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# Complex use of cycle- and power-ergometry in determining the physical working capacity of young athletes

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physical working capacity, diagnostics, cycle ergometry, power-ergometry, young athletes, adolescence.

## Ключові слова:

фізична працездатність, діагностика, велоергометрія, power-ергометрія, юні спортсмени, підлітковий вік.

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**The aim** of this study is to scientifically substantiate the possibilities of complex use of cycle- and power-ergometry in determining aerobic and anaerobic-aerobic performance of power nature.

**Materials and methods.** Young athletes (boys) aged 15–16 (n = 91) of the Brovary Higher School of Physical Education (Kyiv region) (experimental group), who participated in the study, were divided into two groups. Group A (n = 47) – speed-power sports (boxing, freestyle wrestling); group B (n = 44) – endurance sports (track and field athletics: 800, 1500, 3000 and 5000-meters race, bicycle racing 50 and 75 km). Sports experience was 3–5 years and more. The control group (group K) consisted of students aged 15–16, who did not play sports (n = 25). Physical working capacity was determined using two methods: submaximal cycle ergometric test PWC<sub>170</sub> and submaximal power ergometric test PWC<sub>170</sub>. Method of power ergometry (patent of Ukraine No 49417) has no analogues in countries of near and far abroad.

**Results.** The fact of the specific influence of different kinds of dosed physical exercises (strength and power exercises) on PWC<sub>170</sub> indicators was established. Thus, no probable differences in aerobic performance indicators were found in wrestlers and boxers during the cycle ergometric test. And conversely, under the conditions of power ergometric testing, we find a significant increase in their PWC<sub>170</sub> indicators in relation to athletes of endurance sports. The opposite character of changes was observed when testing the track and field athletes and bike riders. According to the results of the conducted cycle ergometry, these athletes had a significant increase in aerobic performance indicators in comparison with the athletes of speed-power sports. However, the changes of anaerobic-aerobic performance were not significant. It was observed that the adolescents, who did not play sports, had statistically insignificant changes in PWC<sub>170</sub> indicators both in the conditions of cycle ergometric and power ergometric testing.

**Conclusions.** The fact of specific influence of different types of training exercises on the body functions of adolescents was confirmed. The possibility of introducing the methods of complex use of aerobic (cycle ergometry) and anaerobic-aerobic loads (power-ergometry) into the practice of medico-biological control of young athletes is shown. Diagnostics of various types of physical working capacity (PWC<sub>170</sub>) will provide the coach with operational information about the functional state of the athletes' body, which will allow to effectively manage a training process.

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## Комплексне використання вело- і power-ергометрії у визначенні фізичної працездатності юних спортсменів

М. Ф. Хорошуха, М. М. Філіппов, А. І. Босенко, Є. Л. Михалюк, О. Ю. Буряк

**Мета роботи** – науково обґрунтувати можливості комплексного використання вело- і power-ергометрії у визначенні аеробної та анаеробно-аеробної працездатності силового характеру.

**Матеріали та методи.** У дослідженні взяли участь юні спортсмени (хлопці) віком 15–16 років (n = 91) Броварського вищого училища фізичної культури (Київська область) (експериментальна група). Обстежених поділили на дві групи: А (n = 47) – швидко-силові види спорту (бокс, вільна боротьба); Б (n = 44) – види спорту на витривалість (легка атлетика: біг на 800 м, 1500 м, 3000 м і 5000 м, велоспорт 50 км і 75 км). Спортивний стаж становив 3–5 років і більше. У контрольну групу (К) залучили учнів віком 15–16 років, які не займалися спортом (n = 25). Фізичну працездатність визначали, використовуючи два методи: субмаксимальний велоергометричний тест PWC<sub>170</sub> і субмаксимальний power-ергометричний тест PWC<sub>170</sub>. Метод power-ергометрії (патент України № 49417) не має аналогів у країнах близького та далекого зарубіжжя.

