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Anaerobic Power and Dependence on Chosen Anthropometric Parameters in Young Handball Players

Marcin Luszczyk
Department of Physiology, Jedrzej Sniadecki Academy of Physical Education and Sport in Gdansk, Poland,
marcinl@awf.gda.pl

Radoslaw Laskowski
Jedrzej Sniadecki Academy of Physical Education and Sport in Gdansk, Poland

Ewa Ziemann
Jedrzej Sniadecki Academy of Physical Education and Sport in Gdansk, Poland

Tomasz Grzywacz
Jedrzej Sniadecki Academy of Physical Education and Sport in Gdansk, Poland

Anna Szczesna-Kaczmarek
Jedrzej Sniadecki Academy of Physical Education and Sport in Gdansk, Poland

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Abstract

Background: The main aim of the present study was an attempt to answer the enquiries concerning the influence of physical training on morphological changes (anthropometric indicators), capability of anaerobic work and their interactions with a natural development of youth in pubertal and post-pubertal age. Material/Methods: The technique of parallel groups was used: experimental (handball trained [TR]) and control (not trained [NT]). The research period comprised two consecutive years. Once per year selected somatic parameters, body composition, biological age, and anaerobic parameters were determined by means of 30 s Wingate Anaerobic Test (WAnT). Results: Results have shown the high intensity of boys' biological development in circumpubertal age in response to several years of training handball. A further analysis indicated smaller dispersion of parameters describing the growth and physiological development of the TR group than in NT. The results suggest that handball training caused a significant improvement in morphological and functional indicators. Consequently, capabilities of physical effort increase and a more harmonic development is achieved. Moreover, the results have shown that capabilities of anaerobic work in the TR group have differently depended on the time of progressive development, whereas in the NT group there has been an increase in these capabilities in relation to the age of the examined boys. Conclusions: Several years of handball training did not influence the increase in anaerobic efficiency of pre-pubertal age boys. On the other hand, handball training in pubertal and post-pubertal age boys caused a statistically significant increase in maximum anaerobic power (MPWAnT). A high positive correlation between weight and MPWAnT confirms a relationship between anaerobic power and body growth during puberty.

Keywords

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Marcin Łuszczyk (A,B,C,D,E,F,G), **Radosław Laskowski** (D,E), **Ewa Ziemann** (D,E), **Tomasz Grzywacz** (C,D,E,F), **Anna Szczęsna-Kaczmarek**(A,B,D,E,F)

Jedrzej Sniadecki Academy of Physical Education and Sport in Gdansk, Poland

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

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Results: *Results have shown the high intensity of boys' biological development in circumpubertal age in response to several years of training handball. A further analysis indicated smaller dispersion of parameters describing the growth and physiological development of the TR group than in NT. The results suggest that handball training caused a significant improvement in morphological and functional indicators. Consequently, capabilities of physical effort increase and a more harmonic development is achieved. Moreover, the results have shown that capabilities of anaerobic work in the TR group have differently depended on the time of progressive development, whereas in the NT group there has been an increase in these capabilities in relation to the age of the examined boys.*

Conclusions: *Several years of handball training did not influence the increase in anaerobic efficiency of pre-pubertal age boys. On the other hand, handball training in pubertal and post-pubertal age boys caused a statistically significant increase in maximum anaerobic power (MP_{WAnT}). A high positive correlation between weight and MP_{WAnT} confirms a relationship between anaerobic power and body growth during puberty.*

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Address for correspondence:
dr Marcin Łuszczyk
Academy of Physical Education and Sport, Department of Physiology, ul. K. Górskiego 1, 80- 336 Gdańsk, Poland
Phone: +48 58 554775 fax. +48 58 552 27 83, e-mail: marcinl@awf.gda.pl

Introduction

Impact of anaerobic effort on children is still not well understood, in spite of a rising number of publications on this topic. At the same time, relationships between physical activity, metabolic changes, and physical efficiency have been reported, due to both a natural progressive development of human beings and the influence of specialized sport training on these processes [1, 2]. Numerous reports demonstrated evidence of positive effects of sport training on the increase of maximal phosphagen power ($MPana_{phosph}$) and other indicators of anaerobic capabilities among children and youth [3]. This anaerobic potential is connected with the increase in fat free mass (FFM), i.e. with the growth of muscles. Wilmore and Costill [1] reported that training based on anaerobic effort leads to an increase in available muscle levels of ATP, phosphocreatine (PCr) and glycogen, the activity of phosphofructokinase (PFK), and in the maximum concentration of lactate in blood (LA_{max}). Consequently, such training increases the potential of anaerobic lactic acid fibres FT.

