RESPIRATORY ADAPTATION OF CHILDREN AND TEENAGERS TO SPORTS STRESSES

Na Puti K Sportivnomu Masterstvu,
N.A. Fomin, V.P. Filin

Age-Related Prerequisites for Respiratory Adaptation

The morphological and functional prerequisites necessary for respiratory adaptation to muscular activity are formed at an early age. Highly intense structural differentiation of pulmonary tissue and air passages occurs during the first years of life.

The formation of pulmonary alveoli ends during the early school years. The number of alveoli remains virtually constant starting from seven to eight years of age, but the mass and volume of pulmonary tissue and air passages continue to increase until the end of puberty. The total lumen of the bronchi and bronchioles increases from the time sexual maturation starts. In boys, the Adam's apple appears — one of the results of growth of the cartilaginous larynx.

We are able to isolate several primary factors that determine respiratory adaptation to physical exercise. They are external respiration (gas exchange with the external air and diffusion of gases through the walls of the pulmonary alveoli); internal respiration (at the tissue level); and the intermediate respiratory link — the binding and transport of gases by the blood.

The indices of external respiration — namely, vital lung capacity, minute respiratory volume, maximum lung ventilation, and the permeability of pulmonary alveoli to oxygen and carbon dioxide — increase with age and physical training. The increase in these indices is associated with three factors: (1) increased bodyweight; (2) increased mass of the working muscles; and (3) increased need for energy reserves.

However, not all of the above indicators of external respiration are subject to the same training effect. The diffusional capacity of the lungs is the most conservative in this respect. It increases at a faster tempo with age than because of the training effect of physical exercises.

Age-related changes occur in an abrupt, steplike pattern, rather than in a continuous straight line. The minute respiratory volume increases most noticeably by the end of a youngster's first year of life. The second age-related leap occurs at the age of six. The third age-related leap takes place at the age of 11–12. Maximum lung ventilation increases quite dramatically at this stage. The age-related growth of the mass of pulmonary tissue increases the surface area of the pulmonary alveoli.

Consequently, the lungs' diffusional capacity increases. At the age of 8, maximum lung ventilation consists of 13 ml/min/mm Hg; at age 15, it is 18 ml/min/mm Hg. This increase is proportional to body growth and lung capacity.

As a whole, respiratory adaptations seek the most effective forms of regulation during different types of muscular activity. These forms are highly efficient during low-intensity aerobic activity. The greater the power output of a muscular activity, the more intense the respiratory function.

In most school-age children, respiration in an environment of relative muscular inactivity bears the earmarks of civilized society — prolonged sitting at a table, and the school groups limits the chest cavity's mobility. Respiration becomes shallow and superficial; the health and physiological value of such breathing is scant.

It is even worse for a child to breathe through his mouth. Mouth breathing does not allow the nose to perform its bactericidal function. Air is not cleansed of dust particles; and the air is not warmed when the temperature is low. The subsequent chain of events forms a vicious circle, that is, inflammatory processes in the nasopharynx render nasal breathing utterly impossible or extremely difficult.

School-age children know virtually nothing about so-called full breathing, which is an effective way of stimulating respiratory function. The idea of deep nasal breathing is only the first stage in mastering full breathing. Full breathing successively ventilates both the lowest regions of the lungs and the apex of the lungs.

A full inhalation starts with a filling of the lungs' lower regions, then the middle regions, and, finally, the apex, or top, of the lungs. The abdomen drops at the start of the inhalation, freeing the diaphragm; the abdomen pulls in at the end of the inhalation, elevating the diaphragm and filling the top of the lungs.

A deep inhalation, followed by a full exhalation, heightens the effectiveness of lung ventilation and increases the utilization of the oxygen from the exhaled air. Special exercises, combined in a group of respiratory gymnastics, are needed in order to exploit the full potential of external breathing. Teaching children and teenagers full, proper breathing is not simply a matter of paying tribute to the technique. Full breathing is a vital need, an essential condition for preserving one's health and expanding one's potential to adapt to physical loads.

External Breathing During Muscular Activity

Systematic muscular activity stimulates respiratory function. Exercise promotes effective, physiologically sound breathing. The deep inhalation and the forced exhalation that take place during cyclical activities not only increase pulmonary and alveolar ventilation, but also promote greater diffusional capacity of the pulmonary alveoli.

