

Trajectories of Functional Status of the Cardiovascular System in 7 Year Old Children during Their Physical Education

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ABSTRACT

Objective: The work objective was to reveal a correlation relationship between the parameters of the cardiovascular system functional state and the trajectories of morpho-functional and Response Quality Indicators in 7 year old children.

Materials and methods: 303 first grade children at the age of 7 were involved in this prospective observational cohort study. PWC170 test has been performed, Body Tension Level (BTL) and Response Quality Indicator (RQI) have been computed as the parameters, closely linked to the Physical Working Capacity. The data have been analysed through ranking comprehensive estimates. Weighed Mean values (M), Standard Deviations (SD), and 95% Confidence Intervals (CI), correlation ratio (r) were computed.

Results: In 76% of first-grade pupils, a low adaptive reserve to exertion is seen. A significant correlation relationship between PWC170 indicators and BTL is

shown. In the vast majority of cases, overweight is related to not only large fat folds, but also unsatisfactory RQI values. It indicates that physical education program is inefficient.

Conclusion: Incorporation of a complex indicator of the Physical Working Capacity into screening control of the child population health will enable unbiased evaluation of the efficiency of organising physical education, taking the functional state of the body systems into consideration.

Keywords: Physical working capacity, Response quality indicator/index, Body tension level, Morpho-functional status

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ABBREVIATIONS

BTL: Body Tension Level; RQI: Response Quality Indicator/Index; PWC170: Index of Physical Working Capacity, measured on one-time physical exertion

INTRODUCTION

An in-depth study of functional reserves of the body and their relationship with morpho-functional indicators is relevant since physical education is highly important in forming a harmoniously developed person (Kuchma VR and Rapoport IK, 2011). Physical culture programmes must facilitate promotion of the child health through prompt development of the main physical qualities, motivation for motor activity, harmonisation of morpho-functional status, formation of the best option for physical development of an individual, cultivation of a healthy lifestyle. However, specialists often reveal ill health of preschool-aged children and school children, their poor physical training, lack of the most essential motor skills, what suggests that physical education classes are inefficient (Kuchma VR, 2012; Kuchma VR, *et al.*, 2013; Makarova AY, 2012; Baranov AA, *et al.*, 2008). Functional reserves of children reflect not only the state of functional systems, responsible for withstanding physical exertion, but also are indicative of working capacity. Physical Working Capacity constitutes an integrated expression of the human potential, is a part of the health concept, and depends on numerous indicators of physical development, forms and means of physical education. The development of certain components of the Physical Working Capacity in various individuals varies significantly (Kuchma VR, *et al.*, 2009; Kuznetsova AP and Tyatenkova NN, 2012).

Few publications are known about the dependence of individual Physical Working Capacity on the body morpho-functional systems (Milushkina OY and Bokareva NA, 2013; Milushkina OY, *et al.*, 2013). To date, there is no clear idea of limits of the cardiorespiratory system reserve capacities (Kuznetsova AP and Tyatenkova NN, 2012; Makarova AY, 2010), particularly, in pri-

mary schoolers (Proudfoot NA, *et al.*, 2019; Jenco M, 2020; Jenco M, 2019).

The research, conducted at the Chear of Hygiene of Children and Teenagers of the First Moscow State Medical University provided the data, indicating that, despite an added 3rd physical education class during the week, 40% of schoolchildren have a low index of the Physical Working Capacity; an inverse correlation relationship between the index of the Physical Working Capacity and the Body Tension Level index was demonstrated; the weak points of organising physical education classes were defined (Makarova AY, 2010; Makarova AY, 2009).

Of interest was to explore the correlation relationship between the parameters, that define the Physical Working Capacity, and the indicators of a child's physical development, which are employed in the comprehensive estimate of the physical development, to deepen the understanding of an interrelation between Physical Working Capacity and physical development, and to use the methodology of evaluating physical development as a tool for identifying the quality of organising physical education in an institution. In addition, it is known that Physical Working Capacity, thus, motor activity as well, depend on functional capabilities of a child, which are not always clearly defined by the presence of medical health issues. It is likewise a common knowledge that harmonious development of an individual is also determined by cultivating certain motor qualities. Seeking an interrelation between functional state of the cardiovascular system, Physical Working Capacity of a child and his morpho-functional status appears to be an important task.

MATERIALS AND METHODS

303 children at the age of 7 took part in this prospective observational cohort study.

