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Training Transfer in Elite Distance Running: From Theory to Practical Application

by Ants Nurmekivi and Harry Lemberg

ABSTRACT

Successful training for endurance running events depends on the optimal connection of training exercises and the transfer of training effects. Not every stimulus will automatically lead to an improvement in running performance. This survey examines the optimal connection of endurance and strength properties and training transfer in the annual training cycle of elite distance runners, applying a logical – analytical approach. The empirical experience of successful coaches confirms contemporary scientific reseach, which tells us that if the effect of endurance and strength exercises is directed at the same muscle fibres – to slow – twitch fibres during the preparatory period and twitch IIa fibres during preparation for competitions – then reciprocal relations between them do not emerge and the training trasfer will be efficient. The logical sequences of developing motor abilities in an annual training cycle, recommended by different authors, provide ideas for programming an individually suited training pattern of a endurance runner, bearing in mind the positive transfer of training.

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Introduction

In the practice of training athletes, it is useful to develop competition movements and the related energy systems as partial elements that can be performed as training exercises. As a higher level of competency is attained in theses exercises, it is relatively easy to apply the gains to the whole movement and in turn improve performance.

The conversion of training exercises into sport performance is called transfer of training[1,2]. This transfer takes place when three demands for specificity have been met:

- there is an equivalent internal structure of movement,
- there is an equivalent external structure of movement,
- there is equivalent generation of energy.

For example, a runner who only exercises with weights will not automatically become more coordinated and begin to run faster. One pattern of exercise can only be used to improve another pattern if the components of the two patterns are similar.

In training for running, each pattern of functional movement is constructed from a fixed series of basic mechanisms[3]:

- the reactive function of specialised muscle groups,
- the fixed reflex – response patterns, which support the movement,
- the sensory function, e.g. the abdominal muscles and the sole of the foot,
- the transfer of force from proximal to distal areas.

One of the central issues of contemporary endurance training is how to attain simultaneous improvement in an athlete's endurance and strength. Both capacities are essential for success in elite distance running but the two processes involved seem to be diametrically opposed: in other words, one tends to prevent the other. In this paper we examine this challenge drawing on the currently existing literature as guidance for coaches of high-potential endurance runners. We will cover the concept of transfer of training, adaptational aspects, hormonal aspects, energetic aspects, developing strength, and linking endurance and strength exercises in a macrocycle.

Transfer of Training

The essence of the concept of transfer of training and its scientific-empirical treatment is covered in great detail in a monograph published by BONDARCHUCK[4], who explains three theories that have influenced the concept and led to the modern understanding of this area, namely *Specificity, General Physical Preparation* and *Integrity.*

According to the *Theory of Specifity*, first put forward by THORNDIKE and also called the *Theory of Similar Elements*, transfer occurs when there are coinciding or similar elements in two actions[5]. The absence of such links works against transfer. In later research, ANOKHIN[6] referred to these coinciding elements in the generation process of functional systems.

The basic feature of the *Theory of General Physical Preparation* is that there is a transfer from general preparation means to specific development and performance. At the time of its widest acceptance and application (1940 – 1960), this theory was considered progressive, however it later emerged that it applies only in cases of athletes of a low qualification level.

The *Theory of Integrity,* or the holistic approach, proceeds from the viewpoint that the human organism is a single whole and any external or internal influence engages in one way or another all its systems. Consequently, development of one kind of ability cannot occur in isolation from the others since they all affect each other. It is well known that different cyclic sports events have a postitive influence on enhancing the functional abilities of the organism.

As a solution to this issue, the renowned coach and theoretician DYATCHKOV[7] suggested the *Principle of Connected Training Effects,* which is directly related to the concept of transfer of training. According to this principle, the means aimed at improving both physical abilities and technique should coincide in their main indices and correspond to the competition movement.

This idea was developed further by BONDARCHUK[8] in the *Principle of Many-Sided Specialised Preparation,* which foresees the preferred application of specialised preparation means throughout the multi-year preparation aimed at elite sport. In this approach, general preparation means are used in small volumes only for warm-up and in recovery activities. It must be said that experts do not all agree on the definitions of the terms “general preparation” and “specialised preparation” for training exercises, but BONDARCHUK advises the use of the following classification:

1. Exercises for general development – exercises where competititon movements are not replicated either totally or partially and, instead, other muscle groups are engaged. These exercises do not lead directly to enhancement of the competition result but promote many-sided development, have a positive effect on the levels of general working capacity and coordination, and promote recovery.

2. Exercises for specialised preparation – similar to the exercises for general development, these do not replicate competition movements either totally or partially, but the muscle groups engaged can be the same as those used in the competition movements. These exercises activate the functions and systems of the organism that influence performance in the athlete’s main discipline.

3. Exercises for specialised development – exercises that replicate single parts of the competition movement. Either the same muscle groups or a major part of the groups used in the competition movement are engaged and the same systems and organs used in competition are activated. With the help of these exercises one can effectively and selectively influence different physical abilities and these exercises promote optimal training condition. The level of ability and condition attained via these exercises is realised in the complete competition exercises.

