41	168.43	5.30	169.60	5.50	0.429
3.	Trunk length (cm)	50.24	5.52	49.56	7.29	49.36	5.81	52.03	5.23	49.98	3.31	–
4.	Upper limb length	72.69	4.09	71.63	5.83	70.74	2.29	73.77	3.83	75.21	2.87	0.375
5.	Lower limb length	87.60	5.62	87.50	3.72	85.76	6.56	88.68	6.36	88.99	4.88	–
6.	Biacromial breadth (cm)	35.33	1.62	34.90	2.14	34.89	0.76	35.33	1.60	36.35	1.68	0.319
7.	Pelvis breadth (cm)	25.67	1.54	24.90	1.82	25.39	1.40	26.00	1.04	26.45	1.66	0.367
8.	Chest depth (cm)	16.23	1.25	16.40	2.12	15.79	0.96	16.38	0.93	16.50	0.71	–
9.	Abdomen depth (cm)	15.48	1.31	15.15	2.11	15.36	0.93	15.25	0.94	16.25	0.98	–
10.	Femur breadth (cm)	8.69	0.57	8.54	0.76	8.64	0.50	8.78	0.52	8.83	0.53	–
11.	Ankle breadth (cm)	6.86	0.46	6.84	0.64	6.76	0.32	6.90	0.43	6.96	0.50	–
12.	Humerus breadth (cm)	6.17	0.39	6.22	0.44	6.90	0.33	6.21	0.43	6.17	0.41	–
13.	Wrist breadth (cm)	5.07	0.29	4.91	0.40	5.13	0.27	5.08	0.23	5.13	0.25	–
14.	Upper chest circumference (cm)	81.23	4.97	81.64	7.53	79.52	4.04	82.10	3.69	82.16	4.47	–
15.	Waist circumference (cm)	67.62	5.65	67.65	7.84	65.83	3.96	67.45	2.63	70.32	7.32	–
16.	Hip circumference (cm)	85.13	9.35	85.11	10.42	81.34	10.83	88.89	3.02	85.93	10.27	–
17.	Upper thigh circumference (cm)	55.09	5.94	54.20	8.16	52.94	5.50	56.80	1.99	57.12	6.65	–

Table 2. (continued).

No	Variable	$\bar{x}$	SD	13 years n = 10		14 years n = 14		15 years n = 12		16 years n = 10		Statistically significant correlation with age (r)
				$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
18.	Upper leg circumference (cm)	34.16	2.68	33.26	3.39	33.26	2.64	35.27	1.77	35.01	2.44	0.304
19.	Lower leg circumference (cm)	22.04	1.58	21.63	2.39	21.63	1.19	22.33	2.23	22.70	1.37	–
20.	Arm circumference (cm)	24.87	2.41	24.17	3.59	24.22	1.74	25.65	1.54	25.55	2.50	–
21.	Forearm circumference (cm)	22.45	1.60	21.92	2.15	21.91	1.39	22.89	1.14	23.18	1.48	0.328
22.	Wrist circumference (cm)	15.73	0.94	15.58	1.54	15.58	0.69	15.73	0.75	16.08	0.71	–
23.	Body mass index	20.26	2.58	20.25	3.98	19.51	2.26	20.58	1.79	20.92	2.14	–
24.	Mean skinfold (cm)	1.08	0.32	1.13	0.47	0.97	0.26	1.14	0.19	1.09	0.37	–
25.	Body density (g/cm^3)	1.061	0.000	1.061	0.001	1.061	0.000	1.061	0.000	1.061	0.001	–
26.	Relat. mass of fat by Siri (%)	16.63	0.21	16.69	0.28	16.56	0.19	16.69	0.13	16.62	0.24	–
27.	Mass of subcutaneous adipose tissue (kg)	7.98	2.94	8.33	4.46	6.83	2.06	8.54	1.38	8.55	3.45	–
28.	Relat. mass of subcutaneous adipose tissue (%)	13.86	3.24	14.41	4.29	12.84	2.73	14.67	2.18	13.75	3.85	–

Table 3. Means and standard deviations of basic anthropometric mesurements and body composition characteristics in body build classes of volleyballers (n = 46)

No	Variable	Small (n = 8)		Medium (n = 8)		Large (n = 6)		Significance 1–3	Pycnomorphs (n = 13)		Leptomorphs (n = 11)		Significance 4–5
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
1.	Weight (kg)	44.56	4.02	54.22	2.63	68.58	7.16	+	60.87	7.41	53.75	5.20	+
2.	Height (cm)	158.39	3.31	166.96	1.15	174.52	3.62	+	163.75	3.15	169.77	4.86	+
3.	Trunk length (cm)	45.33	1.32	49.61	1.90	52.17	2.34	+	52.17	7.18	50.92	6.45	–
4.	Upper limb length (cm)	68.93	4.10	73.64	3.14	76.18	4.03	+	71.11	2.81	74.72	3.42	+
5.	Lower limb length (cm)	83.01	4.85	88.95	2.08	93.30	1.93	+	84.19	5.64	90.87	4.25	+
6.	Biacromial breadth (cm)	33.81	1.56	35.44	0.98	36.33	2.34	+	35.61	1.45	35.45	1.25	–
7.	Pelvis breadth (cm)	24.19	1.62	25.94	0.78	27.00	2.05	+	25.69	1.38	25.82	1.05	–
8.	Chest depth (cm)	15.06	1.05	16.06	0.78	17.17	1.03	+	16.85	1.38	15.95	0.91	–
9.	Abdomen depth (cm)	14.31	1.67	15.63	1.03	16.75	0.69	+	15.96	1.23	14.95	0.57	+
10.	Femur breadth (cm)	8.05	0.49	8.66	0.39	9.05	0.68	+	8.90	0.49	8.75	0.44	–
11.	Ankle breadth (cm)	6.48	0.46	6.65	0.44	7.03	0.66	–	7.01	0.35	7.02	0.29	–
12.	Humerus breadth (cm)	5.88	0.28	6.18	0.30	6.57	0.37	+	6.10	0.41	6.23	0.36	–
13.	Wrist breadth (cm)	4.57	0.32	5.01	0.23	5.20	0.28	+	5.10	0.22	5.23	0.21	–
14.	Upper chest circumf. (cm)	76.29	2.73	79.71	2.24	86.18	3.02	+	85.29	4.50	78.42	2.72	+
15.	Waist circumf. (cm)	63.05	3.23	65.59	2.40	74.88	6.70	+	70.70	5.04	64.84	2.58	+
16.	Hip circumf. (cm)	75.91	11.73	86.89	3.39	88.17	13.9	–	89.01	8.58	84.31	2.64	–
17.	Upper thigh circumf. (cm)	47.31	4.54	55.34	1.96	59.60	8.00	+	59.03	3.21	53.45	3.66	+
18.	Upper leg circumf. (cm)	30.88	1.03	33.79	1.84	37.20	2.34	+	35.61	2.12	33.46	1.90	+
19.	Lower leg circumf. (cm)	19.94	1.12	21.30	0.60	23.95	0.84	+	22.71	1.03	22.29	1.31	–

Table 3. (continued).