**Результати.** Виявили специфічний вплив дозованих фізичних навантажень різного характеру (на силу та витривалість) на показники PWC<sub>170</sub>. Так, у борців і боксерів під час велоергометричного дослідження

не визначили вірогідних відмінностей за показниками аеробної працездатності. Разом із тим, під час power-ергометричного тестування встановили у них суттєве збільшення показників  $PWC_{170}$  порівняно зі спортсменами видів спорту на витривалість. Протилежний характер змін виявили впродовж тестування легкоатлетів і велосипедистів. За результатами велоергометрії, у цих спортсменів зареєстровано значний приріст показників аеробної працездатності (на відміну від спортсменів швидко-силових видів). Зміни анаеробно-аеробної працездатності не мали значущих відмінностей. У підлітків, які не займалися спортом, встановили статистично недостовірні зміни показників  $PWC_{170}$  під час і велоергометричних, і power-ергометричних тестувань.

**Висновки.** Підтверджено специфічний вплив тренувальних навантажень різної спрямованості на функції організму підлітків. Показана можливість впровадження в практику медико-біологічного контролю за юними спортсменами методики комплексного використання навантажень аеробного (велоергометрія) та анаеробно-аеробного характеру (power-ергометрія). Діагностика різних видів фізичної працездатності ( $PWC_{170}$ ) надаватиме тренеру оперативну інформацію про функціональний стан організму спортсменів; це сприятиме ефективному управлінню навчально-тренувальним процесом.

Сучасні медичні технології. 2023. № 4(59). С. 37-44

Determining the physical working capacity of people of different ages, sexes, professional employment, as an important component of somatic health, is an urgent problem and occupies the important place in the practice of physical education and sports, clinical and sports medicine, physical rehabilitation [1,2,3]. Despite the fact that a large number of scientific works and developments of leading specialists is devoted to this problem, the peculiarities of the specific influence of different types of training exercises in determining a physical working capacity are insufficiently taken into account until today [4,5]. All the above significantly complicates the work of a sports doctor, a rehabilitator, and a trainer in determining the functional state, creating a rehabilitation program and managing the educational and training process of young athletes.

It is well known that the physical working capacity, as a person's potential ability to exert maximum physical effort in a static, dynamic, or mixed work, is assessed using many functional tests, among them: cycle, treadmill, and step ergometric tests  $PWC_{170}$ . There are also many methodological approaches to determine both physical working capacity in terms of  $PWC_{170}$  and its components [6]. Physical loads of dynamic character are mainly used in the above-mentioned tests. Conducting the research of such kind allows receiving general information about the state of aerobic capabilities of athletes' body. However, for obtaining an objective information about the athlete's functional capabilities, it is expedient to use indicators of aerobic and anaerobic fitness in a complex manner. This will allow to separately describe the contribution of aerobic and anaerobic potential to the general system of energy supply, to identify strong and weak links in the functioning of athletes' body, etc.

For the determination of anaerobic performance in the practice of sports and rehabilitation, there are a number of functional tests: the Wingate test of anaerobic power on cycle ergometer [7,8,9], the Margaria test [10], speed-strength tests [11]. To measure anaerobic power according to the Wingate test, the cycle ergometers of both the old generation (Monark type) and the new one, such as Lode Excalibur Sport, are widely used. The last cycle ergometer correlates well with the previously known ergometer "Monark" [12].

The mentioned tests with high accuracy allow determining the maximum mechanical power of work that the subjects can

achieve during ergometric testing. However, they cannot diagnose physical working capacity by the value of  $PWC_{170}$ . Some of them, for example the Margaria test (it involves running up the stairs at maximum speed) requires certain practical skills from the subjects. Therefore, it cannot be used without a preliminary training of the subjects (especially children) for its implementation. In addition, in our opinion, it is not an absolutely atraumatic procedure.

