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The results of many years of complex use of cycle- and power-ergometry in determining the physical capacity of young athletes

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A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation; D – writing the article; E – critical revision of the article; F – final approval of the article

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Aim of the work: to assess the results of a complex use of cycle- and power-ergometry in determining the aerobic and anaerobic-aerobic performance in young athletes for the selection of criteria in predicting athletes' sports abilities and performance results at competitions in certain sports.

Materials and methods. Young athletes aged 15–16 (n = 636) took part in the study in which they represented two groups of athletes according to a training process direction: group A (n = 260) – speed-power sports (boxing, freestyle wrestling); group B (n = 376) – endurance sports (athletics, skiing, cycling, swimming). According to the results of their performance at competitions, all athletes were additionally divided into two groups: 1) a group of people who won prize places at competitions in their chosen sports – winners, 2) a group of their peers who unsuccessfully performed at competitions – outsiders. Physical working capacity was determined using two methods: cycle ergometric test PWC_{170} and power-ergometric test PWC_{170}. Submaximal ergometric test PWC_{170} (Physical Working Capacity, PWC) is a method based on the determination of physical working capacity (load capacity) upon reaching a heart rate of 170 beats·min^{-1}.

Results. The fact of possible prediction of sports results at competitions of adolescents in sports chosen by them, depending on the nature of changes in indicators of aerobic and anaerobic-aerobic performance PWC_{170}, was established. Examples of the performance of young athletes at competitions are given. Statistically significant differences were found in the indicators of aerobic (cycle-ergometry) and anaerobic-aerobic performance (power-ergometry) of athletes-winners and outsiders.

Conclusions. A complex use of cycle- and power-ergometry allows to determine the level of contribution of each type of energy potential separately – aerobic (aerobic performance PWC_{170}) and anaerobic-aerobic (anaerobic-aerobic performance PWC_{170}) to the general physical working capacity (PWC). In our opinion, the level of aerobic and anaerobic-aerobic performance PWC_{170} (according to PWC index proposed by us) may be one of the criteria in predicting athletes' sports abilities and performance results at competitions in certain sports.

Modern medical technology. 2024;16(4):284-291

Результати багаторічного комплексного використання вело- і power-ергометрії у визначенні фізичної працездатності юних спортсменів

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

Мета роботи – оцінити результати комплексного використання вело- і power-ергометрії у визначенні аеробної та анаеробно-аеробної працездатності юних спортсменів для вибору критеріїв під час прогнозування спортивних здібностей і виступу на змаганнях з окремих видів спорту.

Матеріали і методи. У дослідженні взяли участь юні спортсмени віком 15–16 років (n = 636), яких за спрямованістю тренувального процесу поділили на дві групи: група А (n = 260) – швидкісно-силові види спорту (бокс, вільна боротьба); група Б (n = 376) – види спорту на витривалість (легка атлетика, лижний спорт, велоспорт, плавання). За результатами виступу на змаганнях усіх спортсменів додатково поділили на дві групи: 1 – група осіб, які отримали на змаганнях з обраних видів спорту призові місця (призери); 2 – група однолітків, які невдало виступили на змаганнях (аутсайдери). Фізичну працездатність визначали за допомогою двох методів: велоергометричного тесту PWC_{170} та power-ергометричного тесту PWC_{170}. Субмаксимальний ергометричний тест PWC_{170} (від англ. Physical Working Capacity (PWC) – фізична працездатність) – метод, що ґрунтується на визначенні фізичної працездатності (потужності навантаження) при досягненні частоти серцевих скорочень 170 уд/хв$^{-1}$.

Результати. Встановлено факт можливого прогнозування спортивних результатів підлітків у виступах на змаганнях з обраних ними видів спорту залежно від характеру змін показників аеробної та анаеробно-аеробної працездатності PWC_{170}. Наведено приклади виступу юних спортсменів на змаганнях. Виявлено статистично значущі відмінності показників аеробної (велоергометрія) та анаеробно-аеробної працездатності (power-ергометрія) спортсменів-призерів (сильна група) та аутсайдерів (слабка група).