No	Variable	Small (n = 8)		Medium (n = 8)		Large (n = 6)		Significance 1–3	Pycnomorphs (n = 13)		Leptomorphs (n = 11)		Significance 4–5
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
20.	Arm circumf. (cm)	22.10	1.77	24.34	1.09	27.13	2.09	+	26.88	1.52	23.67	1.35	+
21.	Forearm circumf. (cm)	20.44	0.99	21.69	0.70	24.05	1.49	+	23.67	1.07	22.14	0.87	+
22.	Wrist circumf. (cm)	14.64	0.64	15.33	0.70	16.58	0.78	+	16.22	0.80	15.77	0.68	–
23.	Body mass index	17.74	1.28	19.45	0.89	22.47	1.50	+	22.66	2.36	18.61	1.18	+
24.	Mean skinfold (cm)	0.83	0.17	1.00	0.20	1.38	0.28	+	1.33	0.28	0.86	0.21	+
25.	Body density (g/m^3)	1.06	0.01	1.05	0.01	1.05	0.01	–	1.05	0.01	1.06	0.01	+
26.	Relat mass of fat by Siri (%)	16.73	4.78	19.58	3.55	19.57	4.09	–	19.78	3.71	16.20	2.10	+
27.	Mass of subcutaneous adipose tissue (kg)	5.31	1.27	7.23	1.58	11.36	2.68	+	9.97	2.60	6.25	1.70	+
28.	Relat. mass of subcutaneous adipose tissue (%)	11.83	2.30	13.27	2.41	16.49	3.12	+	16.21	2.48	11.54	2.55	+

In volleyballers the mean values of some anthropometric variables showed a significant correlation with age (Table 2). These were weight, height, upper limb length, biacromial breadth, pelvis breadth, upper leg circumference and forearm circumference. None of the body composition characteristics revealed a significant correlation with age.

Changes of variables in the height-weight classification (Table 3) in volleyballers were analogous to those in schoolgirls. We could state the same systematic differences in classes 1–3 and also between classes 4 and 5 (see Table 2).

Discussion

Until now, literature has presented no generally recognized method of simultaneous classification of a large number of body measurements for growth-age girls. In this study, the authors presented such a classification as consisting of five SD classes of height and weight. While creating the classification, we relied on two aspects of classification that have been considered most important in literature – the necessity to distinguish between orders of magnitude (Knussmann 1961) and types (Kretschmer 1961). Orders of magnitude were distinguished in the height-weight concordant classes – small, medium and large. Types were distinguished according to the well-known typifying scheme of Kretschmer (1961).

The mentioned classification was applied in six separate age groups from 7 to 18 years for schoolgirls and as a common classification for volleyballers of different ages from 13 to 16 years. In the case of both samples we could show that such a method could be used to systematize comparatively length, breadth and depth measurements, circumferences and body composition characteristics.

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Adolescent female volleyballers' (aged 13–15 years) body build classification and proficiency in competitions

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With 1 figure and 2 tables

Summary: The present paper studies the body build and proficiency in the game of 74 female volleyballers aged 13–15 years from eight teams, who participated in Estonian championships. Fourteen anthropometric measurements were taken from the players, and these data were systematized into a 5 SD height-weight classification (small, medium, large, pyknomorphous and leptomorphous). The players participated in 28 matches, which were recorded in parallel with two computers equipped with the program *Game*. The girls' proficiency in the game was assessed in the same body build classes. For each class, the total number of serves, receptions, attacks and blocks, their mean values per player and percentage from elements performed during the whole tournament were calculated. In the same way, for each class the total number of points scored and separately the number of points scored in serve, attack and block were calculated. For each class the mean index of proficiency was calculated for serve, reception, attack and block. The results showed, that the most successful were the girls of class 3 with big height and weight. The small girls of class 1 were the least successful. The players belonging to the other classes formed an intermediate group. The authors recommend the use of the body build classification as it enables simultaneous assessment of body build and proficiency in competitions.

Key words: Young female volleyball players' anthropometry, body build classification, volleyball performance.

Zusammenfassung: Die vorliegende Untersuchung hat den Körperbau sowie die spielerische Leistungsfähigkeit von 74 Volleyballsspielrinnen im Alter zwischen 13 und 15 Jahren zum Gegenstand, die an den estnischen Meisterschaften teilgenommen haben. An diesen Spielerinnen wurden vierzehn anthropometrische Maße erfasst. Diese Daten wurden in eine 5 SD-Körperhöhen-Körpergewicht-Klassifikation (klein, mittel, groß, pyknomorph und leptomorph) eingeordnet. Die Spielerinnen nahmen an 28 Spielen teil, welche parallel mit zwei Computern aufgezeichnet wurden, die mit dem Programm *Game* ausgerüstet waren. Die spielerischen Leistungen der Mädchen wurden in diesen Körperbauklassen bewertet. Für jede dieser Klassen wurden die Gesamtzahl der Aufgaben, Annahmen, Angriffe und Blockierungen, ihre mittleren Werte pro Spielerin sowie der Prozentsatz dieser Elemente während der gesamten Spieldauer berechnet. In der gleichen Weise wurde für jede Klasse die Gesamtzahl der Punkte und getrennt die Zahl der Punkte für Aufgaben, Angriffe und Blockierungen berechnet. Außerdem wurde für jede Klasse der Leistungsindex für Aufgaben, Annahmen, Angriffe und Blockierungen ermittelt. Die Ergebnisse zeigten, dass am erfolgreichsten die Mädchen der Klasse 3 mit großer Körperhöhe und großem Körperge-

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wicht waren. Die kleinen Mädchen der Klasse 1 waren am wenigsten erfolgreich. Die zu den anderen Klassen gehörenden Spielerinnen nahmen eine Mittelstellung ein. Die Autoren empfehlen die Verwendung der Körperbauklassifikation, da sie gleichzeitig die Einschätzung von Körperbau und spielerischer Leistung in Wettkämpfen erlaubt.

Schlüsselwörter: Anthropometrie junger Volleyballspielerinnen, Körperbauklassifikation, Leistungen im Volleyball.

Introduction

Several well-known anthropometric studies of elite female volleyballers emphasize their greater height and weight, length of extremities, shoulder breadth, highly developed bone and muscle structure of extremities and the upper body (Häkkinen 1993, Viviani & Boldin 1993, Gualdi-Russo & Zaccagni 2001).

Build peculiarities of adolescent female volleyballers have received less attention; most researchers have confined themselves to height, weight and body fat content, which, however, remains insufficient (Avloniti et al. 2001, Martirosov 2001).

The need for detailed research into adolescent female volleyballers' body build is indicated by results that show that ball handling skills as well as physical and psychophysiological abilities are in close correlation with girls' age-related constitutional peculiarities (Thissen-Milder & Mayhew 1991, Kioumourtzoglou et al. 2000, Stamm et al. 2002).

The authors of the present paper have dealt with the problem in greater detail. They have conducted a thoroughgoing study of 13–16-year-old female volleyball players' anthropometric body structure and found essential correlations between body build, results of various tests and proficiency in competitions (Stamm et al. 2003, 2004).

Considering the above mentioned, we applied anthropometric measuring on a larger sample of 13–15-year-old girls participating in Estonian championships and analyzed the relations between anthropometric data and proficiency in the game.

Material and methods

Subjects

The sample consisted of 74 girls aged 13–15 years from the eight most successful volleyball teams of Class C (up to 16-year-olds), who participated in Estonian championships in Pärnu from May 21–22, 2004.

Anthropometric research

During intervals between matches, all the 74 girls were measured anthropometrically using the method of Martin (Knussmann 1988). Lower extremity length was measured according to the method of Jatsuta (1923). Anthropometric measurements were taken by a trained anthropometrist, who had previously shown a test-retest reliability of $r > 0.90$.

Fourteen body measurements were taken, that in the present authors' earlier research (Stamm et al. 2003, 2004) had shown significant correlations with proficiency in the game. These measurements were weight, height, suprasternal height, xiphoidal height, wrist breadth, upper chest circumference, lower chest circumference, waist circumference, hip circumference, upper thigh circumference, lower leg circumference, arm circumference, flexed and tensed arm circumference and wrist circumference.

Assessment of players' proficiency

To record the games, the original computer program *Game* was used, which was first presented by R. Nõlvak (Stamm) in 1995 and has been introduced in a special journal in the USA (Stamm et al. 2000, 2001).