In recent years, the methods of determining physical working capacity ( $PWC_{170}$ ), carried out in the conditions of sports training or in the so called "field conditions", have been widely used in the practice of sports medicine and sports. These methods are based on the use of the loads specific to particular sports. These include tests using track and field running, cross country skiing, swimming, dosed sports walking, rowing, speed skating, cycling, as well as a barbell test. An example can be the research by Helmi Chaabene, et al. [13]. They developed the new tests and revised existing tests for scientific authenticity (stability, objectivity, validity) in the assessment of special physical performance of martial arts athletes. The physical working capacity ( $PWC_{170}$ ) of athletes using cyclic loads is determined by the locomotive speed (m/s) upon reaching a heart rate of 170 bpm. Accordingly, when using acyclic loads – according to the indicator of the actually performed mechanical work per unit of time (Wt) and work power (W). These tests are a necessary condition for assessing special physical performance in the chosen sport as one of the components of athletes' training. We developed a power-ergometry method for determining the physical working capacity of athletes based on  $PWC_{170}$  [14]. However, in comparison with the above-mentioned methods, our development can be used both in «field» conditions, and in the laboratory. There are the data indicating the possibility of using the submaximal power-ergometry test in the educational process of students of the faculties of health, physical education and sports of higher educational institutions as one of the technical means in conducting a practical training in the course of medical and biological disciplines [15,16].

In the case of conducting functional tests to determine physical performance in laboratory conditions, the method of testing is of great importance. After all, it is known that the nature of training (for example, the predominant effect of physical exertion on the muscles of upper or lower extremities) is reflected in different ways on the indicators of the energy supply of body functions [17,18].



From the research of Mathew Hill, et al. [19] we find the following: cardiorespiratory support of ergometric work of equal power was different in men; it was less stressful when using a cycle ergometer, than a manual ergometer. In the opinion of the researchers, this is due to the fact that the participants performed more work with their lower extremities than with their upper extremities in everyday life. In our opinion, the information from those tests that involve a comprehensive evaluation of both aerobic and anaerobic-aerobic performance ( $PWC_{170}$ ) [10] can also be important.

The above mentioned will make it possible to quantitatively (in  $W$  or  $kgm \times min^{-1}$ ) assess the adaptive capabilities of the organism to work of different orientations (for strength, speed or endurance).

At the same time, we have not found any fundamental scientific works, in which when determining a physical working capacity of athletes, the physical loads of different orientation were harmoniously combined. In this regard there is a need to introduce into the practice of medical and biological control the testing for the diagnostics of aerobic (submaximal cycle ergometric test  $PWC_{170}$ ) and anaerobic-aerobic (submaximal power ergometric test  $PWC_{170}$ ) performance of athletes.

The complex use of aerobic and anaerobic loads in laboratory conditions will allow diagnosing various types of physical performance, determining strong and weak links in the functioning of the body, etc. And on this basis to objectively manage the educational and training process of young athletes.

## Aim

The aim of this study is to scientifically substantiate the possibilities of complex use of cycle- and power-ergometry in determining aerobic and anaerobic-aerobic performance of power nature.

## Materials and methods

Young athletes (boys) aged 15–16 ( $n = 91$ ) of the Brovary Higher School of Physical Education (Kyiv region) participated in the study (experimental group). They were divided into two groups: group A ( $n = 47$ ) – speed-power sports (boxing, freestyle wrestling) (average age –  $15.50 \pm 0.23$  years); group B ( $n = 44$ ) – endurance sports (track and field athletics: 800, 1500, 3000 and 5000-meters race, cycling: 50 and 75 km) (average age –  $15.50 \pm 0.29$  years). Sports experience was 3–5 years and more. Control group of the subjects (group K) consisted of students aged 15–16, who did not play sports ( $n = 25$ ) (average age –  $15.50 \pm 0.80$  years). Physical working capacity was determined with the help of two methods: submaximal cycloergometric test  $PWC_{170}$  and submaximal power-ergometry test  $PWC_{170}$ .

**Method of conducting cycle ergometry research.** The subjects successively performed two loads of moderate intensity lasting 5 minutes with a rest interval of 3 minutes between them on a bicycle ergometer of the mechanical type “Monark” (Sweden). The power of the first load was 75 W, respectively, the second – 150 W. The frequency of pedaling was 50–55 revolutions per minute. The speed of pedaling in both cases was constant and made up 20 km/h. Before testing, the saddle height of the bicycle ergometer was adjusted individually for each subject. A saddle

height where the angle of knee bending with the position of leg in its lower point makes up 170–175 degrees is optimal.