Висновки. Комплексне використання вело- і power-ергометрії дає змогу визначити внесок окремо кожного виду енергопотенціалу – аеробного (аеробна працездатність PWC_{170}) та анаеробно-аеробного (анаеробно-аеробна працездатність PWC_{170}) – у загальну фізичну працездатність (PWC). Зробили висновок, що рівень аеробної та анаеробно-аеробної працездатності PWC_{170} (за індексом PWC) може бути одним із критеріїв прогнозування спортивних здібностей спортсменів і результатів виступів на змаганнях з окремих видів спорту.

Сучасні медичні технології. 2024. Т. 16, № 4(63). С. 284-291

It is well known that physical working capacity is one of the components of somatic health of the population and a necessary attribute of human everyday life, and for athletes, respectively, it is a component of their successful self-realization in a chosen sport [1,2,3,4]. A large arsenal of scientific works by leading experts in the field of physical culture and sports, sports medicine, physical therapy and rehabilitation is devoted to the problem of assessing the physical working capacity of people of different ages, genders and occupations [5,6,7].

However, despite the above, the factor of specificity of the impact of training loads on the body is not sufficiently taken into account when assessing the physical working capacity of athletes [8]. The latter is especially acutely reflected in the issue of conducting a comprehensive selection and staffing of Ukrainian national teams in various sports [9,10]. In this connection, leading experts emphasize the need to take into account both sex and age peculiarities of physical development of young athletes and characteristics of their physical working capacity and mechanisms of the body energy supply during sports selection.

As noted earlier [11], there are many functional tests in determining physical working capacity, namely: cycle ergometry, treadmill ergometry, step ergometry, etc. These tests mainly use dynamic aerobic loads, which allow determining the level of aerobic performance capacity in athletes according to the value of PWC_{170}. Submaximal ergometric test PWC_{170} (Physical Working Capacity, PWC) is a method based on the determination of physical working capacity (load capacity) upon reaching a heart rate of 170 beats·min^{-1}.

There are also a number of functional tests in determining anaerobic performance. Among them are: the Margaria anaerobic test (running up the stairs at maximum speed); the Wingate anaerobic cycle ergometer test (pedaling on a cycle ergometer at maximum speed and counteracting high resistance for 30 s); speed and power tests (used to determine the maximum mechanical power when performing work on a cycle ergometer or a hand ergometer) [12,13,14,15,16], etc. However, the above tests cannot a priori diagnose physical working capacity by the value of PWC_{170}. They can only determine the maximum and average anaerobic work capacity for 30 s. Moreover, some of them (e. g., the Margaria anaerobic test) are not considered atraumatic tests.

We have developed a method of power-ergometry (submaximal power-ergometric test PWC_{170}) for determining anaerobic and aerobic performance of power nature in healthy athletes (Patent of Ukraine No. 49417) and people with disorders of the musculoskeletal system (Patent of Ukraine No. 47969). The method has no analogues in the near and far abroad countries. Testing in the diagnosis of physical working capacity can be carried out both in athletic training conditions (in gym rooms, on sports grounds, stadiums, etc.) and in laboratory conditions.

In this regard, we introduced into the practice of medical and biological control of young athletes the method of a complex use of cycle-and power-ergometry in determining the physical working capacity [11]. In our opinion, the use of the mentioned methodology will allow to realize the following:

– to diagnose the levels of aerobic and anaerobic-aerobic performance on the basis of PWC_{170} values;

– to estimate the adaptive capability of an athlete's body to the work of different orientation (on strength, speed, endurance);

– to define strong and weak links in body function;

– to objectively manage the educational and training process of athletes.

Aim

To assess the results of a complex use of cycle -and power-ergometry in determining the aerobic and anaerobic-aerobic performance in young athletes for the selection of criteria in predicting athletes' sports abilities and performance results at competitions in certain sports.

Materials and methods

The study involved the young athletes (boys) aged 15–16 (n = 636) from the Brovary Higher School of Physical Education (Kyiv region), who, by a training process direction, represented two groups of athletes: group A (n = 260, average age 15.00 ± 0.45) – speed and power sports (boxing, freestyle wrestling); group B (n = 376, average age 15.00 ± 0.47) – endurance sports (athletics: 800, 1500, 3000 and 5000 meters race, skiing, cycling, swimming: 200, 400 and 1500 meters). Sports experience was 3–5 years or more. Many years of research and observation of athletes were conducted in two stages of the annual training cycle: stage one (preparatory) – September – October, respectively, and stage two (precompetitive and competitive) – March – April. Besides that, additional examinations were conducted (2–3 days before the competition), the results of which were compared with similar results of the athletes' performance at competitions.