Training helps increase an athlete's maximum voluntary pulmonary ventilation volume. However, the diffusional capacity of the pulmonary alveoli does not change in such a regular manner. Neither does vital lung capacity change as demonstratively as voluntary pulmonary ventilation when an athlete undergoes training.

And although vital lung capacity is not a limiting factor in sports performances, it is taken into account in another index that is important in assessing an athlete's functional potential — the ratio of vital lung capacity to bodyweight (the vital index).

Vital lung capacity ranges between 1700–2200 ml in eight- to nine-year-old children. Among athletic children, the highest vital lung capacity appears in young swimmers; it is 4800–5000 ml at the age of 14–15 years, and by the age of 16 it increases to as much as 5500–5700 ml. The vital lung capacity of athletes engaged in cyclical sports far surpasses that of untrained adults (4500–5000 ml).

For example, vital lung capacity in long-distance runners can reach as much as 6000–6500 ml. The vital index of children is less than that of adults. However, it approaches adult values (75–

80 ml • min^{-1} • kg^{-1}) as early as the end of puberty.

As the aging process alters the structure of vital lung capacity, we also observe a relative decline in both respiratory and residual air volumes when absolute and relative increases occur in the reserve exhalation volume. This change emerges because of the forced breathing that takes place during cyclical activities. The forced underwater exhalation in swimming is part of the structure of the athlete's movement itself and is a gauge of its effectiveness.

An athlete's pulmonary ventilation volume relates directly to his frequency and depth of breathing. The rate of breathing in newborns reaches 70–80 cycles a minute, and respiratory volume ranges from 15–25 ml. A newborn's pulmonary ventilation volume ranges between 600–850 ml. A one-year-old child's pulmonary ventilation expands to 3000–4000 ml • min^{-1}. At the same time, the relative respiratory volume — that is, the volume of respiratory air per unit of bodyweight — declines. The intensity of pulmonary ventilation per unit of bodyweight is greater in children than in adults.

The respiratory system's power increases at a faster rate during puberty. Pulmonary ventilation increases by 150% and reaches adult levels between the age of 11–12 to the age of 17–18.

When affected by physical loads, children's external breathing intensifies primarily because its frequency speeds up. The depth of their breathing hardly changes at all. Maximum pulmonary ventilation improves rapidly as a result of systematic physical exercise. Maximum pulmonary ventilation can reach 50,000–60,000 ml • min^{-1} by as early as nine years of age; by the age of 15–16 it can increase to 140,000–150,000 ml • min^{-1}.

Children are slower than adults at reaching maximum respiratory functions as a result of physical training. Pulmonary ventilation is only 50%, and oxygen uptake is only 60%, of adult levels when children are given a bicycle ergometer test at a heart rate of 196 beats/min, which is 90% of the adult level. Pulmonary airflow resistance in children and teenagers increases during muscular work because of their comparatively narrow bronchial passages. Children's and teenagers' respiratory muscles burn more energy than adults' comparable muscles.

The highly intense pulmonary ventilation in children somewhat compensates for their lower ability to extract oxygen from inhaled air (the utilization coefficient). Younger school-age children can extract 1 liter of oxygen from 29–30 liters of air. As a comparison, an adult can extract 1 liter of oxygen from 24–25 liters of air.

Oxygen transport by the blood becomes more effective with age. The most distinct increase in the blood's ability to transport oxygen occurs during puberty. At the same time, teenagers' ability to tolerate hypoxia which is associated with muscular activity or with a lack of oxygen in the inhaled air (for example, at altitude) — also increases. Fourteen to 15-year-old teenagers can tolerate twice the drop in blood oxygenation that 8–9-year-olds can and still perform muscular work.

Children's low tolerance for hypoxia results from their organs and tissues not being able to utilize oxygen as well as adults. Hence, their drop in blood oxygen tension causes faster oxygen starvation of the tissues than occurs in adults. A blood flow of 21–22 liters will enable a child's tissues to utilize 1 liter of oxygen. An adult can extract 1 liter of oxygen from 15–16 liters of blood flowing through the body's tissues. Consequently, children's hemodynamic loss — the so-called hemodynamic oxygen coefficient — is higher when they receive as much oxygen as adults.