For simultaneous recording of the performance of two opposing teams, two computers with the program *Game* were used. Parallel recordings were made by volleyball experts – the authors of the present paper M. Stamm and R. Stamm. All the participating teams played with one another once; thus, the total number of matches was 28, and 56 parallel recordings were made. Seventy-four players participated in the matches.

The assessment of players' proficiency proceeded as follows: during the match, the expert registered each case when a technical element (serve, reception, block, feint, attack or dig) was performed by a player. This was done by pressing three keys on the computer keyboard, thereby registering 1. the element performed, 2. the grade for its performance on a five-point scale (1 – excellent ... 5 – failed), and 3. the number of the player who performed the element. For all the elements, the program calculated each player's index of proficiency according to the following formula:

$$\text{Index of proficiency} = \frac{\text{number of performances} \times \text{maximum grade} - \text{sum of grades}}{(\text{maximum grade} - 1) \times \text{number of performances}}$$

Proficiency can range from 0 to 1, where 1 means, that in all the cases the element was performed excellently, and 0 a failure in all the cases.

In addition to the index of proficiency, the program calculates the following data for each set and for the whole game: 1. Number of performances of technical elements of the game (serve, reception, block, feint, attack, dig) for each player and for the whole team. 2. Average indices of proficiency of each element for each player and for the whole team. 3. Points scored by performing the elements by each player and by the whole team.

The data obtained from the computer program were further processed by the SAS program by one of the authors of the article – Säde Koskel, MSc. Säde Koskel also performed the statistical analysis of anthropometric data using the SAS program.

Then the proficiency of each player in performing the most significant elements of the game (serve, reception, block, and attack; number of points scored) was related to anthropometric measurements and analyzed in the body build classification formed from these anthropometric variables.

Statistical analysis

The data were analyzed using the SAS system. The mean values of the anthropometric variables were calculated and the variables' relations with age were found. The basis for creating the classification of girls with different age was the mean height, weight and their standard deviations for the whole sample. To create a 5 SD classification, first a classification

		Weight classes		
		Light	*Medium*	*Heavy*
Height classes	*Short*	Small		Pykno-
	Medium	Lepto-	Medium	morphic
	Tall	morphic		Large

Fig. 1. Body build classes.

consisting of $3 \times 3 = 9$ SD classes of height and weight (small, medium, big) was formed. From this classification, three classes of concordant height and weight were taken (small height – small weight; medium height – medium weight; big height – big weight). The remaining six classes were united into two classes of disconcordant height and weight (big weight and small height – pyknomorphs; small weight and big height – leptomorphs; see Fig. 1.

Thus, the five height-weight SD classes were created according to the following rules:

Class 1 (small)
weight $< \bar{x}_w - 0.5\ SD_w$ and height $< x - 0.5\ SD_h$

Class 2 (medium)
$\bar{x}_w - 0.5\ SD_w \leq$ weight $\leq + 0.5\ SD_w$ and $\bar{x}_h - 0.5\ SD_h \leq$ height $< 0.5\ SD_h$

Class 3 (large)
weight $\geq \bar{x}_w + 0.5\ SD_w$ and height $\geq \bar{x} + 0.5\ SD_h$

Class 4 (pyknomorphs)
weight $\geq \bar{x}_w - 0.5\ SD$ and height $< \bar{x}_h - 0.5\ SD_h$ or
weight $\geq \bar{x}_w + 0.5\ SD$ and height $< \bar{x} + 0.5\ SD_h$

Class 5 (leptomorphs)
weight $< \bar{x}_w - 0.5\ SD$ and height $\geq \bar{x}_h - 0.5\ SD_h$ or
weight $< \bar{x}_w + 0.5\ SD$ and height $\geq \bar{x}_h + 0.5\ SD_h$ (see Fig. 1).

Girls of different ages (13-15 years) were placed into the classes of a common height-weight classification according to their individual height and weight. Thereafter the average ages of girls of all classes were compared and as there were no statistically significant differences between the classes, the application of such a common classification was found to be justified (Stamm et al. 2001, Kaarma et al. 2005).

Then the means and standard deviations of all the anthropometric variables were calculated in all the five classes. Using the Scheffé test, the class means of all anthropometric data were compared between classes 1 and 3 but also between classes 4 and 5, using the significance level $\alpha = 0.05$ (Table 1).

The girls' proficiency in the game for the whole tournament was assessed in the same body build classes. For each class, the total number of serves, receptions, attacks and blocks, their mean values per player and percentage from elements performed during the whole tournament were calculated. In the same way we calculated for each class the total number of points scored and, separately, the number of points scored by serve, attack and block. Thus, in all classes the total number of girls who performed the respective elements was calculated, differentiating between the total number of serves, attacks and blocks performed and the number of those that ended by winning a point.

For each class also the mean index of proficiency was calculated for serve, reception, attack and block performances for the whole tournament.

The means of performance of elements of the game in different classes were compared using the Scheffé test; to compare percentages, the z-test was used.

Results

The mean and SD values of the 14 anthropometric variables measured are presented in Table 1. On average, the girls were tall (168.47 cm) and heavy (58.047 kg) for their age, thus surpassing the Estonian national averages for the respective age groups. The Estonian national height for girls aged 13–15 ranges from 158.15–164.92 cm and weight from 46.12–55.07 kg (Grünberg et al. 1998).

Table 1. Adolescent female volleyballer's (n = 74) anthropometric variables in body build classes.

No	Variable	Mean	SD	Small (n=10)		Medium (n=18)		Large (n=12)		Significance 1–3	Pyknomorphs (n=13)		Leptomorphs (n=11)		Significance 4–5
				$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		$\bar{x}$	SD	$\bar{x}$	SD	
1.	Height (cm)	168.47	6.28	159.88	4.23	168.83	1.81	176.93	5.53	+	165.77	3.55	170.54	4.27	+
2.	Weight (kg)	58.047	7.44	48.458	4.780	58.124	2.151	67.908	4.387	+	62.420	5.887	53.888	4.446	+
3.	Suprasternal height (cm)	136.53	5.79	128.63	3.69	137.06	2.13	144.22	5.01	+	134.33	3.10	137.99	4.48	+
4.	Xiphoidal height (cm)	120.35	5.06	113.91	3.61	120.60	2.32	126.92	4.97	+	118.92	3.05	121.22	3.82	–
5.	Upper chest circumf. (cm)	82.79	4.39	78.01	3.76	83.31	2.35	86.84	3.11	+	85.23	4.80	80.52	2.65	+
6.	Lower chest circumf. (cm)	74.52	4.32	70.73	2.59	75.06	2.41	78.38	4.62	+	76.79	4.96	71.81	2.35	+
7.	Waist circumf. (cm)	68.27	4.47	64.15	3.34	68.24	2.06	71.92	3.03	+	71.77	5.50	65.56	2.68	+
8.	Hip circumf. (cm)	88.59	5.13	83.36	3.63	88.03	2.55	32.96	3.58	+	92.05	4.79	86.83	5.40	+
9.	Arm circumf. (cm)	24.79	2.10	22.76	1.71	24.70	1.04	26.95	1.55	+	26.71	1.22	23.12	1.30	+
10.	Arm circumf. flexed and tensed (cm)	26.18	2.39	23.38	2.53	26.22	0.87	28.69	1.49	+	28.20	1.29	24.57	1.24	+
11.	Wrist circumf. (cm)	15.82	0.73	14.91	0.46	15.82	0.63	16.65	0.60	+	16.11	0.55	15.63	0.35	+
12.	Upper thigh circumf. (cm)	54.73	4.30	50.13	3.71	54.85	1.90	58.06	2.74	+	58.66	3.73	52.02	3.16	+
13.	Lower leg circumf. (cm)	22.30	1.39	20.93	0.93	22.15	0.84	23.75	1.34	+	22.32	0.99	21.98	1.50	–
14.	Wrist breadth (cm)	5.22	0.39	4.90	0.18	5.19	0.36	5.62	0.55	+	5.19	0.34	5.21	0.21	–

Table 2. Adolescent female volleyballer's (aged 13 – 15 years, n = 74) proficiency in the game according to body build.