According to the results of their performance at competitions all athletes were additionally divided into two groups: a group of persons who took prize places – winners at competitions in their chosen sports; a group of their peers who unsuccessfully performed at competitions – outsiders.

Physical working capacity was determined using two methods: submaximal cycle ergometric test PWC_{170} and submaximal power-ergometric test PWC_{170}.

The examinations were carried out in the first half of the day from 9:00 till 13:00 and in the second half of the day from 16:00 till 19:00, i. e. during increased working capacity of human body. The day before the examination, the athletes did not train in the second half of the day. The air temperature during the laboratory testing ranged from +18 °C to +23 °C. All the subjects were familiarized with the content of the tests, the peculiarities of tests conducting, and gave their consent to participate in the research. The determination of physical performance using the method of submaximal cycle-ergometry and power-ergometry PWC_{170} was an integral part of the mandatory set of annual medical examinations (dispensary examinations) of young athletes of the specified school. In total, more than 1,500 human studies were conducted. The results of these studies have not previously been published or submitted to other journals.

The research was conducted on with observance of the basic bioethical provisions of the Convention of the Council of Europe on Human Rights and Biomedicine (04.04.1997), the Declaration of Helsinki of the World Medical Association on ethical principles of scientific medical research with the participation of human beings (1964–2008), as well as the Order of the Ministry of Health of Ukraine No. 690 of 23.09.2009.

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 probability of group differences between values (p) was assessed by the parametric Student's t-test. The difference was considered statistically probable at the 5 % level of significance (at $p < 0.05$).

The research of aerobic capacity was carried out according to the submaximal cycle ergometric test using the mechanical cycle-ergometer "Monark" (Sweden), accordingly, anaerobic-aerobic capacity – to the power-ergometry method (developer of the method M. Khoroshukha). Mechanical work was determined using a power-ergometer "PE-2" of our own design (r. p. No. 980 of the Ministry of Health of Ukraine). Method of power-ergometry (Patent of Ukraine No. 49417) has no analogues in the near and far abroad countries (*note:* method of conducting cycle-ergometry research and method of conducting power-ergometry research are described in detail in the work [11]).

So-called Index PWC (Physical Working Capacity) offered by us is determined by the formula:

$$\text{Index PWC} = PE_{170} / CE_{170},$$

where PE_{170} – anaerobic-aerobic performance according to power-ergometry test PWC_{170};

CE_{170} – aerobic performance according to cycle-ergometry test PWC_{170}.

The assessment of the index (in conditional points) was carried out in the following way:

– 0.60 points and more – level of anaerobic-aerobic performance is high, aerobic performance is low;

– 0.31–0.59 points – balance of anaerobic-aerobic and aerobic performance (conditionally);

– 0.30 points and less – level of aerobic performance is high, anaerobic-aerobic performance is low.

Results

Table 1 presents the results of a comparative analysis of the multi-year-research of physical working capacity in 32 best boxers aged 15–16 who won prize places at competitions (winners) and their peers (n = 106) who performed unsuccessfully (outsiders). The data of this table indicate that the boxers-winners had significantly better absolute and relative ($p < 0.001$ in both cases) values of anaerobic-aerobic performance (power-ergometry method) compared to those athletes who performed unsuccessfully at competitions.

However, in the values of aerobic performance (cycle-ergometry method) no statistically significant differences were found between the representatives of the strong (winners) and weak (outsiders) groups of adolescent boxers ($p > 0.05$). PWC index in athletes of the strong group (0.640 ± 0.039 points) was such that it corresponded to a high level of anaerobic-aerobic performance and, accordingly, a low level of aerobic performance. In boxers of the weak group, this index was 0.480 ± 0.041 points, which corresponded to the balance of anaerobic-aerobic and aerobic performance. The differences between these indices are statistically significant ($p < 0.01$).