In case of performing the first load, the force of mechanical brake (on scale) was 1.5 kg. One revolution corresponded to 6m of “path travelled”. Accordingly, the mechanical work ( $W$ ) of one revolution is equal to 9 kgm ( $1.5 \times 6$ ). ~ 250 revolutions were made for 5 minutes of work. Similarly, the work done for 5 minutes was equal to 2250 kgm ( $9 \times 250$ ) or 22065 J ( $2250 \times 9.8066$ ), or 22.1 kJ. The power ( $\dot{W}$ ) of the first load made up 450 kgm/min ( $2250 / 5$ ) or 75  $\dot{W}$  ( $450 / 6$ ). Accordingly, when performing the second load, the force of the mechanical brake made up 3 kg, and the power of work – 900 kgm/min or 150  $\dot{W}$ . The frequency of pedaling remained the same as in the first version. The relative power of the first load was on average  $1.0\text{--}1.2 \dot{W} \times kg^{-1}$ , the power of other one –  $2.0\text{--}2.4 \dot{W} \times kg^{-1}$ . At the end of each load (for the last 30 seconds) the heart rate was recorded with the help of a single-channel electrocardiograph. The tape speed was 25 mm/s.  $PWC_{170}$  was calculated using the formula of V. L. Karpman.

### Method of conducting power-ergometry research.

Submaximal power-ergometry test  $PWC_{170}$  (power-ergometry method) is based on the use of static and dynamic loads of power nature – pulling up vertically on a crossbar with a straight medium grip. Quantitative determination (in J) of mechanical work actually performed was carried out using a power ergometer designed by M. F. Khoroshukha [14]. The method has no analogues in countries of near and far abroad.

The research methodology is relatively simple. A subject was offered (without initial warming up) to perform a physical work consisting of two series of loads lasting 4–5 minutes with a 5-minute rest interval between them. The first load consisted of 15 pull-ups, which were made in the mode of one pull-up during 20 s (3–4 s were given for ascent and descent, 16–17 s for rest, while standing on the floor). The second load included 25–30 pull-ups, which, respectively, were performed in the mode of one pull-up during 10 s (3–4 s were given for ascent and descent, 6–7 s for rest). The exercises were performed on a suspended crossbar, which was fixed to the gymnastic wall at the height of the subject's hands raised from the floor.

The power of the first load was  $0.6\text{--}0.8 \dot{W} \times kg^{-1}$ , respectively, the second one ~  $1.5 \dot{W} \times kg^{-1}$ . At the end of each load (for the last 30 s) the heart rhythm was recorded using an electrocardiograph. Tachycardia at the end of the first load was  $100\text{--}120 f_n$ , at the end of the second one –  $140\text{--}160 f_n$  (the average difference made up  $40 f_n$ ). The work was performed under a sound metronome. A teenager was offered to pull himself up to such position that his chin was above the crossbar. In case of muscular fatigue, he could pull himself to a lower height.

The mechanical work was determined using the formula:

$$W = P \times S \times K,$$

where  $W$  – work performed for an hour  $t$  (J),

$P$  – body weight (kg),

$S$  – height of lifting (indicator of the electronic counter of the ergometer) (m),

$K$  – a correction factor that considers the physical expenses (“negative work”), which are associated with the descent from the crossbar. According to the data of our research it is equal to 1.50.

The average work power was determined using the formula:

$$\dot{W} = W / t,$$

where  $\dot{W}$  – work power (W),

W – performed work (J),

t – time of performing work (min).

Physical working capacity  $PWC_{170}$ , as in the case of cycle ergometric studies, was calculated using the well-known formula of V. L. Karpman [7].

The evaluation of the research results was carried out according to the data of the comparative analysis of the first and second (after 6 months) stages of examination of athletes according to the following scheme:

- 1) separately for each athletic discipline;
- 2) separately for groups of athletes;
- 3) carrying out a comparative analysis with a control group.

Athletes were examined in the middle of the preparatory and pre-competition periods, students in October (the first study) and in April – for a second time (the second research). Altogether there were 227 human studies conducted.

Examinations were conducted in the first half of the day from 9:00 till 13:00, that corresponds to the periods of the increased efficiency of the human body. The day before the study the athletes did not train in the second half of the day. The air temperature during laboratory testing was in the range from +18 °C till +23 °C.