No	Variable	Total			Body build classes: Class I (small) n = 10			
		n	x	total	n	x	total	%
1.	Points scored	55	33.15	182.30	3	31.0	93.0	5.10
2.	Serves							
	Point-winning serves	50	7.48	374.0	3	10.33	31.0	8.29
	Total serves	50	50.38	2519.0	3	56.00	168.0	6.67
3.	Retseptions							
	Total	41	52.12	2137.0	1	26.00	26.0	1.22
4.	Attacks							
	Point-winning attacks	27	37.30	1007.0	1	47.00	47.00	4.67
	Total of attacks	27	87.07	2351.0	1	99.0	99.0	4.21
5.	Blocks							
	Point-winning blocks	29	7.66	222.0	1	0.00	0.00	0.00
	Total of blocks	29	26.52	769.0	1	13.00	13.00	1.69
6.	Index of proficiency serve	50	0.44		3	0.47		
	reception	41	0.52		1	0.59		
	attack	27	0.64		1	0.70		
	block	29	0.52		1	0.32		

No	Variable	Body build classes: Class IV (pyknomorphs) n = 16				Class V (leptomorphs) n = 18			
		n	x	total	%	n	x	total	%
1.	Points scored	12	25.83	310.0	17.0	15	23.47	352.0	19.31
2.	Serves	10	7.16	71.0	18.98	13	5.85	76.0	20.32
	Point-winning serves								
	Total serves	10	44.9	449.0	17.82	13	46.31	602.0	23.90
3.	Retseptions	10	53.7	537.0	25.13	8	43.38	347.0	16.24
	Total								
4.	Attacks	4	38.75	155.0	15.35	5	35.20	176.0	17.48
	Point-winning attacks								
	Total of attacks	4	89.50	358.0	15.23	5	86.60	433.0	18.42
5.	Blocks	5	4.40	22.0	9.91	5	9.0	45.0	20.27
	Point-winning blocks								
	Total of blocks	5	20.60	103.0	13.39	5	30.80	154.0	20.03
6.	Index of proficiency	10	0.44			13	0.41		
	serve								
	reception	10	0.50			8	0.52		
	attack	4	0.65			5	0.62		
	block	5	0.49			5	0.53		

Body build classes								
Class II (medium) n = 18				Class III (large) n = 12				Statistically significant
n	x	total	%	n	x	total	%	differences between classes
13	32.23	419.0	22.98	12	54.08	64.90	35.60	1+4, 2+4, 3+4.1+5, 3+5
12	7.83	94.0	25.13	12	8.50	102.0	27.27	1+4, 2+4, 3+4, 1+5
12	53.17	638.0	25.33	12	55.17	662.0	26.28	1+4, 2+4, 3+4, 1+5, 4+5
11	58.91	648.0	30.32	11	52.64	579.0	27.09	1+4, 2+4, 1+5,2+5, 3+5, 4+5
7	30.0	210.0	20.85	10	41.90	419.0	41.61	1+4, 2+4, 3+4, 2+5, 3+5
7	76.29	534.0	22.71	10	92.70	927.0	39.43	1+4,2+4,3+4,1+5,2+5,3+5
8	6.00	48.0	21.62	10	10.70	107.0	48.20	1+4, 2+4, 3+4, 1+5, 3+5
8	18.38	147.0	19.12	10	35.20	352.0	45.77	1+4, 2+4, 3+4, 1+5, 3+5
12	0.46			12	0.42			—
11	0.53			11	0.52			—
7	0.62			10	0.64			—
8	0.53			10	0.54			—

Statistically significant differences between classes
1+4, 2+4, 3+4, 1+5, 3+5
1+4, 2+4, 3+4, 1+5
1+4, 2+4, 3+4, 1+5, 4+5
1+4, 2+4, 1+5, 2+5, 3+5, 4+5
1+4, 2+4, 3+4, 2+5, 3+5
1+4, 2+4, 3+4, 1+5, 2+5, 3+5
1+4, 2+4, 3+4, 1+5, 3+5
1+4, 2+4, 3+4, 1+5, 3+5
–
–
–
–

Significant correlations with age were found in six variables – weight (r = 0.311), and circumferences of upper chest (r = 0.33), hip (r = 0.23), arm (r = 0.40), upper thigh (r = 0.34) and lower leg (r = 0.27).

Thereafter, we correlated all the girls' body measurements between themselves and found that all the variables were in significant correlation, and all the variables had the strongest correlations with height and weight.

Then we correlated all the anthropometric variables with individual indices of proficiency for elements of the game and individual numbers of points achieved. We found statistically significant correlations between wrist circumference and proficiency index of attack (r = 0.375). Reception of serve was essentially better in the case of smaller circumference of lower chest (r = – 0.346), waist (r = – 0.411) and hip (r = – 0.343).

The total number of points won in the game correlated with greater height (r = 0.290), xiphoidal height (r = 0.306), suprasternal height (r = 0.303) and wrist breadth (r = 0.423).

Analysis of the impact of age on performance of the elements of the game revealed that there was only one (negative) statistically significant correlation with the efficiency of attack (r = –0.418). Therefore, considering that all the girls belonged to the same competition class (C), we are further not going to take into account the impact of age on proficiency in the game.

To characterize body build not only by separate variables but also from the viewpoint of the body as a whole, we formed a body build classification from the 14 variables measured (see Table 1) and found statistically significant gradual increase in weight, height, trunk and extremities circumferences, wrist breadth in classes small-medium-large and the most typical significant differences between pyknomorphous and leptomorphous girls (Table 1).

Such systemic changes in body build classes gave us reason to use namely such a classification for analyzing the data of proficiency in the game on the basis of body build.

In Table 2 we present the data of proficiency in the game according to body build classes. As we can see, there are significant differences in proficiency between classes.

The least successful were the girls of the first class – with small weight and small height. The ten girls belonging to this class brought their teams only three points. Attacks and blocks were performed by only one player, serves – by three and receptions by one.

The most active players belonged to the third body build class – girls with big height and big weight. All twelve of them scored points for their teams and were successful at serve. Ten of them performed successful attacks and blocks, and eleven – receptions.

The players of other classes 2, 4 and 5 occupied an intermediate position.

Out of the total number of points (1823), the girls of class 1 scored 5.10 % and the girls of class 3 scored 35.60 %; classes 2, 4 and 5, respectively, scored 22.98 %, 17 % and 19.31 %.

Analogously, there were differences between classes 1 and 3, and 2, 4 and 5. The number of successful attacks in class 1 (47) and class 3 (419) differed by almost nine times. The results of the girls in classes 2, 4 and 5 had intermediate values. Successful blocks, serves and receptions, and receptions in general, were most often performed by girls of class 3.

However, if we compare the mean indices of proficiency in performing separate elements, we do not notice essential differences between the classes. The reason lies in the fact that there were successful players in all the classes; there were also players with relatively modest abilities (except in class 3).

Discussion

The present study confirmed once again the viewpoint expressed in literature (Thiessen-Milder & Mayhew 1991, Stamm et al. 2002) that adolescent female volleyballers' body build is essential for proficiency in the game.

Body build has been characterized by height, weight and body fat content (Farkas et al. 1991, Malina 1994). Several anthropometric variables have been used to predict proficiency in performance of different elements of the game (Stamm et al. 2001, 2003).

We have studied in detail the anthropometric structure of adolescent volleyballers' body build and found, that it does not differ in principle from the body build structure of ordinary schoolgirls of the same age (Stamm 2004, Kaarma et al. 2005). This enabled the authors to use for volleyballers' anthropometric data the same body build classification as for schoolgirls of the same age.