Almost the same type of changes in indicators of physical working capacity PWC_{170} of both (strong and weak) groups was registered in young wrestlers aged 15–16 (*Table 2*). Like boxers, in wrestlers-winners (n = 27) PWC index was such that it corresponded to a high level of anaerobic-aerobic performance (0.690 ± 0.043 points), while in athletes-outsiders (n = 95) – to balance of anaerobic-aerobic and aerobic performance (respectively, 0.500 ± 0.052 points). Differences between these indices are also statistically significant ($p < 0.01$).

A comparative analysis of indicators of physical working capacity PWC_{170} of the strong and weak groups of young track-and-field athletes aged 15–16 is specified in *Table 3*. From the data of this table, it can be seen that the winners (n = 22) had reliably better absolute and relative ($p < 0.001$ in both cases) values of aerobic performance according to the data of the cycle ergometry test compared to those athletes (n = 64) who performed unsuccessfully at competitions. At the same time the values of anaerobic-aerobic performance (power-ergometry method) in two groups of runners did not have statistically significant differences ($p > 0.05$). PWC index in athletes of the strong group (0.220 ± 0.033 points) and weak (0.260 ± 0.037 points) was such that it corresponded to a high level of aerobic performance and, accordingly, a low level of anaerobic-aerobic performance. No statistically significant differences were found between the values of both indices ($p > 0.05$).

The results of a comparative analysis of indicators of physical working capacity PWC_{170} in young bicycle riders aged 15–16 some of whom successfully performed at competitions (winners) with their peers, who took one of the last places (outsiders), are illustrated in *Table 4*. From the data of the table, it follows that in bicycle riders, like runners, who also develop the quality of aerobic endurance, and their physical activity engages the muscles of

Table 1. Indicators of physical performance of PWC_{170} young boxers of 15–16 years old, who performed successfully (winner group) and unsuccessfully (outsider group) at competitions (n = 138), X ± m

Group	n	Power-ergometry method		Cycle-ergometry method		PE_{170} / CE_{170}, points
		PWC_{170}, W	PWC_{170}, W·kg^{-1}	PWC_{170}, W	PWC_{170}, W·kg^{-1}	
Winners	32	112.60 ± 2.35	1.70 ± 0.05	172.40 ± 4.07	2.60 ± 0.05	0.640 ± 0.039
Outsiders	106	86.70 ± 2.49	1.30 ± 0.04	176.20 ± 3.84	2.70 ± 0.04	0.480 ± 0.041
Reliability of difference, p		<0.001	<0.001	>0.05	>0.05	<0.01

Table 2. Indicators of physical performance of PWC_{170} young wrestlers of 15–16 years old, who performed successfully (winner group) and unsuccessfully (outsider group) at competitions (n = 122), X ± m

Group	n	Power-ergometry method		Cycle ergometry method		PE_{170} / CE_{170}, points
		PWC_{170}, W	PWC_{170}, W·kg^{-1}	PWC_{170}, W	PWC_{170}, W·kg^{-1}	
Winners	27	123.30 ± 2.44	1.80 ± 0.05	178.00 ± 3.97	2.60 ± 0.05	0.690 ± 0.043
Outsiders	95	85.40 ± 2.52	1.30 ± 0.05	170.90 ± 3.76	2.60 ± 0.04	0.500 ± 0.052
Reliability of difference, p		<0.001	<0.001	>0.05	>0.05	<0.01

Table 3. Indicators of physical performance of PWC_{170} young track and field athletes of 15–16 years old, who performed successfully (winner group) and unsuccessfully (outsider group) at competitions (n = 86), X ± m

Group	n	Power-ergometry method		Cycle ergometry method		PE_{170} / CE_{170}, points
		PWC_{170}, W	PWC_{170}, W·kg^{-1}	PWC_{170}, W	PWC_{170}, W·kg^{-1}	
Winners	22	49.20 ± 2.43	0.70 ± 0.03	222.80 ± 3.18	3.20 ± 0.05	0.220 ± 0.033
Outsiders	64	47.40 ± 2.44	0.70 ± 0.03	183.20 ± 2.49	2.70 ± 0.04	0.260 ± 0.037
Reliability of difference, p		>0.05	>0.05	<0.001	<0.001	>0.05