Young school-age children have the least effective pulmonary ventilation, but it improves in teenagers and youths. Children's ability to perform work in hypoxic conditions increases with systematic muscular activity.

However, the oxygen utilization coefficient reaches its maximum values only in mature children. The less-than-adequate pulmonary ventilation in children and teenagers results from their shallow, fast breathing and their relatively low diffusional ability.

The diffusional ability of an athlete's lungs increases as his specialized trainedness increases. Diffusional ability increases because the volume of blood flow in pulmonary tissue increases and also because the thickness of the alveolar-capillary membranes decreases. The expanding contact area between the surface of the pulmonary alveoli and the capillary walls accelerates oxygen transport into the blood.

The amount of oxygen in exhaled air diminishes with age because of the lungs' increased diffusional capacity. At the age of six, oxygen comprises 17.6% of exhaled air; and the utilization of oxygen is 3%. At the age of 10, the corresponding numbers are 17.4% and 3.6%; at the age of 14, the corresponding numbers are 17.1% and 3.9%. By the time a child reaches his teen years, his oxygen transport in the blood does not differ from that of adults, which is 4.3–4.5%.

Younger school-age children have higher resting minute respiratory volumes per unit of bodyweight than teenagers. Younger school-age children's minute respiratory volume is 160–170 ml • min^{-1} kg^{-1} as opposed to 125 ml • min^{-1} • kg^{-1} for 13–14-year-old teenagers. Minute respiratory volume drops to 110 ml • min^{-1} • kg^{-1} in 15–17-year-olds.

The relative decline in teenagers' and youths' minute respiratory volume coincides with an increase in their absolute pulmonary ventilation. Systematic, diverse training helps reduce the minute respiratory volume in conditions of relative muscular rest.

Children have relatively low economy and efficiency of external breathing and blood transport: their oxygen regimens are less intense than adults. This means that children have high potential for increasing their breathing economy and efficiency because of age and because of increased levels of training.

By the end of puberty, the pulmonary ventilation that occurs during intense muscular activity approximates the levels for fully matured individuals (100 or more liters a minute). The age-related decline in the frequency, and increase in depth, of breathing help increase the lungs' diffusional capacity.

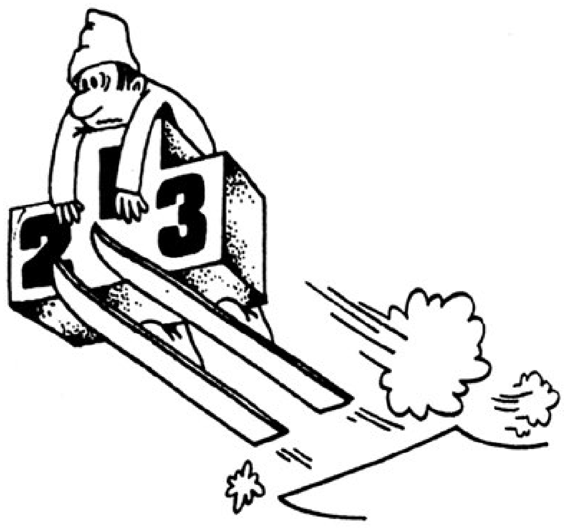
Deep breathing increases the lungs' functional respiratory surface. Fast, shallow breathing fails to create a broad respiratory surface area because the roots of the lungs become functionally inactive. The economizing effect that training has on external breathing is clear. External breathing fails to reach its maximum level during the muscular activity that is involved in most types of sports. A person's maximum potential for increasing his pulmonary ventilation can be judged according to the maximum pulmonary ventilation that occurs when he voluntarily speeds up and deepens his breathing for 15–30 seconds.

The nature of an athlete's sports activity has a strong influence on his external breathing. The highest voluntary pulmonary ventilation per kg of bodyweight has been observed in middle-distance runners; the lowest, in sprinters and weight lifters. Fifteen to 16-year-old middle-distance runners have pulmonary ventilation rates of 2090 ml • min^{-1} per kg of weight; 17–18-year-olds, 1960 ml • min^{-1}. For 15–16-year-old sprinters, the rate is 1780 ml • min^{-1}; for 17–18-year-old sprinters, 1930 ml • min^{-1}. In weight lifters, voluntary ventilation is 1650 ml • min^{-1} and 1590 ml • min^{-1}, respectively.