Anthropometric data were collected from eight most successful volleyball teams of the 13-15 years age group at Estonian championships in May 2005.

In 74 girls, 14 body measurements were taken, which, as the authors' earlier research had shown, were essential for proficiency in the game.

To assess proficiency, all the matches were recorded using the original computer program *Game* created by the authors. For the first time in Estonia, two computers were used in parallel for simultaneous recording of the performance of opposing teams. Seventy-four players participated in the matches; the present study analyzed number of performances of the most essential elements of the game – serve, reception, block and attack – for each player, the number of points a player brought to her team and individual proficiency of performance of the elements of the game. The computer program *Game* recorded the activity of all the players within their teams. To compare the data of all players between the eight teams, the SAS program was used. All the girls were placed into a common body build classification and the means of anthropometric variables and data characterizing proficiency were calculated for all the classes. The results showed that such a classification proved to be appropriate for classifying the anthropometric data as well as for comparing the results achieved in the game. The most successful were the girls of class 3 with big height and weight. The small girls of class 1 were the least successful. The players belonging to other classes formed an intermediate group. As the girls were placed into classes relying on body build data only, then all the classes included girls with different individual proficiency. Therefore, the mean indices of proficiency did not differ significantly between the classes.

In summary, one might say that the body build classification applied by the authors proved to be appropriate for simultaneous assessment of body build and proficiency in the game.

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A System for Recording Volleyball Games and Their Analysis

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The article provides an overview of a new, original volleyball recording program, *Game*, which has been devised on the basis of recording systems used before. The advantages of the new computer program include its simplicity of use (the application of the program can easily be learned by anyone interested in the matter), and modest requirements for equipment and labor, as the whole game of a team (performance of nine technical elements) can be recorded by one portable computer (which has at least 386 processor with at least 2 Mb of memory and 5 Mb free hard disk space; the program works with MS-DOS 6.0 and higher) and one recording assistant. By means of the volleyball recording program, *Game*, the performance of a university female volleyball team was studied at the Estonian Championships in 1994 and 1995. The efficiency of performing technical elements for each player separately as well as for the whole team was calculated after each game, and the results of two years were compared. As the data can be summed up after each game as well as during the game and can be compared with previous games, the program was of great help for the coach in modifying tactics of the current game and in preparation for following ones. It also gives the coach the knowledge which player should pay more attention to practicing specific technical elements. The use of recording and the conclusions drawn by the coach on its basis were also one of the reasons why the team under investigation was placed third at the championships of the country in the first year of the study and achieved first place in the second year. Analysis of the data showed that serving had improved significantly, its efficiency being 0.48 in the first year and 0.56 in the second year. Digs (0.61 in the first year and 0.81 in the second year) and blocks (0.38 and 0.53 respectively) also improved. Player proficiency had increased or decreased during the period under discussion. The composite index of quality for all players for each game separately and its correlation with the number of games $r = 0.68$ was calculated. It was also found that $p = 0.014$, was positive and statistically reliable. On the basis of these data, it can be concluded that over the period studied, the quality of the games improved.

Key words: statistical system; volleyball

In order to improve the quality of volleyball games, assess the level of players, help the coach make appropriate decisions, and analyze the contribution of each player, games should be recorded. In this article, an original Estonian system for recording volleyball games using the computer program, *Game,* is presented.

Review of Literature

While creating the program, several recording systems were considered (Aunin, 1973, 1969; Huimerind, 1971; Amalin, 1973), as well as Fiedler's system for young German volleyballers (1978). In Finland, a very interesting graphic recording program *Sportgame Volley Ver 2.x Lentopallon atk - ohjelma* (Oulu, et al., 1993) has bee used, which enables one to record in a very simple way, at only one keystroke, who did what and how they did it. The FIVB (International Volleyball Federation) uses the *Volleyball Information System, Version 2.51* by which it is possible to evaluate both teams simultaneously. Unfortunately, such a system of recording requires at least three computers and five experts to record a game. Viera and Ferguson (1996) and Neville (1990) also consider recording most essential. There is no doubt that volleyball games should be recorded. This is necessary in order to evaluate the performance of each player as well as the technical and tactical peculiarities of the entire game. The possibility of saving data collected and comparing the technical development of the game in subsequent years enables the assessment of players' development and efficiency of coaching while comparing objectively the level and development of several teams (Nederlandse Volleybal Bond, 1995; Rieuwers, 1994; Viera & Ferguson, 1996)..

Naturally, the most advanced method of recording is through computer and video (Frohner, 1995; McGown, 1994), where one can visually watch the performance of both teams, and by the special FIVB program (Volleyball Information System for DOS Software, 1992-1997), which simultaneously needs three computers and five recording assistants. This kind of equipment and number of trained experts, however, are not affordable for everyone interested in the matter and can be applied only at major sports centers for most important games (Huimerind, 1971). In Estonia, this system was used during the World Championship Prequalification Tournament last year.

Daily life, however, requires that Estonian championships and games of local importance for both adults and children should be recorded and analyzed later (Kurg, 1977; Liik, 1994). Students and younger coaches could be used for this kind of work. Statistical analysis of data after the games is also within the abilities of students of physical education who have acquired computer skills.

METHODS

When devising the new system of recording and the respective computer program based on it, the following principles were followed:

1. The program should be as simple to use as possible so that it could be widely applied.
2. It should provide as precise information on the progress of the game as possible.
3. As many activities as possible should be recorded during the game.
4. Possibly few people and computers should be used for assessing the performance of the team.
5. It should be possible to preserve and analyze the data obtained while recording the games.

The program registers nine elements of the game. Each of them can be evaluated according to a corresponding scale. These nine elements are serve, serve from jump, reception, attack from zone 2, attack from zone 3, attack from zone 4, feint, block and dig.

The registration of the elements has been made as simple as possible with the aim of achieving great speed and precision at recording them. Each element can be entered by three keystrokes (the first of them determines the element, the second the grade, and the third the player who performed it).

The game can be currently analyzed (for example during the intervals). Rapid analysis can be obtained during the game according to the players and elements performed. Proficiency is calculated by the following formula:

$$\frac{\text{number of performances} \times \text{maximum grade} - \text{sum of grades}}{(\text{maximum grade} - 1) \times \text{number of performances}}$$

The program's requirements for environment

The program has been developed in Paradox 4.5 for DOS. Technical requirements: at least 386 processor with at least 2 Mb of memory and 5 Mb of free hard disk space. The program works with MS–DOS 6.0 and higher. The program is compatible with Windows 95.

Proficiency of the female team of Tallinn Pedagogical University at Estonian Championships and analysis of proficiency

In order to assess the quality of the program *Game* and check its reliability, recordings were made at Estonian championships in two consecutive years — 1994 and 1995, and the performance of the women volleyballers of Tallinn Pedagogical University was evaluated. The team achieved third place in 1994 and first place in 1995.

The statistical part of the program enables us to calculate the sum of grades for each player (Figure 1) and for each element (Figure 2), the statistical average of grades, and separately, the index of proficiency according to the formula presented above.