Table 4. Indicators of physical performance of PWC_{170} young cyclists of 15–16 years old, who performed successfully (winner group) and unsuccessfully (outsider group) at competitions (n = 103), X ± m

Group	n	Power-ergometry method		Cycle ergometry method		PE_{170} / CE_{170}, points
		PWC_{170}, W	PWC_{170}, W·kg^{-1}	PWC_{170}, W	PWC_{170}, W·kg^{-1}	
Winners	28	48.70 ± 2.52	0.70 ± 0.03	225.90 ± 3.31	3.20 ± 0.05	0.220 ± 0.035
Outsiders	75	50.30 ± 2.48	0.70 ± 0.03	202.10 ± 3.54	2.80 ± 0.05	0.250 ± 0.038
Reliability of difference, p		>0.05	>0.05	<0.001	<0.001	>0.05

mainly the lower extremities, the same type of changes in these indicators was noted.

So, adolescents of the strong group (n = 28) had reliably better values of aerobic performance according to the cycle-ergometry test compared to those athletes (n = 75) who performed unsuccessfully at competitions ($p < 0.001$). At the same time, no probable differences in the values of anaerobic-aerobic performance of power nature ($p > 0.05$) was established. As would be expected, PWC index in bicycle riders of both groups was consistent with a high level of aerobic performance and a low level of anaerobic-aerobic performance. Also, no statistically significant differences ($p > 0.05$) were found between the values of PWC indices of both groups. Thus, the winners' index was 0.22 ± 0.035 points, outsiders' – 0.250 ± 0.038 points.

A comparative analysis of indicators of physical working capacity PWC_{170} of both groups of young skiers aged 15–16 (*Table 5*) showed the following:

1. winners (n = 25) had significantly better values of both aerobic ($p < 0.05$) and anaerobic-aerobic performance ($p < 0.001$) compared to outsiders (n = 51);

2. PWC index in skiers of both groups was such that it corresponded to a high level of aerobic performance and a low level of anaerobic-aerobic performance of power nature (on an average of 0.25 points in both groups).

Finally, the results of a comparative analysis of indicators of physical working capacity PWC_{170} in young swimmers aged 15–16, some of whom successfully performed at competitions (winners), and others unsuccessfully performed (outsiders), are

Table 5. Indicators of physical performance of PWC_{170} young skiers of 15–16 years old, who performed successfully (winner group) and unsuccessfully (outsider group) at competitions (n = 76), X ± m

Group	n	Power-ergometry method		Cycle ergometry method		PE_{170} / CE_{170}, points
		PWC_{170}, W	PWC_{170}, $W \cdot kg^{-1}$	PWC_{170}, W	PWC_{170}, $W \cdot kg^{-1}$	
Winners	25	55.70 ± 2.36	0.80 ± 0.03	222.80 ± 3.42	3.20 ± 0.05	0.250 ± 0.037
Outsiders	51	48.60 ± 2.45	0.70 ± 0.03	194.30 ± 3.54	2.80 ± 0.05	0.250 ± 0.034
Reliability of difference, p		<0.05	<0.05	<0.001	<0.001	>0.05

Table 6. Indicators of physical performance of PWC_{170} young swimmers of 15–16 years old, who performed successfully (winner group) and unsuccessfully (outsider group) at competitions (n = 111), X ± m

Group	n	Power-ergometry method		Cycle ergometry method		PE_{170} / CE_{170}, points
		PWC_{170}, W	PWC_{170}, $W \cdot kg^{-1}$	PWC_{170}, W	PWC_{170}, $W \cdot kg^{-1}$	
Winners	30	129.50 ± 3.36	1.80 ± 0.05	224.70 ± 3.42	3.10 ± 0.05	0.580 ± 0.047
Outsiders	81	98.70 ± 3.49	1.40 ± 0.05	197.50 ± 3.54	2.80 ± 0.05	0.500 ± 0.041
Reliability of difference, p		<0.001	<0.001	<0.001	<0.001	>0.05

Table 7. Comparative analysis of the PWC index in prize-winning athletes and outsiders of groups A and B (n = 636), X ± m