Study design

Throughout a year, the children underwent a series of examin-

ations, divided into 2 visits, with a 10 ± 8 days interval. The first visit involved anthropometric studies and evaluation of physical development. In the end of the visit, Physical Working Capacity was explored, employing the functional test on a step with one-time physical exertion, on which the heart rate increases to 170 beats per minute (The Carolina University PWC170 test). During the second visit, the functional state of the cardiovascular system was evaluated by functional tests. To evaluate functional reserves of the body, Body Tension Level (BTL) and Response Quality Indicator (RQI) were selected, as the parameters closely related to Physical Working Capacity of the body, not highly labour-intensive when computed mathematically. At that, BTL characterises the Body Tension Level on standardised physical exertion and reflects an expended reserve of the body. RQI indicates adaptation of the cardiovascular system on standard exertion. Only children with normotonic type of the cardiovascular system reaction were involved in the examination since it is improper to compute RQI with other types of reaction.

The data were collected from October 2019 to March 2019. The written informed consent from a legally authorised representative of a child (e.g., a parent) was obtained during the first visit. The Sechenov University Ethics Committee approved this research study (Protocol No. 34/20 of 09.12.2020).

In computing average weighted values of the relative indices of Physical Working Capacity, a centile method of statistical analysis was employed, allowing for compilation of score tables for 7 year old children with different adaptive capacities of the cardiorespiratory system. The cardiovascular health indicators included estimated indices of Physical Working Capacity, changes in heart rate (%), Body Tension Level index.

Comprehensive Estimate of Physical Working Capacity (PWC CE) was made, based on computing integral characteristics (indices) using the conducted tests. A quantity-related description was given to each centile interval of the estimated indicator, expressed in scores from 1 to 5. The score reflects the conformity degree of age-gender physiological characteristic of an attribute: the better the indicator, the higher the score (Table 1).

The score of each indicator was further transformed into numerical coefficient k_i using formula: $k_i = \log_5 i$ (Table 2).

Comprehensive Estimate of the Physical Working Capacity index is obtained through dividing the sum of all obtained numerical coefficients k_i by the number of estimated indicators. The coefficient of the Physical Working Capacity Comprehensive Estimate (PWC CE) was ranked according to Table 3.

When estimating the results of testing functional state parameters of the body systems, a methodological approach was applied, which allows, based on a centile method of statistical analysis, computation of the quantity-related characteristic, expressed in scores from 1 to 5 for each estimated indicator. A score reflects the conformity degree of age-gender physiological characteristic of an attribute: the better the indicator, the higher the score (Table 4). To characterise further, the score of each indicator was transformed into numerical coefficient k_i using formula: $k_i = \log_5 i$, with their subsequent ranking (significant, moderate, low Body Tension Level and satisfactory, or unsatisfactory RQI).

RESULTS

The studies have shown that Physical Working Capacity of examined schoolchildren is within 225.23-952.95 kgm/min in boys and 112.13-1153.8 kgm/min in girls.

Scoring tables were compiled separately for boys and girls, average weighted values of the indicator, mean square deviation, error of mean, median, dispersion were found. The results of individual evaluation of Physical Working Capacity are given in Table 5.

There are gender-related differences in Physical Working Capacity of first grade pupils: girls 2 times more often show moderate working capacity, boys therewith 3.5 times more often than girls have higher than moderate indices of working capacity. Of note is the fact that regardless of gender, about 40% of pupils have low index of Physical Working Capacity.

The results of comparing the indicator of Physical Working Capacity and Body Tension Level on one-time physical exertion, computed using the known formula, are presented in Table 6.

Table 1: Score of the indicators of functional tests based on centile intervals

Estimated indicators	Estimate of centile interval numbers				
	5 scores	4 scores	3 scores	2 scores	1 score
PWC ₁₇₀ , kgm/min	7.8	6	4.5	3	1.2
Change in HR, %	3	6	4.5	2.7	1.8

Table 2: Values of coefficient k_i

Score (i)				
1	2	3	4	5
0	0.43	0.68	0.86	1

Table 3: Ranking of comprehensive estimates

Ranges of values	Estimate
1.00-0.90	Best
0.89-0.68	Good
0.67-0.48	Satisfactory
0-0.47	Unsatisfactory

Table 4: Score of the indicators of functional tests based on centile intervals

Estimated indicators	Estimate of centile interval numbers				
	5 scores	4 scores	3 scores	2 scores	1 score
Body Tension Level (BTL), %	1.2	3	4.5	6.7	8
Response Quality Indicator/Index (RQI)	6	7	4.5	2.3	1.8

Table 5: Distribution of first-grade pupils according to Physical Working Capacity levels, %