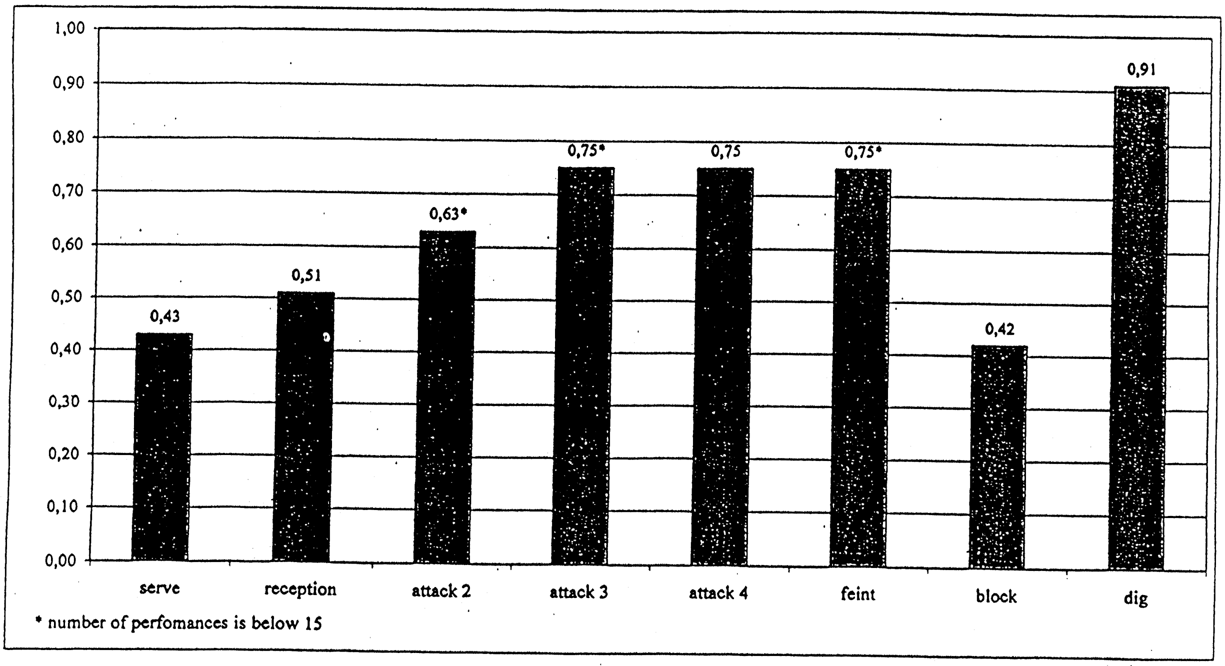

Figure 1. E.K. proficiency of different technical elements in 1995

Statistical processing of the data obtained continued in the following way:

1. Correlations between all the elements performed by a player were calculated.
2. Correlations between different elements performed by different players were calculated.
3. Average indices of the team's proficiency, taking into account all the technical elements in 1994 and 1995, were calculated, then the significance of differences was assessed by Student t-test.

RESULTS AND DISCUSSION

As a result of this investigation, it was found that the serve had become significantly more proficient. In 1994, the average grade of the efficiency of serve for all players was 0.48 and in 1995, 0.56. On the contrary, reception was considerably worse in the second year than in the first year, the grades being 0.58 and 0.49, respectively. The efficiency of attacks from all zones did not increase statistically significantly. The efficiency of feints did not improve essentially either. However, the efficiency of blocking (0.38 in the first year and 0.53 in the second year) and dig (0.61 in the first year and 0.81 in the second year) increased considerably. Thus, it can be concluded that the team of Tallinn Pedagogical University became champions of Estonia as a result of improvement in three technical elements — block, dig and serve.

Also, players whose proficiency had steadily risen or decreased from one game to another was found. While observing the correlations between technical elements, we found that the strongest correlation existed between serve and dig. This is rather logical as after a very strong serve it is more difficult for the opponents to take up an attack, and therefore the ball is more easily caught during the dig.

A summary table of proficiency for two seasons is presented (Table 1), which shows that the most successful player was the attacker T. S., followed by A. S. and R. N. The program *Game* enables the coach to see who was the best at attack or who at reception (Figure 2), and thus plan the structure of training and the tactics of the team for the following season. It also reveals which technical element each player should pay more attention to.

TABLE 1 – Comprehensive table of proficiency over two seasons

Name		Serve	Reception	Attack 2	Attack 3	Attack 4	Feint	Block	Dig	Total
E.K.	Proficiency	0.447	0.597	0.708	0.800	0.675	0.643	0.363	0.716	0.619
	Number of grades	103	129	12	5	100	21	51	74	*0.573
	Average grade	3.21	2.61	1.58	1.40	1.65	1.71	2.27	1.28	
M.L.	Proficiency	0.493	0.618	0.656	0.500	0.628	0.529	0.453	0.765	0.580
	Number of grades	152	136	32	2	207	35	53	102	*0.591
	Average grade	3.03	2.53	1.69	2.00	1.74	1.94	2.09	1.24	
E.L.	Proficiency	0.474	0.585	0.636	0.553	0.538	0.450	0.453	0.570	0.532
	Number of grades	95	123	22	19	117	20	86	86	*0.532
	Average grade	3.11	2.66	1.73	1.89	1.92	2.10	2.09	1.43	
R.N.	Proficiency	0.518	0.438	0.500	1.000	0.444	0.600	0.512	0.667	0.585
	Number of grades	123	12	29	3	9	20	86	60	*0.559
	Average grade	2.93	3.25	2.00	1.00	2.11	1.80	1.98	1.33	
T.O.	Proficiency	0.656	0.439	0.000	0.000	0.500	0.500	0.000	0.667	0.345
	Number of grades	8	33	0	0	3	3	1	9	*0.439
	Average grade	2.38	3.24	0.00	0.00	2.00	2.00	3.00	1.33	
K.P.	Proficiency	0.565	0.591	0.625	0.000	0.750	0.633	0.455	0.588	0.526
	Number of grades	69	11	16	0	2	15	55	34	*0.558
	Average grade	2.74	2.64	1.75	0.00	1.50	1.73	2.09	1.41	
P.R.	Proficiency	0.602	0.485	0.667	0.000	0.750	0.625	0.458	0.839	0.553
	Number of grades	32	34	3	0	8	4	12	31	*0.642
	Average grade	2.59	3.06	1.67	0.00	1.50	1.75	2.08	1.16	
A.S.	Proficiency	0.502	0.593	0.635	0.689	0.641	0.561	0.473	0.638	0.591
	Number of grades	147	153	52	53	39	41	167	94	*0.591
	Average grade	2.99	2.63	1.73	1.62	1.72	1.88	2.05	1.36	
T.S.	Proficiency	0.607	0.450	0.700	0.788	0.692	0.625	0.557	0.860	0.660
	Number of grades	56	40	20	26	13	12	79	43	*0.660
	Average grade	2.57	3.20	1.60	1.42	1.62	1.75	1.89	1.14	
R.S.	Proficiency	0.500	0.750	0.500	0.000	0.000	0.400	0.400	0.600	0.394
	Number of grades	25	3	2	0	1	5	10	15	*0.500
	Average grade	3.00	2.00	2.00	0.00	3.00	2.20	2.20	1.40	
K.S.	Proficiency	0.450	0.529	0.629	0.660	0.627	0.600	0.449	0.625	0.571
	Number of grades	130	136	58	78	63	45	166	64	*0.571
	Average grade	3.20	2.88	1.74	1.68	1.75	1.80	2.10	1.38	
I.T.	Proficiency	0.455	0.530	0.661	0.500	0.500	0.630	0.449	0.678	0.550
	Number of grades	133	25	28	1	7	23	68	121	*0.550
	Average grade	3.18	2.88	1.68	2.00	2.00	1.74	2.10	1.32	

* Sum of proficiency for two seasons if the number of performances of activity exceeded 15

In further statistical calculations we did not take into consideration the players who had performed an element less than 15 times. Therefore, Figure 2 also presents the number of performances of an element by each player.