The results of the conducted research were statistically processed using the package of the standard computer program Statistica 10. Arithmetic mean (X), mean square deviation (SD) and error of the mean (m) were calculated. The significance of group differences between values (p) was assessed by the parametric Student's t-test. The difference was considered statistically significant at the 5 % level of significance (at  $p < 0.05$ ).

## Results

Table 1 shows the values of  $PWC_{170}$  estimating physical working capacity in adolescents who play speed-power sports (wrestlers, boxers). The research was conducted using two alternative methods of testing: cycle ergometry (in determining aerobic work capacity) and power-ergometry (respectively, anaerobic-aerobic work capacity of power nature).

The fact of the specific influence of training loads of different orientation (in this case, mainly on strength and speed) on the nature of changes (in dynamics) of physical performance values comes to the front. In wrestlers and boxers, during the cycle ergometry study, no significant differences were found in indicators of both absolute and relative aerobic capacity ( $p > 0.05$  in both cases). While in the conditions of power-ergometry testing, a significant increase (at  $p < 0.001$ ) in both above-mentioned indicators of static and dynamic work was found.

The opposite nature of changes was observed when testing representative of endurance sports (track and field athletes, cyclists) (Table 2).

Thus, a significant increase (in dynamics) of the absolute and relative values of the aerobic capacity was recorded in these athletes when conducting cycle ergometry (in all cases  $p < 0.001$ ).

While the changes in their working capacity of power nature were insignificant ( $p > 0.05$ ).

In adolescents who did not play sports (control group), statistically insignificant ( $p > 0,05$ ) changes in absolute and relative indicators of  $PWC_{170}$  were predictably observed in conditions of cycle- and power-ergometry testing (Table 3).

The next stage of experimental research was to conduct a comparative analysis of the physical performance indicators in young athletes who, according to the classification of sports by A. G. Dembo, were united in two large groups: group A – sports that mainly developed speed and strength qualities (wrestlers, boxers) and group B – endurance sports (track and field athletes, cyclists) (Tables 4, 5).

From the materials of Table 4 we find the following:

– there was a statistically significant increase in absolute and relative values of  $PWC_{170}$  in athletes of group B noted under the conditions of conducting cycle ergometry studies in comparison with athletes of group A and representatives of the control group ( $p < 0.001$  in all cases);

– significantly higher values of absolute and relative indicators of  $PWC_{170}$  were also observed in adolescents playing speed-power sports in comparison with the students who did not play sports ( $p < 0.05$  in both cases).

The opposite nature of changes in the physical performance of young athletes was observed when conducting a power-ergometry test.

Thus, the representatives of group A had a significant increase (at  $p < 0.001$ ) in both absolute and relative values of  $PWC_{170}$  in comparison with their peers-athletes who mainly developed the quality of endurance (Group B), and non-athlete students (Group K). Paradoxically, no statistically significant differences were found in the absolute and relative indicators of  $PWC_{170}$ , which were registered among athletes of group B and students of group K ( $p > 0.05$  in both cases).

Repeated (after 6 months) dynamic examinations (Table 5) did not reveal any differences in the nature of changes in  $PWC_{170}$  indicators that had been registered in previous studies (Table 4). Thus, the indicators of relative and absolute values of physical working capacity in representatives of speed-power sports (Group A) were during conducting power-ergometry test, significantly higher compared to athletes of group B and non-athlete students ( $p < 0.001$  in both cases). And conversely, the data of cycle ergometry studies show that the highest values of indicators of aerobic performance are registered in track and field athletes and cyclists compared to other subjects ( $p < 0.001$  in all cases). It should be noted that the endurance is the dominant motor quality for athletes of group B, and for cyclists, among other things, the work on a bicycle ergometer is also a specific load.

From a practical point of view, it was interesting to determine the relationship between the results obtained and the success of the surveyed athletes at the Championships of Ukraine in the selected sports. By means of a survey, according to groups, young athletes who successfully performed at competitions and justified the forecasts of specialists (strong group) were identified. Similarly, athletes who, according to objective results and coaches' opinions, performed unsatisfactorily were identified (weak group) (Tables 6, 7).