4. Competition exercises – essentially, these exercises are the discipline in which the athlete is competing. They are applied both in competition and the training process. In the training process they can be repeated under competition conditions or they can be made either easier or more difficult.

The above classification is relevant and consistent with the concept of transfer of training since it proceeds from the external and internal structure of the applied exercises and their correspondence to the competititon movement. It also takes into account the similar features in the basic parameters of energy production and other functional characteristic between the exercieses and the competition activity.

Exercises for specialised preparation and specialised development create a basis for enhancing performance of the competition movements at each stage or period of the training programme. The number and volume of these exercises depends on the concrete targets set for each period. Their transfer effect depends, first of all, on their similarity with the competition activity and higher training potential.

Adaptational Aspects of Endurance Training

In order to successfully conduct the training process of an endurance runner and thereby yield the desired transfer of training, it is necessary to know the genetic, energetic and hormonal features that influence the working capacity of the individual athlete. This knowledge makes it possible to select the appropriate training activities and the most effective variants of their combinations in a training session, in training cycles of different lengths, and in a multi-year programme.

Sport training is an adaptational process during which the specific adaptation to loads and improvement of performance occurs. According to ANOKHIN[9], adaptation and development in living organisms is triggered by an aim and the functioning of the system is directed at attaining this aim. Contemporary training can be seen as a targeted, organised system of components in which the creating factor, (in the sense of Anokhin), is the desired sport performance. From the standpoint of this methodology, it is essential that the observed system, depending on the aim, i.e. the sport performance, changes in structure during the course of the long-term development process. Improvement of the performance is the main criterion of the efficiency of this adaptation.

The adaptational process in humans is subject to general biological laws and reacts to influences similarly to other organisms. One feature to be considered in this context is the probability of adaptation: organisms are likely to respond and adapt to repeated challenges or stimuli that are important for survival. In the case of endurance runners, we can say this challenge is in coping great loads of training. Consequently, it is possible to facilitate coping and shape the planned adaptations in a certain direction with the help of expedient choices and connected training means.

A second feature connected to the probability of adaptation is that the more steadily and continuously the same stimuli are applied, the more quickly the organism will adapt to them. From this standpoint, the most effective preparation programmes are possibly the uncomplicated ones, focusing on the basic components of the structure of the result. The organism's systems are thereby freed from different orientating reactions. In the case of training aimed at high-level performances in endurance running, it is also necessary that the effect of the applied programme increases continuously.

Protein synthesis is the basis of adaptation. It requires considerable energy expenditure and, consequently, the higher the cell's energy potential, the better the possibilities for intensifying the synthesis during the rest period. MEERSON[10] emphasises an important issue from the standpoint of training theory: "Preferentially and selectively developed are the mass and power of the structures responsible for nervous regulation, transportation of ions and energy supply." In this way the optimal functional results of adaptation connected to the cell's temporary hypertrophy are attained, i.e. they are attained at the minimal structural cost.

In this context it is essential to consider the *Principle of the Dominant*. When planning a training programme, one has to consider the sequence of adaptational changes and increase the dynamics of different bioenergetic functions through the concurrence of the training effects.

One more factor to be taken into account is the exhaustion of the adaptational potential of the functional system or the so-called current adaptational reserve[11]. The specificity of adaptation increases with enhanced skills. The highest training transfer is attained by applying specific exercises. However, adaptation to training exercises is strictly individual, and attempts to simply copy the training of elite athletes have proved inefficient.

Hormonal Aspects of Endurance Training

Increase in strength properties is connected with either enhanced innervation or hypertrophy. Hypertrophy is mainly related to myofibrils, i.e. muscle strength. This process includes accelerated protein synthesis, determined by sufficient supplies of energy and amino acids in the muscle and cell, enhanced level of anabolic hormones in the blood and the enhanced level of free creatine and hydrogen ions. The most important elements in this context are anabolic hormones, e.g. testosterone and somatotropin[12].

In this case, the essential factors are the high energetic cost and participation of another group of hormones, the so-called stress hormones, mainly glucocorticoids (adrenalin, noradrenalin). The anabolic function of glucocorticoids is the acceleration of mitochondrial proteins synthesis[13].

Paradoxically, during training these hormones simultaneously fulfil the task of mobilisation (decomposition) of the organism's protein supplies. In other words, they evoke the decomposition of muscle proteins and the lymphatic system proteins, which fulfil the function of the organism's immune (defence) system. For this reason overtraining frequenly leads to the athlete falling ill. Consequently, the simultaneous development of strength and endurance properties is controversial from the standpoint of hormonal regulation. The main practical question with endurance runners is if it is more expedient to develop endurance first and then strength, or vice versa.