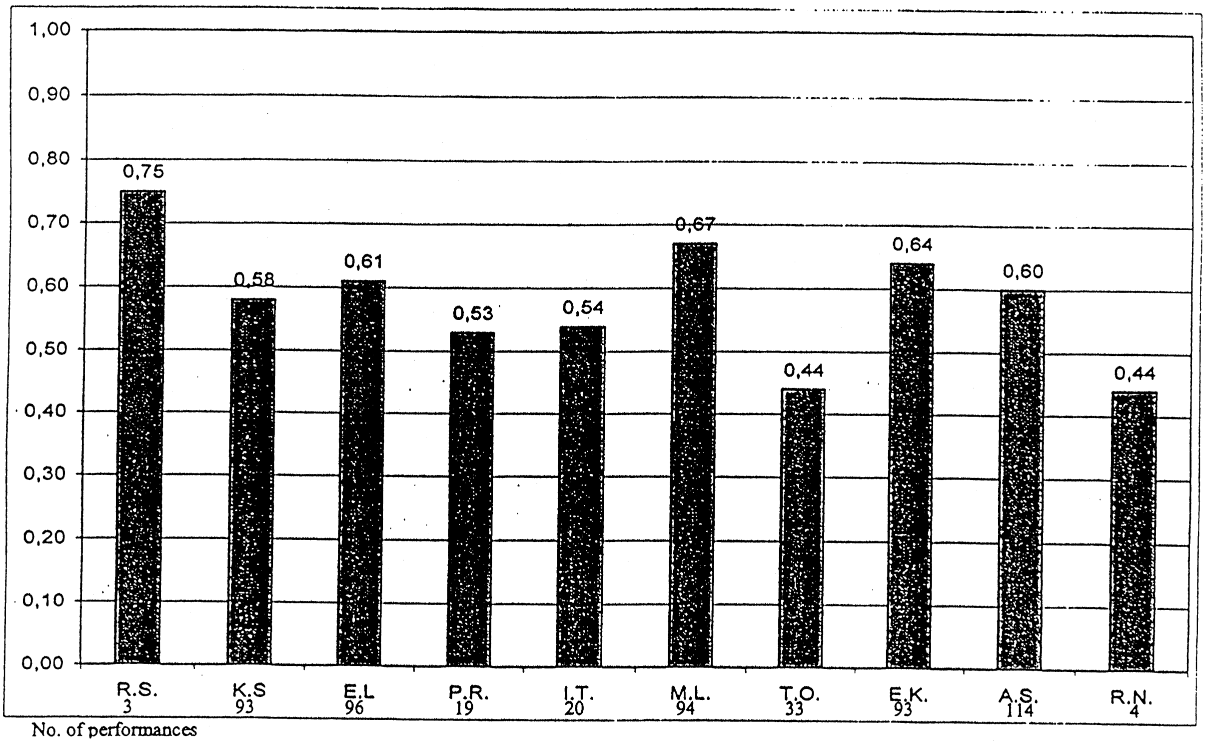

Figure 2. Proficiency of the reception and number of performances in 1994

In the course of data analysis, another interesting index was calculated: the composite index of quality of all players and performance of all technical elements for all the games separately. Also calculated was its correlation with the number of games (r=0.6803). It was also found that p=0.14, being positive and statistically reliable. Taking into account the above mentioned, it can be stated that, with the increase in the number of games, the quality of games improved.

CONCLUSION

The computer program, *Game,* has been presented in this article, which was created in Estonia. To record a game using this program, only one computer and one recording assistant were needed. Also introduced was a longitudinal study and statistical analysis with the help of this program.

Performance of the female team of Tallinn Pedagogical University at Estonian championships was recorded during two years. In the first year of recording, the team achieved the third place, and in the second year became the champions of Estonia.

IMPLICATIONS FOR COACHES

The volleyball recording program, *Game,* is simple to use. It enables coaches to record the proficiency of performance of nine technical elements in the game, while utilizing only one computer and one recording assistant. Recording of volleyball game proficiency is necessary for the coach to get objective information on the performance of technical elements by players.

Knowing the players' level of technical elements performance, the coach can plan practices, taking into consideration the individual skills of all the players. Analyzing the data gathered about the team, the coach can modify team tactics.

Immediately receiving data on proficiency during the game, the coach can make appropriate changes and attempt to alter the course of the game. Through the application of the recording system, *Game,* it is possible to follow the players' development in performing technical elements, objectively evaluate the game, and find the most proficient players of the tournament or the season.

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Young Female Volleyball Players' Anthropometric Characteristics and Volleyball Proficiency

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The purpose of the study was to analyze the role of a number of anthropometric characteristics in the performance of female volleyball players in the 13- to 16-year-old age group at competitions. The sample consisted of female volleyball players (N = 33), aged 13–16 years. A special anthropometric study included 43 body measurements. To assess proficiency in the game, an original volleyball recording program, *Game* (Stamm, Stamm, & Oja, 2000), was used to record all the main elements of the game and to calculate the index of proficiency of their performance. Thereafter, the proficiency index of all elements of the game was correlated with all the anthropometric data. Anthropometric variables that statistically correlated with performance were used to form respective linear predictive models.

Anthropometric measurements were significant in all the five main elements of the game, determining the efficiency of their performance within 32–83 percent. They proved to be most essential for attack, block and feint (71–83 percent). Along with weight and height, the significant anthropometric variables included circumferences of the trunk (chest, waist and hips) and the extremities (relaxed arm circumference, flexed and tensed arm circumference, upper thigh, wrist and lower leg circumference).

REVIEW OF LITERATURE

The game of volleyball requires the application of a variety of different abilities (Buck, 1990; Dufer, 1996; Stamm et al., 1997, 1999; Zadrasnik, 1999). A significant role also belongs to the individual features of the players' body build. Until now, only a relatively small number of variables such as height, weight (Malina, 1994), proximal, mean and distal thigh circumferences (Häkkinen, 1993), and skinfolds to determine the total mass of adipose tissue (Thisser-Milder, Mayhew, 1991; Smith et al., 1992; Häkkinen, 1993) have been studied. There is no clarity about the significance of other anthropometric characteristics and the anthropometric structure of the body, as a whole, for successful game performance.

Therefore, there is a need for more detailed research involving the anthropometry of young volleyball players. The aim of the present study was to analyze the role of a number of anthropometric characteristics in the performance of 13- to 16-year-old female volleyball players at competitions. The methodology of the anthropometric study relied on long-term research carried out on many populations at the Center for Physical Anthropology, University of Tartu (Kaarma, 1995).

METHODS

The sample consisted of 33 female volleyball players, aged 13–16 years (M = 14.61 ± 0.36). All of them practiced volleyball regularly and participated in championships in the age group of 13- to 16-year-olds. They were healthy and their sexual development corresponded to Tanner's stages III–V (Thissen-Milder & Mayhew, 1999). The series of anthropometric measurements was taken by a trained anthropometrist, who had previously shown test-retest reliability of $r > 0.90$.

The females were measured according to the classical method of Martin (Knussmann, 1988). For measuring skinfolds, similar methodology was used (p. 274). To measure lower extremity length, the Jatsuta method was used. It has been widely accepted in Russia and has been the principal method used in Estonia since Aul's work (1977).

Body height was measured in centimeters (± 0.1 cm) using a Martin metal anthropometer and body weight in kilograms (± 0.05 kg) on medical scales. Depth and breadth measurements were assessed with Martin calipers, circumferences with a metal measuring tape, and skinfolds with Holtain skinfold calipers. A total of 43 body measurements, including 11 skinfolds, were taken.

To determine length measurements (n = 10), body stature and the height from the ground of a number of classical anthropometrical points (processus xiphoideus, symphysion, spina iliaca anterior superior, acromion, dactylion) were measured with an anthropometer. From the differences between the heights of these points, several projected segment lengths were calculated in the following way: sternum length was the difference between suprasternal height and xiphoidal height; abdomen length was the difference between xiphoidal height and symphyseal height; upper limb length was the difference between acromial height and dactylion height. Lower limb length was calculated by the method of Jatsuta (1923), where half of the difference between iliospinal height and symphyseal height was added to symphyseal height.