The body's exercise-induced morphological restructurings favorably affect respiratory function. Various indicators of external breathing can be important in choosing children for specialized sports and also for assessing their level of training. The peculiarities of age-related respiratory development need to be considered during the initial phase of sports activity.

The inadequate utilization of oxygen from inhaled air, that is, a low breathing-efficiency coefficient, presumes that young athletes will take more frequent, and longer, rest intervals between exercises than adults. Such controlling of the physical workload normalizes the breathing function and helps improve the child's body's oxygen regimen. ❖

(To be continued)



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PART 2

(Continued from Volume 26, Number 2)

Internal Respiration During Muscular Activity

Children have several characteristics that limit their potential for performing muscular work, and these characteristics apply to internal respiration and external respiration. Maximum oxygen uptake — its absolute value and relative to bodyweight — increases with age. In addition, age also increases the efficiency of oxygen utilization from inhaled air.

Starting at around the age of 10–12, we observe higher rates of maximum oxygen uptake in trained, as opposed to untrained, children. However, these differences are insignificant at the age of 8–9.

Calculations of maximum oxygen uptake per unit of muscle mass show that children, on the other hand, have advantages over adults. At the age of 9–11, maximum oxygen uptake per unit of mass is greater than the corresponding figure for adults.

Children's maximum oxygen uptake depends on several different factors. For example, children have a lower oxygen capacity of the blood, that is, the ability of the blood to bind oxygen. Lower blood hemoglobin levels explain children's limited capacity to uptake, or consume, oxygen. The amount of hemoglobin per kg of bodyweight is 7.5 gm in 7–9-year-olds; 7.4 gm in 10–11-year-olds; and 8.4 gm in 12–14-year-olds. Blood hemoglobin levels do not reach adult levels until about the age of 15.

As young athletes become more highly trained, external and internal respiration become more highly mobilized during intense muscular activity. The minute respiratory volume that occurs during moderate-intensity muscular activity declines in children and teenagers as they become more highly trained.

The oxygen regimens of even highly trained young athletes are not as efficient as those of adults. For example, young athletes who have maximum oxygen uptake levels that rival adults will still stop exerting themselves sooner than adults. The reason? Their energy expenditure is less efficient.

Nonathletic girls' maximum oxygen uptake stabilizes at age 14, under normal circumstances; the equivalent age for nonathletic boys is 16. However, we do not observe this stabilization in young athletes. As athletes become more highly trained, maximum oxygen uptake increases, reflecting the cardio-respiratory system's functional condition.

School students of different levels of training are less variable in their maximum oxygen uptake than adults. On average, young athletes are less able than adults to increase their metabolism when performing maximum-intensity muscular activity. Teenagers and youths reach their maximum oxygen uptake faster than adults do, but they are unable to sustain it as long as adults can. As young athletes become more highly trained, they are able to expend their energy potential more economically than their untrained age-mates.

A striking example of the difference between trained and untrained youngsters occurs when they perform submaximal work. A group of highly trained 15–18-year-old track athletes performed 800-meter repetitions of increasing intensity. The oxygen uptake of these highly trained athletes fluctuated within the range of 34.7–39.3 $ml \bullet min^{-1} \bullet kg^{-1}$. A less- trained group did the same regimen and their oxygen uptake ranged from 41.3–44.6 $ml \bullet min^{-1} \bullet kg^{-1}$, that is, it significantly exceeded highly trained athletes' levels.

Eight- to 11-year-olds outpace teenagers at liquidating their oxygen debt after brief physical loads, such as 30–60-meter sprints. The reason: their aerobic resynthesis processes develop faster. Children are slower in recouping their oxygen debt after performing more significant workloads, such as 100-meter sprints.

Oxygen consumption hinges on the intensity of the work performed. Interestingly enough, oxygen uptake drops when speed increases from medium to near-maximum. The likely reason for this change is the increased amount of anaerobic energy being supplied.