Physical Working Capacity (PWC)	Total	Boys	Girls
Lower than moderate	40	40	32
Moderate	36.7	31.4	60
Higher than moderate	23.3	28.6	8

Table 6: Interrelation between the index of Physical Working Capacity and Body Tension Level in 7 year old boys and girls, %

Physical Working Capacity (PWC)	Body Tension Level (BTL),%					
	Significant		Moderate		Low	
	b	g	b	g	b	g
Lower than moderate	31.4	32	2.9	0	2.9	0
Moderate	8.6	24	17.1	28	0	8
Higher than moderate	0	0	20	0	17.1	8

Schoolchildren with low level of Physical Working Capacity withstand a standard physical exertion predominantly at the expense of significant Body Tension Levels (31%-32%). In children with the moderate level of working capacity, gender-related differences are seen in the Body Tension Level on exertion: in boys due to moderate BTL, in girls due to both significant (3 times more often than in boys), and moderate level of BTL. Boys with higher than moderate working capacity experience moderate and low tension level of functional systems of the body (20% and 17%, respectively), and girls with high levels of working capacity have only slight tension.

There has been demonstrated a significant correlation relationship between the PWC170 and BTL indicators: correlation ratio -0.569; estimated criterion $t=5.357$ ($p \leq 0.05$) at the critical criterion of 2.001.

Analysing the Body Tension Level has shown that 31% of first grade pupils have a significant level of tension, 34% of those examined demonstrate moderate tension level, and 35% of schoolchildren have low tension level.

The results of studying RQI indicate that the great majority of pupils in undergoing a standard test have poor functional status of the cardiovascular system (81%), only in 19% this state is acceptable and good.

A comparison between these two parameters has shown that children with slight body tension often have poor functional CVS status (45.2%), hence low BTL here cannot be considered as a beneficial indicator. Thus, 2/3 of first grade pupils will have low adaptive reserve on exertion, thus, low Physical Working Capacity.

From the results of our studies, a high and medium correlation between the indicators of BTL and body weight, BTL and fat deposition, BTL and RQI (Table 7) has been inferred.

The results of studying the variants of morpho-functional status with Response Quality Index are presented in Table 8.

In 23.3% of children, overweight coupled with large fat folds has been detected (in 100% of cases), at that in 88% of cases, i.e., in 20.5% an unsatisfactory RQI is found. Children with body weight deficit in 100% of cases have low RQI. 72.6% of first grade pupils have harmonious morpho-functional status; unsatisfactory RQI is observed in 2/3 (66%) of them. All this indicates an overall unsatisfactory adaptation of the cardiovascular system to exertion.

The study results suggest that Physical Working Capacity parameters are interrelated: Body Tension Level reflects the functional state of the cardiovascular system. In its turn, the Body Tension Level is closely linked to somatoscopic parameters, characterising morpho-functional status: muscle mass and fat fold size. Overweight is combined in most cases with not only large fat folds, but also unsatisfactory RQI values.

The results of exploring the correlation relationship between the parameters, reflecting functional state of the cardiovascular system-Body Tension Level and Response Quality Index and morpho-functional indicators in 7 year old children have demonstrated that:

- Regardless of gender, about 40% of first grade pupils have low index of Physical Working Capacity;
- There are gender-related differences in Physical Working Capacity from the first form: girls 2 times more often demonstrate moderate working capacity, boys therewith 3.5 times more often than girls have higher than moderate indices of working capacity (60% and 31% with moderate level of working capacity and 29% and 8%-with high working capacity);
- An inverse correlation relationship between the Physical Working Capacity index and Body Tension Level index is shown: the lower the working capacity level, the more pronounced the tension level ($p \leq 0.05$);
- Boys and girls aged 7 years contribute different amount of the tension in

Table 7: Correlation ratios of some estimated indicators

Statistical criteria	BTL and body weight	BTL and fat fold size (reflecting fat deposition degree)	BTL and RQI
Correlation ratio	0.621	0.432	-0.362
Estimated criterion t	3.895	2.058	2.324
Critical criterion t	1.993	1.993	1.098

Table 8: Interrelation between the variants of morpho-functional status and Response Quality Index in 7 year old children

Morpho-functional status	Satisfactory RQI	Unsatisfactory RQI
Harmonious	24.7	47.9
BMI	2.8	20.5
BWD	0	4.1

functional systems of the body on exertion at the equal level of Physical Working Capacity: in girls, the tension level is more pronounced at the moderate level of working capacity, in boys-at the high level.