Despite this knowledge, there is still a lack of a more definite answer to the question to what extent anaerobic training effects overlap with a normal development of an organism for anaerobic work [20]. Praagh [12] explained this fact by restrictions of ethical and methodological nature, which makes studying children's effort capabilities very difficult. According to many authors – Bar-Or and Rowland [4], Eriksson and Saltin [5], Saavedra et al. [6], Szczęsna-Kaczmarek et al. [7, 8, 9] – children's abilities to achieve anaerobic efforts increase with age. Boys have two periods of increase in maximum anaerobic power (MP_{WAnT}): (a) fast – between the 8th and the 11th year of life and (b) slow – starting from the 11th year of life. In the period between 8 and 14 years of age, the increase in MP_{WAnT} reaches 43 % of initial value. Levels of MP_{WAnT} for children make up about 30% of absolute values (W) and 60-70% of relative values ($W \cdot kg^{-1}$) in relation to values reported for adults. During the puberty period the increase in anaerobic power is connected to the increase in muscles size and the increase in efficiency of muscle-nerve coordination (mainly in the range of stimulating fast twitch – FT). In children, to a bigger degree than in adults, we can observe a delay in cramp appearance with relation to the time of stimulus functioning and also a lower speed of muscle contraction, which can suggest restraints on the myoneural junction level.

What is important in this study, the maximum anaerobic power determines the standards of accomplished work in pace-strength sports, in which handball is included. Here, because the energetic cost for a time period is so significant and oxygen processes are so slow, it is not possible to secure proper resynthesis of adenosine triphosphate (ATP). Consequently, the energy is produced based on anaerobic sources: phosgene and glucose. Secondly, Åstrand [10] proposed that in the description of data obtained from children and youth references to their body size, which depends on their age, are particularly important. Clearly, in this situation, the estimation of children and youth organism responses to physical effort has to be achieved in the context of growth and development processes.

In the present study, we searched for an answer to questions concerning the type and the range of influence of physical training on morphological changes (anthropometric parameters), anaerobic efficiency capabilities and their mutual correlations resulting from natural progressive pubertal and post-pubertal youth development.

Materials and Methods

The technique of parallel groups was used: the experimental one (handball training [TR], n=12) and the control one (not trained [NT], n=58). Boys from both groups were on average about 16 years old when the study began, and the period of the experiment took two years. The examined handball players were pupils from Polish Handball Federation Sports Masters' Secondary School in Gdansk [*Szkoła Mistrzostwa Sportowego Związku Piłki Ręcznej w Polsce*] (starting their education in 1986). The control group, which was tested on the same parameters as the handball players group, were secondary school pupils from Gdynia, Gdansk and Sopot, and they were only subjected to typical obligatory P.E. activities at their respective schools. In choosing this control population, the only condition that was of significance was their height, with the criterion of being taller or at least the same as 170 cm.

Full examination, which is written in the research protocol, was taken 3 times shortly before the final pre-competitive preparation, in which a sportsperson is at the highest level of sport form. Obtained in this process results allowed gathering the comparison material, as essential to determine the outcomes of the preceding year of training and the influence of several years of handball training on the progressive physical development of children and youth.

Measurement of choice were anthropometric parameters and indices, and they were taken each time before the laboratory test of anaerobic efficiency. Total body weight, fat weight and height were measured. *Tanita Body FAT Monitor/Scale TBF-300P* and antropometer from the set *GPM-Skinfold Caliper Users Manual* were used. *Tanita Body FAT Monitor/Scale* allowed measuring fat tissue weight (FAT) with a bioelectric impedantion method (BIA), which led to subsequent calculation of fat free mass (FFM). Further, using the values of weight and body height, body mass index (BMI) was calculated. The values of BMI were compared with norms given by the American Health Institute (1991 as cited by [11]). To account for the developmental age of the examined pupils special, a graphic method proposed by Cieślik et al. [12] was used. The chronological age was established as a difference between birth date and the date of examination [11].