The increase in maximum oxygen uptake that occurs during muscular work is accompanied by an age-related decline in oxygen consumption during relative muscular rest. This decline relates to the increased amount of motor activity and the activation of chronic homeostatic mechanisms.

As teenagers and youths undergo systematic training, they rapidly improve in indicators that reflect their oxygen-uptake efficiency. Maximum oxygen uptake grows faster in trained than untrained children. After young athletes train for one to two years, their minute respiratory volume and resting oxygen uptake approach levels typical of untrained adults.

The trainability of aerobic mechanisms has been demonstrated experimentally. Outstanding long-distance and ultra-long-distance runners show high results over the course of many years, with a tendency to improve. Their maximum indicators of aerobic metabolism change little during this time. At the same time, one of the most important indices of energy metabolism increases: namely, their economy or efficiency — the ability to generate a high work output at a relatively constant level of energy production.

Relative resting oxygen uptake declines with age; that is, less energy is needed to maintain normal vital activity. When children and teenagers perform moderate-intensity muscular work, their cardio-respiratory functions clearly become more efficient as they become more highly trained. We observed a pronounced increase in the efficiency of youngsters' energy supply when they performed muscular work whose power output increased in step-like fashion. This efficiency increased as the athletes became more highly trained.

The table shows that all of the examined cardio-respiratory indicators increase from phase to phase. The most substantial oxygen-uptake increases that occur during work of increasing power output occur in the 10–11-year-old children and the 13–14-year-old teenagers. The increase in the functional oxygen-uptake maximums occurs slower in 16–17-year-old youths.

The link between cardio-respiratory indicators and sports performances can be characterized as moderate and significant. Maximum oxygen uptake and sports performances are closely related in endurance events. Examples: the 2500-meter run for 10–11-year-olds, the 3000 meters for teenagers, and the 3500 meters for 16–17-year-olds.

The correlation coefficients were 0.71, 0.74, and 0.81, respectively, during the preparatory training period. The correlations remained substantially unchanged during the competitive period: in children and teenagers the correlations were 0.69; in youths, 0.82.

The correlation between oxygen pulse and sports performances was expressed by coefficients of 0.75, 0.80, and 0.75 during the preparatory period and 0.48, 0.61, and 0.71 during the competitive period. We noted a similar correlation between sports performances and the systolic speed of oxygen transport.

Energy Metabolism During Physical Loads

Children's aerobic potentials seem limited when compared with adults. Children expend significantly more total energy than adults when they perform the same amount of work. We have observed no substantial differences between 7–8-year-olds and 9–10-year-olds in regard to their energy expenditure during submaximal work.

When 7–8-year-olds perform a maximum-intensity load, 91% of their energy comes from anaerobic sources. When 9–10-year-olds perform work of maximum power output, they cover 95% of their energy needs from anaerobic sources. In other words, both 7–8- and 9–10-year-old children perform intense work by maximally mobilizing their anaerobic metabolisms.

However, aerobic resources are more highly intensified in 9–10-year-olds than in 7–8-year-olds. The load stress of such work for the energy-supply system is obvious. A situation develops in which the tissues make relatively low utilization of oxygen. The arterio-venous oxygen difference in children is 8–9%, as opposed to a difference of 15–18% in adults. The oxygen utilization coefficient is 50–60% in children; in adults, 85–90%.

The amount of oxygen debt and the maximum oxygen uptake are indirect indicators of the athlete's energy metabolism during physical loads. The maximum energy-metabolism indices during muscular activity are the most important characteristics of the athlete's functional readiness to achieve high performances. We consider these indices when we construct models of functional indices for high-class athletes, that is, potential Olympic and world champions.

The maximum oxygen uptake of 17–18-year-old middle- and long-distance runners should range from 70–73 ml • min^{-1} • kg^{-1}; in girls of the same age, 65–67 ml • min^{-1} • kg^{-1}. These are high numbers; however, they are inadequate if we're talking about the highest sports performances.