**Table 1.** Dynamics of values of PWC<sub>170'</sub> estimating physical working capacity in adolescents aged 15–16 who play speed-power sports (Group A), according to the data of cycle- and power-ergometry testing (n = 92), X ± m

Stages of research	n	Cycle ergometry method		Power-ergometry method	
		PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>	PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>
<b>Wrestlers</b>					
First	24	169.70 ± 3.28	2.60 ± 0.03	79.00 ± 2.25	1.20 ± 0.03
Second	22	174.80 ± 3.11	2.70 ± 0.04	97.30 ± 2.46	1.40 ± 0.04
Significance of difference		>0.05	>0.05	<0.001	<0.001
<b>Boxers</b>					
First	23	173.80 ± 3.13	2.65 ± 0.04	77.50 ± 2.02	1.10 ± 0.04
Second	23	177.20 ± 3.45	2.73 ± 0.05	96.40 ± 2.13	1.40 ± 0.04
Significance of difference		>0.05	>0.05	<0.001	<0.001

**Table 2.** Dynamics of values of PWC<sub>170'</sub> estimating physical working capacity in adolescents aged 15–16 who played endurance sports (Group B), according to the data of cycle ergometry and power-ergometry test (n = 87), X ± m

Stages of research	n	Cycle ergometry method		Power-ergometry method	
		PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>	PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>
<b>Track and field athletes</b>					
First	23	194.20 ± 2.06	2.90 ± 0.03	51.90 ± 2.39	0.80 ± 0.03
Second	22	212.80 ± 3.18	3.10 ± 0.05	54.40 ± 2.80	0.80 ± 0.03
Significance of difference		<0.001	<0.001	>0.05	>0.05
<b>Cyclists</b>					
First	21	204.60 ± 2.34	3.00 ± 0.03	55.20 ± 2.03	0.80 ± 0.03
Second	21	221.60 ± 3.29	3.20 ± 0.04	57.10 ± 2.49	0.80 ± 0.03
Significance of difference		<0.001	<0.001	>0.05	>0.05

**Table 3.** Dynamics of values of PWC<sub>170'</sub> test estimating physical working capacity in adolescents aged 15–16 who did not play sports (Group K), according to the data of cycle- and power-ergometry testing (n = 48), X ± m

Stages of research	n	Cycle ergometry method		Power-ergometry method	
		PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>	PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>
First	25	133.90 ± 3.04	2.30 ± 0.03	52.00 ± 3.53	0.70 ± 0.03
Second	23	136.70 ± 3.35	2.30 ± 0.03	54.20 ± 4.31	0.80 ± 0.04
Significance of difference		>0.05	>0.05	>0.05	>0.05

**Table 4.** Comparative analysis of values of PWC<sub>170'</sub> estimating physical working capacity in adolescents aged 15–16, according to the data of the first stage of research (n = 116), X ± m

Group	n	Cycle ergometry method		Power-ergometry method	
		PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>	PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>
Group A	47	171.70 ± 3.20	2.60 ± 0.04	78.30 ± 2.13	1.20 ± 0.04
Group B	44	199.40 ± 2.20	2.90 ± 0.03	53.60 ± 2.21	0.80 ± 0.03
Group K	25	133.90 ± 3.04	2.30 ± 0.03	52.00 ± 3.53	0.70 ± 0.03
Significance of difference	p1–p2	<0.001	<0.001	<0.001	<0.001
	p1–p3	<0.001	<0.001	<0.001	<0.001
	p2–p3	<0.001	<0.001	>0.05	>0.05

**Table 5.** Comparative analysis of values of PWC<sub>170'</sub> estimating physical working capacity in adolescents aged 15–16 according to the data of the second stage of research (n = 111), X ± m

Group	n	Cycle ergometry method		Power-ergometry method	
		PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>	PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>
Group A	45	176.00 ± 3.28	2.70 ± 0.05	96.80 ± 2.30	1.40 ± 0.04
Group B	43	217.20 ± 3.23	3.20 ± 0.05	55.80 ± 2.65	0.80 ± 0.03
Group K	23	136.70 ± 3.35	2.30 ± 0.03	54.20 ± 4.31	0.80 ± 0.04
Significance of difference	p1–p2	<0.001	<0.001	<0.001	<0.001
	p1–p3	<0.001	<0.001	<0.001	<0.001
	p2–p3	<0.001	<0.001	>0.05	>0.05