The estimation of anaerobic efficiency was performed using Anaerobic Test in a 30 second time version (WAnT) for lower extremities (legs). Bicycle ergometer *Ergomedic E-818* produced by *Monark* and computer programme *MCE v 5.1* [13] were used for testing. In this study, a modification proposed by Zdanowicz et al. [14] was used, in which the full resistance of fly-wheel is established at the start of effort, and the duration of rotation measured starts from the moving of the pedals of cycloergometer. Thus, it is a modification of the original test created by Bar–Or [15]. In 30s time of Wingate test the computer programme *MCE v 5.1* calculated: the amount of maximum anaerobic efficiency (MP_{WAnT}), the time of approaching maximal power (TUZ) and the time of sustaining maximal power (TUT).

The data were statistically analysed using a computer programme *STATISTICA PL* version 8, *StatSoft.* To define the statistical difference between the group means, we used the test of multiple comparisons (*Post-hoc*). The constant number of the examined group allowed the usage of Tukey's test of reasonable essential difference (RIR) for the even size of the two samples. In the case of the control group we chose the second variant of the test – for uneven size of the samples. For variables which did not fulfil the assumptions of normal distribution or homogeneity variance, we used *Kruskal-Wallis test.* In this case we verified the difference between group means using *multiple averages comparison for all samples test.* To estimate the intensity and the direction of lined correlation between variables, a *Pearson's factor of lined correlation (r)* was used. To calculate the determination factor (r^2), a proportion of mutual variable of two variables was calculated [10]. For the purpose of recognition of the amount of dependence between the explained and explaining variables we used lined regression models [16]. For all conducted analyses statistical significance was determined at the level of $p \leq 0.05$ [17].

Results

Changes in the anthropometric parameters and indicators for the two-year period of observation in TR and NT are presented in Table 1.

Tab. 1. Changes of the chosen anthropometric parameters and coefficients, in the two-year period of observation in a training group (TR; n=12) and not a training group (NT; n=58)

	Group	NT16	NT17	NT18
Age [years]	**TR**	**16.3**±0.07	**17.1**±0.20[a]	**18.3**±0.13[a,b]
	NT	**16.1**±0.28	**17.2**±0.23[c]	**18.1**±0.28[c,d]
Biological age * [years]	**TR**	**18.0**±0.12[*c]	**18.0**±0.00[*c,d]	**18.0**±0.00[*c,d]
	NT	**16.4**±1.31	**16.7**±1.38	**17.7**±0.70[c,d]
Body height [cm]	**TR**	**185.9**±4.80	**186.7**±4.65[c,d]	**187.6**±4.67[c,d]
	NT	**179.3**±4.44	**179.6**±5.18	**180.2**±4.54
Body mass [kg]	**TR**	**78.8**±9.43[c]	**79,8**±8.09[c,d]	**82.1**±5.02[c,d]
	NT	**63.5**±7.34	**67.5**±7.93	**75.7**±7.85[c,d]
FAT [kg]	**TR**	**7.40**±2.30[c]	**10.3**±3.13[a]	**11.2**±2.40[a]
	NT	**6.20**±2.88	**7.20**±3.11	**10.5**±4.23[c,d]
FFM [kg]	**TR**	**71.4**±7.63	**69.6**±6,79[c,d]	**70.4**±4.38[c]
	NT	**57.3**±5.32	**60.3**±5.41	**65.3**±5.11[c]
BMI [kg·m^{-2}]	**TR**	**22.8**±2.46[c]	**23.0**±2.11[c]	**23.1**±1.48[c]
	NT	**19.7**±1.93	**21.1**±2.26	**23.4**±2.74[c,d]

*The results introduced as average (x) ± standard deviation (SD), TR – training group at the age from 16 to 18 years, NT – not training group at the age from 16 to 18 years, n – number, FAT – fat tissue, FFM – fat free mass, BMI – body mass index, [a] – average significant differences statistics in comparison with TR16, [b] – average significant differences statistics in comparison with TR17, [c] – average significant differences statistics in comparison with NT16, [d] – average significant differences statistics in comparison with NT17, (p≤0.05), * - increase percentiles meshes in Poland contain the period of the progressive development to 18 years.*