- One third of first grade pupils have a significant level of body tension, 34% and 35% of those examined have moderate and low tension level, respectively;
- Most pupils have poor functional state of the cardiovascular system (low Response Quality Index);
- Children with slight body tension in 45% of cases have poor functional state of the cardiovascular system;
- 76% of first grade pupils have low adaptive reserve on exertion;
- A correlation relationship exists between morpho-functional indicators-body weight and fat deposition size-and Body Tension Level, Body Tension Level and Response Quality Index (correlation ratios are 0.62; 0.43; -0.36, respectively; $p \leq 0.05$);
- In the vast majority of cases, overweight is coupled with not only large fat folds, but also unsatisfactory RQI values;
- Children with body weight deficit in 100% of cases have low RQI.

DISCUSSION

New regularities in developing Physical Working Capacity in 7 year old children from the age-gender aspect have been obtained. There are few publications showing these interrelationships, and no 7 year old children were incorporated in these works (Kazuma N, *et al.*, 2002; Veldman SL, *et al.*, 2021; Carson V, *et al.*, 2021; Kuzik N, *et al.*, 2017; Dangardt F, *et al.*, 2019; Falkner B, *et al.*, 2004). Gender-related differences in Physical Working Capacity of first grade pupils have existed: girls 2 times more often demonstrate moderate working capacity, boys therewith 3.5 times more often than girls have higher than moderate indices of working capacity (Huang RC, *et al.*, 2011).

The results of comparing the Physical Working Capacity index and Body Tension Level on one-time physical exertion, demonstrate new relationships (correlation relationship) between functional systems of the body and the index of Physical Working Capacity in 7 year old boys and girls.

The results of comparing BTL and RQI indices with indicators, characterising morpho-functional status of a child (muscle strength of hands, vital lung capacity, body weight, fat deposition) demonstrate new relationships (correlation relationship) between morpho-functional indicators of the body and the Physical Working Capacity index.

Body Tension Level is closely linked to somatoscopic parameters, characterising morpho-functional status.

Our research suggests an essential role of somatoscopic examination in evaluating an individual variant of physical development and predicting adaptive capacities of the body.

Low adaptation to exertion, revealed in first grade pupils, is likely to reflect the specifics of organising physical education in an institution and inefficient physical education programme.

The studies of Physical Working Capacity in relation to options of evaluating physical development have shown that the existing physical education programme is less than adequate:

- A propensity of the programme for an “average” child, the same type of physical training for a child,
- Ignoring age-related specifics of children development, starting from the first form,
- A strong impact of “feminine” pedagogics on formation of Physical Working Capacity indicators and the right time for the children growth and development from gender-related aspect.

This study advances our understanding of the role of organising physical education in child collectives, adaptation reserve of the cardiovascular system due to new interrelationships between Physical Working Capacity and morpho-functional indicators. Studying functional reserves of the body will enable expansion of the concepts of Physical Working Capacity as a complex indicator, what will allow determination of the weak points in the physical education programme content and enhancement of the potential of physical education programmes to preserve health (Falkner B, *et al.*, 2004; Butte NF, *et al.*, 2016; Aris IM, *et al.*, 2019). Incorporation of a complex indicator of Physical Working Capacity into the screening control set of child population health will make it possible to manage cardiovascular risks to health (Aris IM, *et al.*, 2019).

CONCLUSION

The studies of Physical Working Capacity parameters show that regardless of morpho-functional status, first grade pupils have low level of adaptation to physical exertion at high Body Tension Level, which is often coupled with poor functional state of the cardiovascular system. The result suggests that the current practice of organising physical education programme is less than adequate.

The correlation relationship between the Physical Working Capacity parameters has been revealed: Body Tension Level reflects functional state of the cardiovascular system. In its turn, Body Tension Level is closely linked to somatoscopic parameters, characterising morpho-functional status: muscle mass and fat fold size, what is indicative of an important role of somatoscopic examination when evaluating an individual variant of physical development and predicting adaptive capacities of the body in medical practice.

For practical healthcare, the study results suggest revising of the content of standard physical education programmes. It is recommended that, for predicting adaptive capacities of a child body, school medical officers pay attention to somatoscopic examination when evaluating an option for physical development according to the comprehensive methodology.

The study indicates the key role of organising physical education in child collectives, the significance of adaptive reserve of the cardiovascular system in connection with new relationships between Physical Working Capacity and morpho-functional indicators. It is suggested that a methodology of estimating the complex indicator of Physical Working Capacity with determination of the functional reserve level of the body be employed for purposes of health service practices in physical training and sports.

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