Maximum oxygen uptake should be 80–85 ml • min^{-1} • kg^{-1} for high-class adult athletes, specifically, 5–10 km runners, cyclists. Maximum oxygen uptake in women 800–1500 m runners should be 55–70 ml • min^{-1} • kg^{-1}. Maximum oxygen uptake fluctuated from 80 ml • min^{-1} • kg^{-1} in Olympic medal-winning skiers. This high level of oxygen uptake is achieved at a pulse rate of more than 200 beats/min and at pulmonary ventilation of as much as 180–200 liters/min.

The anaerobic-threshold oxygen uptake at a running speed of 4.2 to 4.6 m/sec should be 55–60 ml • min^{-1} • kg^{-1} for boys and 50–55 ml • min^{-1} • kg^{-1} for girls. Young athletes' anaerobic thresholds increase as they become more highly trained. In other words, the foundation is laid for performing more intense work at a level that does not dip into anaerobic reserves. At the same time, the level of alactate oxygen debt grows; however, serum lactic acid increases insignificantly.

We have observed age-related differences in the changes that occur in the anaerobic threshold. Puberty is the least economical period for utilizing the body's aerobic resources. Anaerobic metabolism starts at a pulse rate of 175–180 in 9–10-year-olds. Anaerobic metabolism starts at a pulse of 160 in teenagers; that is, the range in which aerobic resources are utilized becomes constricted during puberty.

However, this is evidence of the fact that children's glycolytic mechanisms are not fully developed, as indicated by the shift of the anaerobic threshold to a lower level of power output.

Maximum oxygen uptake and oxygen debt are considered in assessing the body's adaptive potential. High maximum oxygen uptake, it seems, should completely satisfy the body's oxygen needs. However, the higher an athlete's maximum oxygen uptake, the greater his oxygen debt. This is a seeming contradiction.

Indeed, the higher an athlete's oxygen efficiency, the higher his potential for performing long, intense work. We observe a high correlation between the duration of intense work and the amount of oxygen debt.

The ideal amount of oxygen debt is 310–320 ml • kg^{-1} for high-class athletes who specialize in the 800–1500 meters; that is, oxygen debt should be 19–20 liters at the optimal running bodyweight of 60–65 kg.

An athlete must engage in an extremely intense training program in order to achieve maximum oxygen efficiency and be able to perform work in the face of high oxygen debt. In the case of 800–1500 meter runners, the total amount of running fluctuates from 4.5–5.0 thousand km (800-meter runners) to 5.5–6.0 thousand km (1500-meter runners).

Athletes run from 1000 to 1200 km in a mixed aerobic-anaerobic regimen and 250–300 km in an anaerobic regimen en route to performing these running volumes. Performing these running volumes requires 500–510 workouts a year.

Women 800-meter runners cover 4.0 to 4.2 thousand km a year; women 1500-meter runners, 4.5 to 5.4 thousand km. Their amount of mixed (aerobic-anaerobic) running is 340–360 km, and the amount of anaerobic running is 210–250 km. These high training volumes have become possible because we have expanded our ideas of young athletes' potentials and because we have drawn general conclusions from our practical experience in working with them.

Middle-distance (800–1500 m) runners have been running from 4.3 to 4.6 thousand km a year in recent years. Of this total distance, 480–500 km consists of mixed aerobic-anaerobic running, and 200–220 km consists of anaerobic running. Young athletes closely approach these workloads, despite the higher functional costs of performing workloads that are on par with those of adults.

Coaches, when they are planning young athletes' training loads, should remember that oxygen debt builds up faster in young athletes. Teenagers and youths will build up large amounts of lactic acid in their blood if they perform the same training loads as adults.

Exercise-induced oxygen deficiency develops even faster in children. Children are less able than teenagers and youths to perform work in the presence of oxygen debt. Children also have lower absolute amounts of oxygen debt.

We have observed the most pronounced increase in oxygen debt toward the end of the competitive period in 16–17-year-old athletes. The increased total oxygen debt that arose in all age groups resulted primarily from the lactate fraction. The increased alactate fraction of oxygen debt was insignificant in all cases. The intergroup differences in the growth of oxygen debt were statistically significant in all cases.

We found a high correlation between oxygen debt and achieving high sports performances during all phases of the training cycle.