The data from the first examination of handball training boys from Sport School (TR16), compared with the results of NT boys group, allowed concluding the influence of 4-6 years of training handball on pubertal children. Specifically, the values obtained from youth sportspersons (TR16) in first examination were statistically different from their biological age contemporaries. Group TR16 was biologically assessed at the level of 18 years old. Because Polish centile norms are developed only through 18 years of age, therefore in the following year of observation it was impossible to estimate the biological age of the examined training group. The first examination of NT 16-year-old boys (NT16) showed that they were characterized by small biological development progress (i.e., 0.3 year). In TR16 we observed the biological development progress at the 1.7 calendar year level. Handball players, who during the first examination were classified to be of the biological age of 18, had the progress of 1.6 year (p≤0.05) in comparison to NT16. The NT 17-year-old group revealed an average delay of biological age by 0.3 years. Such biological age delay was also seen in the NT18 group. NT groups were widely diversified in their development. In some cases, this delay was more than a year delay in their biological development in comparison to their chronological age. On the other hand, a very small group of NT boys showed about a year of biological development advance over the chronological age. Such a large diversity of biological development of non-training boys was also seen in groups NT17 and NT18. Explanation of this spread of biological age of NT boys can be seen in their large spread of weight and height. Disproportions between weight and height might suggest, that after puberty youth diet is not proper. This statement can be supported by large dispersion of contained fat percent (FAT) which ranged from 3,5 % to 16 % in the examined groups. TR16 and TR17 boys showed statistically higher values than NT groups in body height, body mass, fat free mass and BMI.

Changes in the values of anthropometric parameters and indices in the two years of TR group observation suggested an insignificant increase in body height (0.85 cm/year). Two-year delta (Δ) for this parameter was 1.70 cm. TR boys were characterized by a higher body weight. In the two-year training time this parameter increased in handball players by about 3.35 kg.

In the TR group, we observed the largest increase in FAT between 16 and 17 year of age (i.e, 2.92 kg) and it was statistically significant. The increase in fat components in the TR group was accompanied by a decrease in FFM by 1.79 kg for TR17 and TR16, and by an increase of 0.76 kg for TR18 and TR17. Consequently, the decrease in FFM value between TR18 and TR17 was 1.03 kg. In the NT group the largest increase in FAT occurred between 17 and 18 year of age (i.e., 3.28 kg) and was also statistically significant. In NT groups, we observed an increase in fat-free weight by about 2 kg at the age of 17, and by about 4 kg at the age of 18. An analysis of BMI indicated a higher increase in the control group (NT).

Results dealing with anaerobic efficiency for TR and NT groups, between 16 and 18 year of their life, are shown in Figure 1. The first parallel estimation of anaerobic efficiency as measured during 30 second supramaximal allowed concluding the influence of 4–6 years of handball training on the change of parameters characterizing anaerobic efficiency of pre-puberty boys. In the first examination of TR16, they had higher anaerobic efficiency than the NT group; however, these differences between anaerobic efficiency parameters of both groups were not statistically significant. While analyzing parameters of anaerobic efficiency of the TR group after 1 year of training (Fig. 1B), we noted a statistically significant increase in maximal anaerobic power (MP_{WAnT}) in the measure units converted to kg of fat-free weight ($p = 0.02$). The second year of training deepened the difference in value MP_{WAnT} ($p \leq 0.05$). However, it is interesting that after the second year of training boys from theTR18 group had a shorter time of maitaining maximum power (TUT) by 0.78 s, in comparison to the NT18 group (Fig. 1D). In this group, trained boys thereinafter had higher MP_{WAnT} values in comparison to the NT group. Reflecting on these results, handball training between 17 and 18 year of life (but not during pre-puberty) influenced ($p \leq 0.05$) anaerobic power capabilities at a statistically significant level.

Designed models of regression (Figures 2 to 4) allowed explaining changes in anaerobic efficiency parameters, which ranged from 10 to 29 %.

Statistically significant correlations were obtained between the chronological age and relative values (converted to kg FFM) in MP_{WAnT} (Fig. 2A). This correlation was positive and had an average size. Statistically significant negative correlation (TR) was obtained between the chronological age and TUT (Fig. 2B). In this model, the correlation size was medium and the determination factor low. There were statistically significant, medium in size negative relationships (for both TR and NT) between body mass and TUZ (Fig. 3B). Similar relationships were found between BMI and TUZ (Fig. 4B). There were statistically significant, medium in size positive correlations between body mass and MP_{WAnT} (Fig. 3A) as well as between BMI and MP_{WAnT} (Fig. 4A).