**Table 6.** Indicators of physical performance of PWC<sub>170'</sub> young sportsmen of 15–16 years old, representatives of high-speed and power sports who performed successfully (strong group) and unsuccessfully (weak group) at competitions (n = 47), X ± m

Group	n	Cycling ergometry method		Power-ergometry method	
		PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>	PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>
Strong	10	179.90 ± 3.24	2.80 ± 0.04	98.50 ± 2.24	1.40 ± 0.04
Weak	37	172.80 ± 3.42	2.70 ± 0.05	90.20 ± 2.33	1.30 ± 0.03
Significance of difference (p)		>0.05	>0.05	<0.01	<0.001

**Table 7.** Indicators of physical performance PWC<sub>170'</sub> of young sportsmen of 15–16 years old, representatives of endurance sports, who performed successfully (strong group) and unsuccessfully (weak group) at competitions (n = 44), X ± m

Groups	n	Cycling ergometry method		Power-ergometry method	
		PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>	PWC <sub>170'</sub> W	PWC <sub>170'</sub> W × kg <sup>-1</sup>
Strong	10	226.70 ± 3.41	3.30 ± 0.04	56.70 ± 2.73	0.80 ± 0.03
Weak	34	207.80 ± 3.47	3.00 ± 0.05	54.20 ± 2.44	0.80 ± 0.03
Significance of difference (p)		<0.01	<0.001	>0.05	>0.05

The data of *Table 6* show that 10 sportsmen of group A (5 boxers and 5 wrestlers) who performed well at competitions and took prizes, according to the results of power-ergometric researches, had significantly better absolute ( $p < 0.01$ ) and relative ( $p < 0.001$ ) values of anaerobic-aerobic work capacity than those persons ( $n = 37$ ) who did not take prizes. It should be noted that there were no significant differences in aerobic performance (cycling ergometry method) between PWC<sub>170'</sub> athletes of strong and weak groups ( $p > 0.05$ ).

Accordingly, *Table 7* presents the results of the comparative analysis of physical performance of 10 best sportsmen of 15–16 years old of group B (endurance sports) who got prize places at competitions (strong group) and their peers ( $n = 34$ ) who performed unsuccessfully (weak group). The data of this table indicate that the athletes-winners of group B (4 runners and 6 cyclists) had significantly better absolute ( $p < 0.01$ ) and relative ( $p < 0.001$ ) values of aerobic performance (cycling ergometry method) in comparison with other ( $n = 34$ ) athletes of this group who performed unsuccessfully at the competitions. However, in the values of anaerobic-aerobic performance by power-ergometry there were no statistically significant differences between representatives of strong and weak groups of endurance sports ( $p > 0.05$ ).

## Discussion

Assessment of physical performance occupies one of the leading places in functional diagnostics and is the basis for managing the educational and training process in both sports and recreational physical education. Despite the fact that a large number of scientific papers and developments by leading specialists are devoted to this problem, the specific impact of different types of training exercises on the determination of physical performance is still not sufficiently taken into account [1,2,3,4,5]. This substantiates the relevance, theoretical and practical significance of the chosen direction of study on the search and development of the latest technologies of functional diagnostics [13]. After all, today in Ukraine there are acute issues of selection and recruitment of national teams of different levels and sports. A number of sports cultivated in Ukraine still lag behind the world level [23,25].

Experts emphasise the need to take into account not only age and gender characteristics or physical development, but also the characteristics of physical performance and energy supply mechanisms [23]. To solve such problems, knowledge of individual characteristics of physical and functional fitness depending on the specialisation or role of the athlete [5,6,23]. Teachers and

coaches also need feedback on the impact of the applied means, in particular physical exercises, on individual systems and the athletes' body [16,19,20,25].