Group	n	Index PWC, points	Group	n	Index PWC, points
Winners (group A)	59	0.660 ± 0.040	Outsiders (group A)	201	0.490 ± 0.042
Winners (group B)	105	0.300 ± 0.033	Outsiders (group B)	271	0.310 ± 0.034
Reliability of difference, p		<0.001	Reliability of difference, p		<0.001

presented in *Table 6*. As can be seen, athletes of the strong group (n = 30) had reliably better values of both aerobic performance determined by cycle-ergometry method ($p < 0.001$), and anaerobic-aerobic performance by power-ergometry method ($p < 0.001$) compared to those adolescents (n = 81) who unsuccessfully performed at competitions. PWC index in swimmers of both groups was such that it corresponded to the balance of anaerobic-aerobic and aerobic performance (0.580 ± 0.047 points in winners and 0.500 ± 0.041 in outsiders respectively).

A comparative analysis of the PWC index, as one of the integral indicators of anaerobic-aerobic and aerobic performance of prize-winning athletes and outsiders of both groups, is given in *Table 7*. As expected, statistically significant differences in the PWC index were recorded between the winners and outsiders of groups A and B. Thus, the prize-winning athletes of group A had a high level of anaerobic-aerobic (average statistical values of the PWC index were 0.660 ± 0.040 points) and a low level of aerobic capacity PWC_{170}. Prize-winning athletes in endurance sports (group B) are characterized by the PWC index, which reflects a high level of aerobic capacity PWC_{170} and a low level of anaerobic-aerobic capacity (0.30 points and less). Athletes-outsiders mostly had a balance of anaerobic-aerobic and aerobic capacity with a significant difference in their average arithmetic values (from 0.490 ± 0.042 points in representatives of group A to 0.310 ± 0.034 points in group B; $p < 0.001$).

A characteristic feature of the PWC index of swimmers of both groups (prize winners, outsiders) is that these athletes had a balance of anaerobic-aerobic and aerobic performance (respectively, 0.580 ± 0.047 points for prize winners and 0.500 ± 0.041 points for outsiders). The identified phenomenon can be explained by the lack of dominance of the upper or lower limbs in providing sports activities.

Discussion

It is generally known that the testing of physical working capacity in the practice of sports, sports medicine and physical rehabilitation occupies one of the leading places in the diagnostics of functional state, assessment of cardiorespiratory reserves of the body and is the basis for managing the educational and training process of athletes. Despite the fact that a large number of scientific works and developments of leading specialists are devoted to this problem, the specificity factor of the influence of training loads of different orientations, as noted earlier, is still insufficiently taken into account enough [2,5,6,13,17].

The results of our previous studies [11], which provided for the integrated use of aerobic and anaerobic-aerobic loads in the diagnostics of physical working capacity, indicate a dual nature of changes in PWC_{170} indices in young athletes at different directions of the training process. The result of this effect was the improvement of one (aerobic or anaerobic-aerobic) type of performance and the deterioration of another. Thus, for high-speed sports the most characteristic was a statistically significant increase in the dynamics of anaerobic-aerobic performance indicators (according to power-ergometry; $p < 0.001$) and non-significant changes in aerobic performance indicators (respectively, during cycle-ergometry; $p > 0.05$). On the other hand, endurance sports were characterized by a significant increase in aerobic performance indicators ($p < 0.001$) and the non-significant changes in anaerobic-aerobic performance ($p > 0.05$). The results obtained about the special influence of the sport type and training loads are consistent with the data of many authors [8,9,18,19].

The data of the comparative analysis of indicators of physical working capacity PWC_{170} in adolescents aged 15–16 in various sports, some of whom successfully performed at competitions (winners), and others unsuccessfully (outsiders), indicated the fact that it is possible to predict the results of their performance at competitions in a chosen sport, depending on the nature of changes in aerobic and anaerobic-aerobic performance indicators. So, the winners of competitions among boxers and wrestlers (group A – speed-power sports) were those adolescents who had significantly better ($p < 0.001$) values of anaerobic-aerobic performance (power-ergometry method) in comparison with those athletes who performed unsuccessfully at competitions. PWC index in strong group athletes was consistent with a high level of anaerobic-aerobic performance and a relatively low level of aerobic performance.