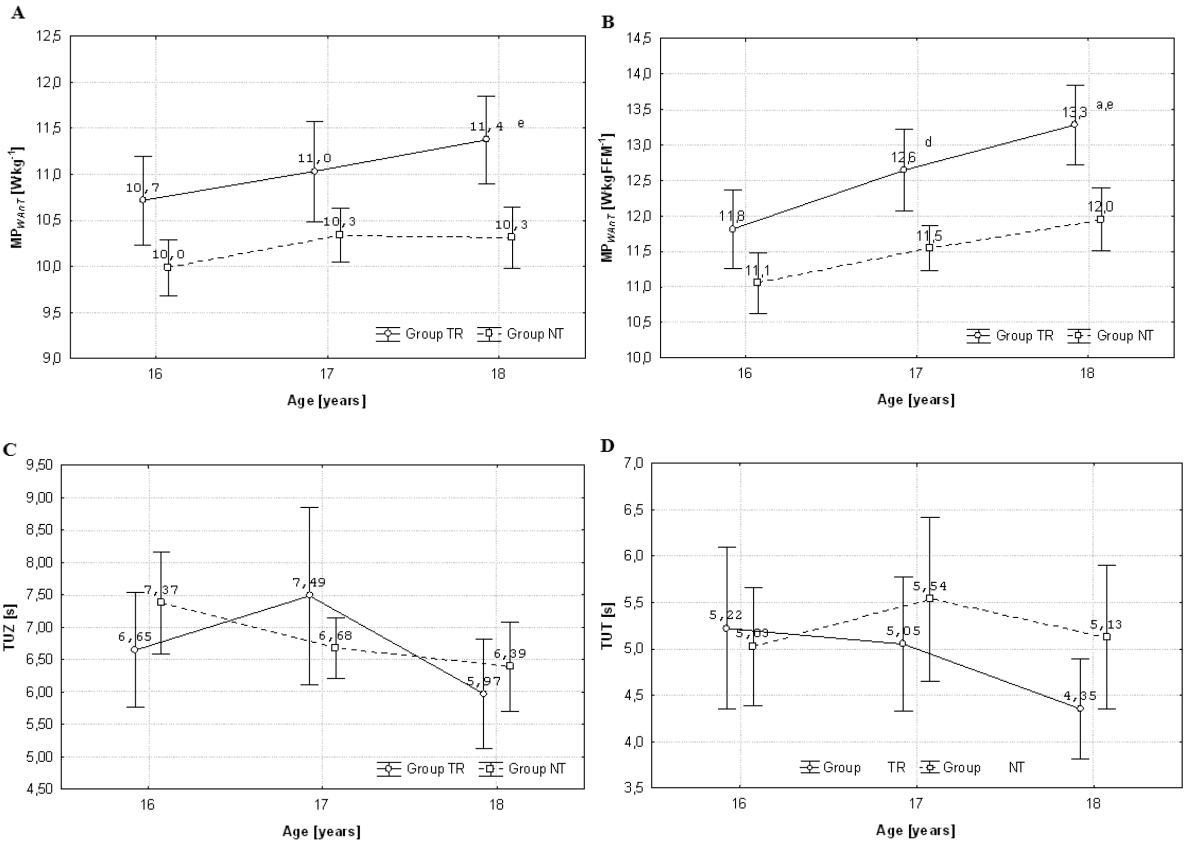

Fig 1. (A, B, C, D) Changes in maximal anaerobic power [MP$_{WAnT}$] (A,B), time of approaching maximal power TUZ] (C), time of sustaining maximal power [TUT] (D) in a two-year period of observation in a training group [TR; n=12] and a not training group [NT; n=58] (vertical posts mark 0.95 compartment of the trust, [a] *average significant differences statistics in comparison with TR 16,* [d] *average significant differences statistics in comparison with NT 17,* [e] *average significant differences statistics in comparison with NT 18 (p≤0.05)*