The results of our researches which provided complex use of aerobic and anaerobic-aerobic activities in diagnostics of physical work capacity of young sportsmen, testify to the double nature of changes of PWC<sub>170</sub> indicators. The opposite nature of the above changes depends on the following two factors. The first factor is the predominant orientation of the training process. The second factor is the type of dosed physical activity, namely:

- 1) anaerobic-aerobic power activities during power ergometric tests;
- 2) aerobic activities, respectively, during cycling ergometric tests.

According to the results of our studies, the most widespread for high-speed and power sports (group A) was a statistically significant increase in dynamics of absolute and relative indicators of anaerobic-aerobic work capacity, according to power-ergometry ( $p < 0.001$ ) and insignificant changes of aerobic work capacity at cycling ergometry ( $p > 0.05$ ). For endurance sports (group B) there was a significant increase ( $p < 0.001$ ) in aerobic performance and a slight increase ( $p > 0.05$ ) in anaerobic-aerobic performance. As expected, the representatives of the control group (group K) showed insignificant nature of changes ( $p > 0.05$ ) in both aerobic and anaerobic-aerobic performance. The above is indisputable evidence of the specific impact of physical activity on body functions (including physical performance) of people of different ages and occupations [3,6,8,20,21,22]. The result of this impact is the improvement of some and deterioration of other body functions.

This can be confirmed by the results of comparative analysis of physical performance data obtained by different methods of sportsmen-winners with those who failed to perform at high-level competitions. On the basis of the conducted researches it was found that the sportsmen-winners of group A had significantly better indicators of anaerobic-aerobic productivity ( $p < 0.01$ ) (power-ergometry method), than the rest of the group. Accordingly, there were no significant differences ( $p > 0.05$ ) in aerobic power (cycling ergometry) between the athletes of this group. On the contrary, the athletes-winners of group B had significantly better ( $p < 0.01$ ) values of aerobic capabilities compared to other representatives of this group.

Therefore, the complex use of cycle- and power-ergometry methods in laboratory conditions in determining aerobic and anaerobic-aerobic performance can be a component of the medical and pedagogical examination of athletes. The purpose of such examinations is to adjust the educational process in relation to specific pedagogical tasks. These tasks include:

- 1) transition to another state of fitness of an athlete;
- 2) assessment of the state of fitness;
- 3) resolving issues related to changes in activities in the training cycle, etc.

In the process of mass examinations of athletes in order to save time we suggest using only one dosed power-ergometric load of submaximal power. Physical capacity in this case is calculated according to the formula L. I. Abrosimova [14].

The sequence of complex testing in determining the physical performance of athletes is as follows. First, static-dynamic work

of a power nature (power-ergometry method) is performed, then (after 5 minutes of rest) – dynamic work of an aerobic orientation (cycling ergometry method).

**Note.** For trained athletes for whom pull-ups are one of the specific activities (gymnasts, climbers, wrestlers, workouters, etc.), you can offer 50 (60) pull-ups. Under these conditions, one pull-up is performed for 6 (5) s (respectively, 3–4 (2–3) s are allocated for ascent and descent, and 2–3 s for rest). For young athletes of 10–12 years old, the senior lecturer of the Department of Physical Therapy and Ergotherapy, co-author of this article, O. Y. Buriak suggests power loads of 10 pull-ups (one pull-up is performed for 30 s; 3–4 s are allocated for ascent and descent, 26–27 s for rest, standing on the floor).

## Conclusions

1. The fact of specific influence of various training loads on the body functions of adolescents has been confirmed. The possibility of introducing into the practice of medical-biological control over the young athletes the methods of complex use of aerobic (cycle ergometry) and anaerobic-aerobic (power-ergometry) loads is shown. The diagnostics of various types of physical working capacity (PWC<sub>170</sub>) will provide the coach with operational information about the functional state of the body of athletes, which will allow to effectively manage the educational and training process.

2. In case of mass health examination with complex testing of aerobic and anaerobic-aerobic performance (for example, during the annual medical check-up of athletes), for the purpose of saving time, it is expedient to use only one dosed cycle- and power-ergometry load of submaximal power.

**Prospects for further research** is to scientifically substantiate the possibilities of complex use of cycle-and power-ergometry in determining the physical capacity of athletes with disorders of the musculoskeletal system.

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