Accordingly, the winners in endurance sports (group B – runners and cyclists), whose physical load engaged the muscles of mainly the lower extremities, had significantly better values of aerobic performance according to the data of the cycle-ergometry test compared to outsiders ($p < 0.001$). PWC index of the winners corresponded to a high level of aerobic performance.

It is noteworthy that other winners in endurance sports (skiers and swimmers), for whom a physical load engaged the muscles of the arms and legs, had significantly better values of both aerobic and anaerobic-aerobic performance compared to outsiders. It is interesting to note the fact that if the PWC index in skiers of the strong group corresponded to a high level of aerobic performance and a low level of anaerobic-aerobic performance then in swimmers-winners it corresponded to the balance of anaerobic-aerobic and aerobic performance. The above is indisputable evidence of the specific effect of physical exercises on body functions (including physical working capacity) of people of different ages and occupations [18,17,19,20]. In addition, the result of such influence is the acquisition of some and the "loss" of other functions of the body.

In the scientific publications available to us, there is no data on the complex use of bicycle and power-ergometry in determining the physical capacity of young athletes. Therefore, the method proposed by us, as evidenced by the study of works in this direction, is original, that currently limits the possibilities of comparative analysis with the work of other authors.

Below are the examples of a comparative analysis of changes in indicators of physical working capacity PWC_{170} in adolescents specializing in various sports with the results of their performance at competitions.

The first example. Young skier L., 15 years, body weight 68 kg. The research was conducted in two stages. The first stage was in the middle of the preparatory period (September); the second stage – at the end of the pre-competition period (December). The data of physical working capacity of athlete at the first stage: aerobic performance in terms of PWC_{170} (cycle-ergometry method) made up 169.6 W (2.5 $W \cdot kg^{-1}$), anaerobic-aerobic (power-ergometry method), respectively, – 51.5 W (0.8 $W \cdot kg^{-1}$). The data of the second stage (after 4 months) of research of physical working capacity are presented as follows: $PWC_{170,}$ which was determined by the cycle-ergometry method, increased by 21.6 % and was equal to 206.7 W (3.0 $W \cdot kg^{-1}$), while the mentioned indicator, which was registered by the power-ergometry method, increased by only 6.5 % (respectively, 54.4 W and 0.8 $W \cdot kg^{-1}$). At the All-Ukrainian cross-country skiing competition among the children and youth sports schools (CYSS), which was held in January of the following year, an athlete showed a result lower than expected. In our opinion, one of the reasons, why the skier performed poorly at the competition, was a relatively low level of anaerobic-aerobic performance of power nature. After all, it is known that modern ski tracks make great demands on the physical fitness of ski racers. In order to successfully complete a distance with a complex profile and at high speed, the athletes must not only be endurance athletes, but also strong ones. The latter is achieved using weight-bearing exercises (bending and straightening the arms in a push-up position and on parallel bars, climbing a rope without the help of legs, squatting on one or two legs, pulling up on a crossbar, etc.).

The second example. Here we present the results of aerobic and aerobic-anaerobic performance (PWC_{170}) of young track and field athlete, allrounder B., 16 years, according to the data of annual medical examinations that were made in autumn (September–October) and in spring (March–April). The first stage – data of physical working capacity of athlete according to the autumn examination: body weight – 71 kg; aerobic performance according to submaximal cycle ergometry test – 178.7 W (2.5 $W \cdot kg^{-1}$), respectively, anaerobic-aerobic performance according to submaximal power-ergometry test – 74.0 W (1.0 $W \cdot kg^{-1}$). Within 2.5 months of the training cycle (Autumn–Spring), due to traumatic injuries of the soft tissues of the knee joint, the athlete was forced to suspend aerobic training (especially, the performance of running loads). However, at the instruction of the coach he continued to persistently perform the strength exercises in an athletic hall. Below are the data of the second stage (after 6 months) of research of allrounder: body weight – 72 kg; physical working capacity according to the PWC_{170} value that was established through the power-ergometry method, increased by 26.6 % and made up 95.5 W (1.3 $W \cdot kg^{-1}$). While the PWC_{170} indicator, when conducting a cycle ergometry test of the physical working capacity, increased by only 4.5 % (respectively, 190.0 W and 2.6 $W \cdot kg^{-1}$).