The breadth-depth measurements taken (n = 6) were biacromial, chest, waist and pelvic breadths, chest and abdomen depths. To assess the thickness of limb bones, femur, ankle, humerus and wrist breadth were measured. The circumferences measured included head, neck, upper and lower chest, waist, pelvis, hip, proximal and mid-thigh, upper and lower leg, forearm and wrist, arm relaxed and arm flexed and tensed (n = 15). The measured skinfolds (n = 11) were chin, chest, side, abdominal, subscapular, triceps, biceps, waist, suprailical, thigh and calf.

To assess the players' proficiency at competitions, an original volleyball recording program, *Game*, devised by the authors (2000), was used (Nõlvak, 1995; Stamm et al., 2000). The data were recorded at Estonian Championship and Cup matches for up to 16-year-olds with the participation of the 33 players under study.

All the females played on the teams where they practiced. The games were recorded within three months in different cities of Estonia where the matches took place. All the players were assessed on the basis of at least four matches. Technically, the assessment of players' proficiency proceeded as follows: during the game, a recording assistant (a volleyball expert) fixed the performance of each technical element by each player of a team by pressing, according to the computer program, three keys on the computer keyboard. The following was recorded: (1) which element of the game was performed; (2) grade for its performance on a five-point scale (1-excellent ... 5-failed); (3) the number of the player who performed the element.

Each player's proficiency in all elements performed was calculated by the following formula:

$$\text{Index of proficiency} = \frac{\text{number of performances x maximum grade - sum of grades}}{\text{(maximum grade - 1) x number of performances}}$$

Proficiency ranged from 0 to 1, where 1 represented in all the cases the element was performed excellently, and 0 — failure in all the cases.

Data were processed using the SAS-system at the Institute of Mathematical Statistics, University of Tartu. Comparison of means (t-test), correlation analysis, and linear regression with stepwise argument selection were used.

RESULTS AND DISCUSSION

The present study attempted to link the analysis of proficiency in games with the players' individual anthropometric characteristics. The mean index of proficiency at serve was 0.545 (SD = 0.279), at reception 0.513 (SD = 0.183), at feint 0.657 (SD = 0.246), at block 0.523 (SD = 0.360), and at spike 0.563 (SD = 0.226). The mean value of the proficiency index was 0.539 (SD = 0.161). None of these indicators was correlated with age.

Thereafter, the proficiency index of all elements of the game was correlated with all the anthropometric data. From the anthropometric variables statistically significantly linked with performance, linear models were formed to predict game proficiency. There were 14 such significant arguments. None of the characteristics showed any statistically significant correlation with age.

For comparison, the anthropometric data of the young female volleyball players were compared with the same characteristics of schoolgirls who did not practice volleyball (n = 586). The volleyball players' data were expressed on the scale of z-scores of ordinary females of the same age. The average z-scores of volleyball players' anthropometric measurements differed considerably from the average z-score of the control group (which was 0) in four cases: height, wrist circumference and proximal thigh circumference were larger; hip circumference was smaller.

In order to define the relationship between the variables studied and their role in the composition of the body as a whole, all variables were correlated between themselves. The strongest correlations existed between other characteristics and height and weight. Height and weight turned out to be the leading characteristics – determiners of the body as a whole – because only from height and weight was it possible to predict all the other variables within 20–90 percent. Consequently, because of the regularity of the body build system, each variable represented not only a concrete measurement of the body, but also partially represented the body as a whole. Thus, the peculiarities of the whole body can be represented by height and weight, as well as by different combinations of other anthropometric variables or by height and weight in combination with other measurements.

Next, by means of stepwise selection, the best models of linear regression for predicting the proficiency in different elements of the game were found (see Table 1). As shown in Table 1, antrhopometric characteristics were essential for all five main elements of the game, determining their efficiency within 32–83 percent. Those most essential (71–83 percent) included the attack, block and feint.

Table 1
Optimum anthropometric models for prediction of efficiency in different elements of volleyball (N = 33). All parameters in the models are significant ($p < 0.05$).

No.	Predicted variables	Regression equations	R-square
1	Efficiency of serve	$-0.99 - 0.02x_1 - 0.03x_2 + 0.06x_3 + 0.09x_9$	0.32
2	Efficiency of reception	$3.36 + 0.03x_1 - 0.09x_3 + 0.08x_4 + 0.55x_{14} - 0.02x_5 - 0.13x_{11}$	0.50
3	Efficiency of block	$-3.48 + 0.07x_1 + 0.06x_2 - 0.16x_{12}$	0.80
4	Efficiency of feint	$-3.22 - 0.05x_1 - 0.06x_2 + 0.11x_3 - 0.07x_7 + 0.03x_8 + 0.19x_9$	0.83
5	Efficiency of attack	$6.44 + 0.05x_1 - 0.03x_2 - 0.04x_6 + 0.12x_{13} - 0.12x_{10}$	0.71

Explanatory variables of models:
x_1 - weight (kg)
x_2 - height (cm)
x_3 - ziphoidal height (cm)
x_4 - suprasternal height (cm)
x_5 - upper chest circumference (cm)
x_6 - lower chest circumference (cm)
x_7 - waist circumference (cm)
x_8 - hip circumference
x_9 - arm circumference relaxed (cm)
x_{10} - arm circumference flexed and tensed (cm)
x_{11} - wrist circumference (cm)
x_{12} - upper thigh circumference (cm)
x_{13} - lower leg circumference (cm)
x_{14} - wrist breadth (cm)

As weight and height are the most often used anthropometric variables, regressions were also compiled from models relying only on height and weight. These models, however, did not prove statistically significant for predicting any of the game elements. Other body characteristics were then added sequentially that were significantly correlated with the respective elements of the game, making sure that all the characteristics in the model were significant ($p<0.05$).

While observing height and weight in the models among other arguments, weight was essential in three models (reception, block and attack) out of five. Height has a mostly negative value in the formulae, except in the case of the feint. At the same time, some other length measurements also have a positive value. Therefore, in the case of serve and feint, xiphoidal height had a positive value, while in reception, suprasternal height had a positive value. The length measurements were replaced by the indicator of leg strength in the form of lower leg circumference in the attack only. The muscle and bone strength necessary for volleyball are demonstrated by arm and thigh circumferences, lower leg and wrist circumferences, and wrist breadth.

CONCLUSION

The results of this investigation indicate the need for more comprehensive anthropometric studies of young volleyball players. The preconditions for volleyball proficiency are a certain size in weight and height, trunk (chest, waist and hip circumferences), extremity circumferences (relaxed arm circumference and flexed and tensed arm circumference, proximal thigh, wrist and lower leg circumference), and wrist breadth. The available literature did not contain any analogous data that could have been used for comparison.

In the future, the analysis of young female volleyball players' anthropometric characteristics by various other complex testing programs will facilitate the better selection of promising players and help to evaluate the development of the whole team.

IMPLICATIONS FOR COACHING

As young female volleyball players' proficiency in the game depends on the characteristics of their body build, then it would be advisable to add a program of anthropometric measurements in conjunction with other data collected.

Anthropometric measurements should be taken by trained anthropometrists who use standardized methods and appropriate instruments. The measurements should not be limited to height and weight only. The data suggest the other essential dimensions include trunk (chest, waist and hip) and extremity circumferences (relaxed arm circumference, flexed and tensed arm circumference, proximal thigh, wrist and leg circumference), and wrist breadth.

The coach may use the anthropometric data for assessing the physical development of each player, as well as of the whole team, for comparison with other teams and for correlating them with the team's achievements at competitions.

If, however, one is interested in correlations between body measurements of individual players and the efficiency of performing different elements of the game, matches should be recorded, proficiency index calculated, and respective regression models formed.

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