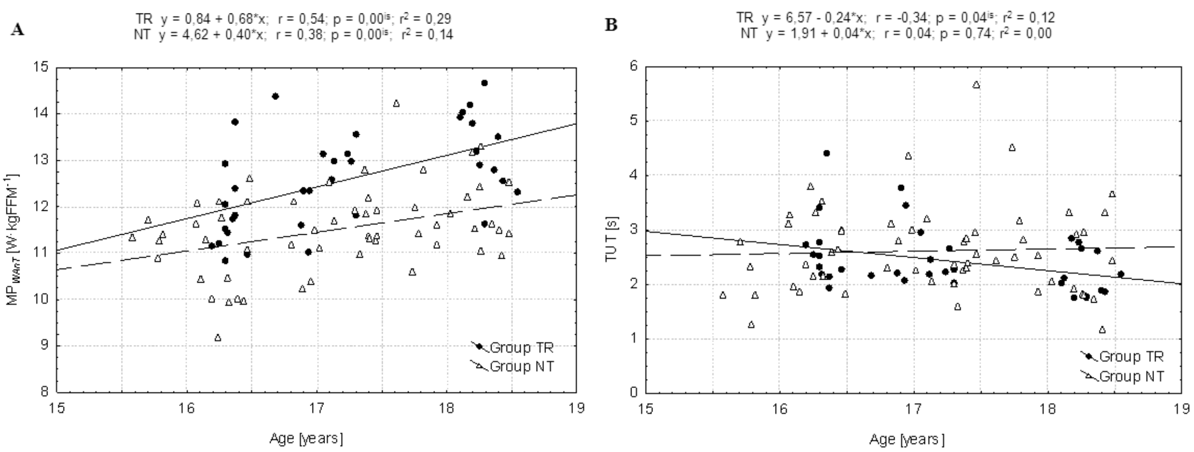

Fig. 2. Correlation between the calendary age and maximal anaerobic power [MP$_{WAnT}$], time of sustaining maximal power [TUT] in a two-year period of observation in a training group [TR] and a control group [NT] *(p – level of significance; is – significant statistics; r – coefficient of Pearson's linear correlations; r^2 – coefficient of determination)*

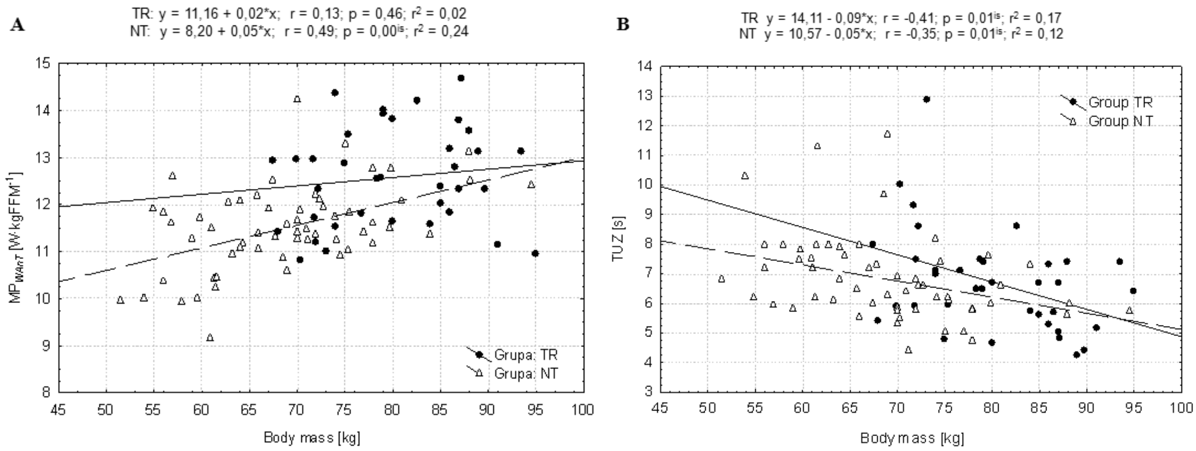

Fig. 3. Correlation between body mass and maximal anaerobic power [MP_{WAnT}], time of approaching maximal power [TUZ] in a two-year period of observation in a training group [TR] and a control group [NT] *(p – level of significance; is – significant statistics; r – coefficient of Pearson's linear correlations; r^2 – coefficient of determination)*