The third example. Two 15-year-old wrestlers with a body weight of 68 kg had the same (2.7 $W \cdot kg^{-1}$) values of aerobic performance determined by the cycle ergometry method. However, they had different values of anaerobic-aerobic performance according to the power-ergometry test. In one athlete, the above-mentioned indicator was equal to 1.1 $W \cdot kg^{-1}$, in the other one, respectively, – 1.4 $W \cdot kg^{-1}$. Difference of PWC_{170} values was 0.3 $W \cdot kg^{-1}$. As shown by the results of the control wrestling match for qualifying for the Ukrainian Freestyle Wrestling Championship, the wrestler with a higher level of the physical working capacity of power nature was the best.

The fourth example. Physical working capacity (PWC_{170}) was determined in two swimmers aged 15 by means of cycle- and power-ergometry tests. Tests were conducted in a pre-competition period (April) of the annual training cycle. Here is the data of their physical working capacity. Thus, swimmer C., 1st category (specialization – freestyle swimming, breaststroke), body weight 71 kg, aerobic performance during a submaximal cycling ergometric test made up 218.4 W (3.1 $W \cdot kg^{-1}$), accordingly, anaerobic-aerobic performance during a submaximal power-ergometric test – 127.6 W (1.8 $W \cdot kg^{-1}$). Another athlete – swimmer K., 1st category (specialization is the same as in athlete C.), body weight 70 kg, aerobic performance was 95.8 W (2.8 $W \cdot kg^{-1}$), anaerobic-aerobic performance, respectively – 104.8 W (1.5 $W \cdot kg^{-1}$). From the above data it is seen that the best values of PWC_{170} in both cases are registered in athlete C. Thus, the difference in values of both aerobic and anaerobic-aerobic performance was equal to 0.3 $W \cdot kg^{-1}$ (in the first case 3.1 $W \cdot kg^{-1}$ against 2.8 $W \cdot kg^{-1}$, in the second case – 1.8 $W \cdot kg^{-1}$ vs. 1.5 $W \cdot kg^{-1}$). Higher levels of aerobic and anaerobic-aerobic performance in swimmer C. compared to swimmer K. contributed largely to the achievement by such sportsman of better sports results. He met the standard of a candidate for master of sports in swimming 200 m freestyle and 200 m breaststroke. Thus, the specificity of swimmers' training which is conducted on land and water with the use of physical loads of various kinds (strength, speed, endurance), which (loads) involve the muscles of the upper and lower extremities while exercising, contributes to the achievement of high rates of both aerobic and anaerobic-aerobic performance. The latter is known to have a positive effect on a swimmers' sports result.

Conclusions

1. A complex use of cycle- and power-ergometry allows to determine the level of contribution of each type of energy potential – aerobic (aerobic potential PWC_{170}) and anaerobic-aerobic (anaerobic-aerobic performance PWC_{170}) to the physical working capacity (PWC) as the athlete's potential ability to exhibit submaximal efforts in aerobic (dynamic) and anaerobic-aerobic (static-dynamic) work.

2. The PWC index in prize-winning athletes of speed-power sports (group A) corresponds to a high level of anaerobic-aerobic (0.60 points and more) and a low level of aerobic performance PWC_{170}; outsider athletes have a balance of anaerobic-aerobic and aerobic capacity. Prize-winning athletes in endurance sports (group B) are characterized by the PWC index, which indicates high level of aerobic capacity PWC_{170} and low level of anaerobic-aerobic capacity (0.30 points and less). In swimmers of both groups (prize-winners, outsiders), the PWC index indicates a balance of anaerobic-aerobic and aerobic performance (respectively, 0.580 ± 0.047 points in prize-winners and 0.500 ± 0.041 in outsiders).

3. The results of the complex use of cycle-ergometry and power-ergometry indicate that the PWC index proposed by us for evaluating the aerobic and anaerobic-aerobic performance of young athletes can be one of the criteria for predicting sports abilities of athletes and the results of performances at competitions in some sports.

Prospects for further research will consist in a scientific substantiation of the potential of a complex use of the cycle- and power-ergometry in determining the physical working capacity of adolescent female athletes.

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