Glycolytic anaerobic capacity increases as athletes become more highly trained, but it fluctuates within a narrow range. This applies, first, to the alactate component and, second, to the lactate component of anaerobic capacity. Creatine phosphate stores increase insignificantly as athletes become more highly trained, and of course a sprinter's genetic talent for speed plays a critical role in his achieving sports success.

Glycogen stores, which are a fuel source for the second phase of anaerobic energy production, fluctuate within broad limits. However, lactic acid limits an athlete's power output that comes from glycolytic processes. An excess of lactic acid disturbs the acid-alkaline balance.

The glycolytic energy mechanism is an athlete's main energy source for running the 400 meters. As much as 80% of the body's energy for running the middle distances is drawn from the anoxic, or oxygen-free, breakdown of glucose. The glycolytic mechanism changes comparatively little with training. Therefore, we should give preference to athletes who show strong running performances due to their aerobic resources.

In other words, the higher the speed that an athlete can develop before he has to switch to glycolytic energy resources, the more promising his prognosis for performing strongly as a result of building up his anaerobic power.

The speed of an athlete's restorative processes during his rest intervals between repetitions of exercises that stimulate lactate and alactate energy mechanisms is one of the reliable indicators of special work capacity. All other things being equal, a fast restoration rate will allow an athlete to perform a large volume of training, on which the athlete's sports performance ultimately depends.

The speed of restorative processes is an indicator of how effective the cardio-respiratory system's adaptive reactions are. Children recover from medium and light workloads faster than adults. However, children's recovery after intense workloads is slower than more mature athletes.

The duration of the work that can be performed increases with age; at the same time, energy resources increase, but the speed of recovery slows. Volkov (1967) observed that adults take longer to recover than children when an individually tailored muscular load is used.

Apparently, the increased range of the changes in the cardio- respiratory system has a critical influence on the restoration rate. The increased range of changes in the cardio-respiratory system results from age-related increases in the system's functional ceilings and, consequently, increases in the volume of work that can be performed.

The cardio-respiratory system's reactivity and coordination increase with age; the increased reactivity and coordination expand the range of potential changes that can occur in the cardio-respiratory system during intense muscular work, thus prolonging the restorative period.

The age-related differences in the speed of restorative processes can be offset by an individual's level of training: children who train systematically will reach a higher level of work capacity — and, consequently, greater energy expenditure — than untrained teenagers. An individual's level of training also determines the flow of his restorative processes. ❖

HOW TO STRUCTURE TRAINING

Chapter 4 from Vozmi V Sputniki Silu (Moscow, 1988)

V.N. Plekhov

(Continued from Volume 26, Number 2)

Transitional Period (maintenance training).

Duration: 4 weeks.

Content: the goal is to maintain your performance levels and to correct certain lagging groups. The intensity of one training session is about the same as in the preceding stage (special training A), but the rest days are more numerous. You can rearrange, or transpose, exercises and their blocks; you can test new combinations. The diet remains the same. You can finish working the compulsory and optional competitive programs.

Preparatory Period II (supplementary training).

Duration: 4–6 weeks.

Content: to maintain one's results. Other sports are used extensively in conjunction with weight-training exercises. Swimming, rowing, volleyball, cycling, walking, fresh air and sunshine are all beneficial. The diet should be high quality. This is a period in which a foundation is laid for further training.

Special workouts are conducted no oftener than three to four times a week during this period. The intensity and duration of these workouts should be light. You should fly threw them, including each muscle group. Don't become overly enthusiastic! This period of training is designed to restore strength and maintain muscularity, which are helped by switching to other types of activities and using sun, air, water, and other natural factors.

Main Period II (special training B).

Duration: 12–14 weeks.

Content: This is a period in which good conditions are created for improving the form achieved earlier. You should gradually shift to a hard training regimen (preparation for competition) during this time. The first two weeks are devoted to the transitional process. Each muscle group is worked twice a week. The use of complex methods is optional. The training intensity is medium. Later you should switch to work which, in content, is similar to special training A. The strength and muscle volume that declined during the previous period are to be restored in this period.

Improvisation has a place during the training process, but only up to a certain point. Dogmatism isn't a part of athletics. Each athlete is distinguished by his own individual traits. You need to know your capabilities and make note of your strong and weak spots. Some of the prerequisites for success are: consistency, patience, and confidence in your system.