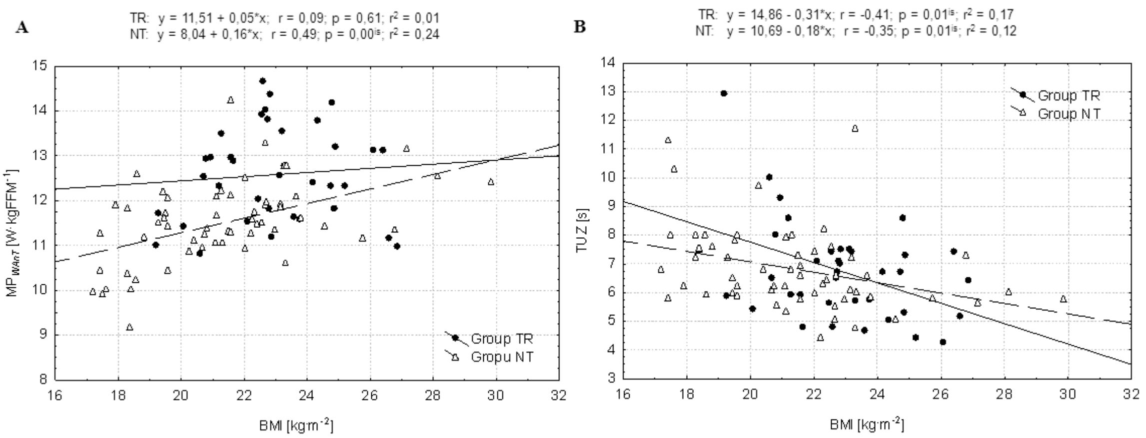

Fig. 4. Correlation between body mass index [BMI] and maximal anaerobic power [MP_{WAnT}] time of approaching maximal power [TUZ] in a two-year period of observation in a training group [TR] and a control group [NT] *(p – level of significance; is – significant statistics; r – coefficient of Pearson's linear correlations; r^2 – coefficient of determination)*

Discussion

The results suggest the increase in capabilities of anaerobic work in relation to age of the examined boys (i.e., natural developmental change). On the other hand, training influenced this development with various strength at the particular time of progressive development (i.e., change due to specialized training). Also, the results form the first examination indicate that 4-6-year training of boys of 10-15 years of age did not influence the increase in anaerobic efficiency in the group of handball players.

Assuming the maximal anaerobic power (MP_{WAnT}) as a measure of anaerobic efficiency, we noted that in the TR group there was a systematic and statistically significant increase in MP_{WAnT}

value. Additionally, the MP_{WAnT} value converted into kg FFM showed a high correlation with BMI. We suppose that the reason for this finding was the increase in muscle size (mass) in relation to the whole body mass, which is coincidental with observations of Eriksson and others [3]. Some confirmation of this finding can be seen in the positive correlation (r = from 0.07 to 0.48) between body mass and $MP_{WAnT.}$ We claimed that in the NT group there was a stabilization of this value in absolute measures. On the other hand, after converting fat-free weight into kg we could observe a systematic and statistically insignificant increase in the MP_{WAnT} value.

The results concerning MP_{WAnT} power in the NT group are similar to results of Inbar and others [18]. On the other hand, comparing MP_{WAnT} values measured in the TR group to norms for the chosen WanT test parameters that were proposed by Norkowski [19] specifically for handball players, we can classify the examined players as average anaerobic efficiency group. Results obtained in this research suggest that anaerobic power level of examined handball players is similar to the MP_{WAnT} value measured for 16–18-year-old players of the Polish national team [20] as well as similar to values of 18-year-old basketball players of the Greek national team [21]. Our examined boys from the TR group achieved 78% and 79% of MP_{WAnT} measures in absolute and relative values, respectively, which was reported for 23-year-old French handball national team players [22].

Bar-Or and Rowland [4] believe, that the reason for lower children's anaerobic power could be a lower concentration of PCr in muscles. On the other hand, the pace of PCr utilisation is the same for children and adults. The time of approach of maximal anaerobic power (TUZ) was lowered along with age for all examined boys, and through the whole time of observation it was shorter in the TR group. Still, the TUZ decrease dynamics in this group was unequal, unlike in the NT group. Subjecting the statistical results to deeper interpretation, we can say that physical training does not cause essential changes in TUZ values. Great dispersion of results in the training group gives evidence of a diversified influence of training load on capabilities of generating high powers in the examined population. Time increases in sustaining maximal power (TUT) were not statistically significant in both groups. TUZ and TUT correlation analysis with the chosen anthropometric parameters and indicators did not show an important link. We observed a correlation between a chronological age and TUZ (r=-0.46) in the group of NT17 and WSM in the group of TR17 and TR18 handball players.

Conclusions

1. Several (4–6) years of handball training for boys at the pubertal age contributed to about 2 years' increase in biological development.
2. Handball training at the pubertal age stimulates the development of anaerobic power (MP_{WAnT}), whose value shows a high correlation with BMI.

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