The answer can be found in research conducted in the area of functional molecular biology on the role of two key enzymes, AMPK and mTORC1 in simultaneous development of endurance and strength abilities[14]. The first enzyme is connected with the transportation of fats and carbohydrates to the muscle as well as with increase in mitochondrial mass, both of which condition improved endurance properties. The other enzyme switches on during the application of strength exercises and is considered one of the best markers of muscle strength increase.

But why is it difficult to increase both endurance and strength aspects simultaneously? The answer is in the fact that AMPK can block the activation of mTORC1. AMPK is turned on during exercise, but it is rapidly turned off when we refuel. This is because it senses the glycogen depletion in the muscle as well as the metabolic state of the muscle. When these return to normal, AMPK turns off. On the other hand, mTORC1 is not turned on during exercise, but rather during the recovery phase from resistance exercise.

Therefore, if endurance training is performed first, early in the day, and glycogen is reloaded, then AMPK will be low later in the day (when the strength exercises can be performed) and will not interfere with mTORC1. Training for strength at the end of the day allows mTORC1 to be high for the rest of the evening and during sleep. When the athlete wakes, he/she will have at least 12 hours with high mTORC1, promoting muscle growth and improved strength. When beginning endurance training the next day, AMPK is switched on and with it the strength signal, mTORC1 is switched off. In this respect, BAAR[15] emphasises that the key factor of each training programme is the timing of the exercise and the application of a corresponding diet.

Energetic Aspects of Endurance Training

One of the most important challenges in contemporary endurance training is the optimisation of training via better understanding of the energetic factors influencing performance[16]. The importace of the aerobic component of endurance competition is clear and a developed aerobic capacity is also essential for creating favourable conditions for the gradual intensification of training and recovery. Therefore so are the adaptation and development of VO_2max mechanisms and the function of aerobic enzymes.

At the same time, strength and power, and the related enegy metabolisms, are essential for generating the running velocity necessary for performance and success at any desired level. For this purpose, the training loads used for endurance running have to be aimed at both the duration and power of the corresponding metabolic processes and be orientated at the uniform bioenergetic spectrum[17]. This proceeds from the obvious fact that the majority of metabolic processes in a living organism occur simultaneously, are mutually influenced and complement each other.

However, the so-called *Superposition Principle*18 shows the organism's preferred ratio of metabolic energy sources for activities in a specific period of time and at a specific level of power, even though other metabolic processes will be operating in parallel. The scheme of the uniform bioenergetic spectrum (see Figure 1) was compiled proceeding from this principle, i.e. the zones of maximal shares of different metabolic energy sources were desynchronised. The points N_3, N_4, N_5 and N_6 on the figure mark the limit of the maximal maintaining zones of the metabolic sources, following which the power gradually decreases. Points E_3, E_4 and E_5 mark the crossing points of principal metabolic processes, the so-called metabolic transitions, in which two neighbouring biochemical substrates are applied simultaneously. The numbers across the bottom of the figure correspond to metres of running. The indices of the main energy sources shown are for elite male runners.

The scheme reveals that the sequenced metabolic sources are subject to a strict sys-

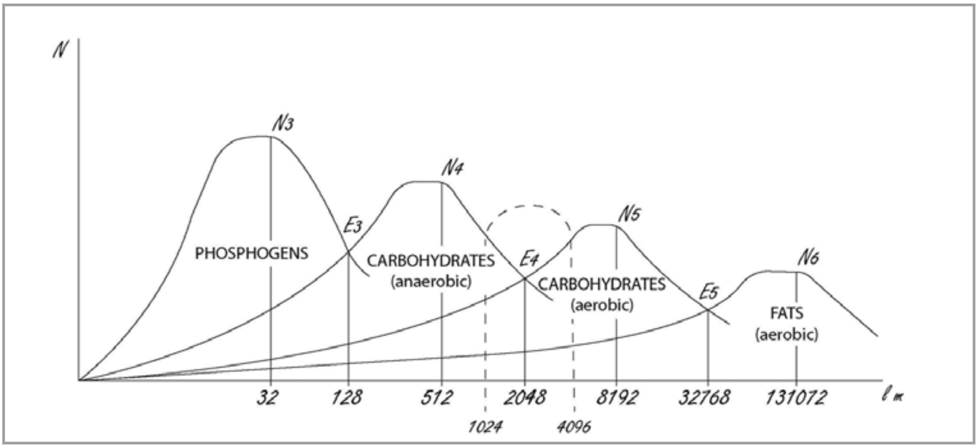

Figure 1: Metabolic sources of energy for intense running efforts

tem. Thus, during running of a certain duration and power requirement, one corresponding metabolic energy source prevails in each time interval. When working with greater duration, and correspondingly lower power, the main role in energy production will be played by the next energy source along the spectrum. Of interest here is research by SPENCER, GASTIN & PAYNE[19], which reveales that the share of aerobic processes in the muscle energetics of runners has been underestimated, not only in middle-distance running but even in te 400m.

High-volume aerobic endurance training cannot be successful if the creatine phosphate mechanism is not developed simultaneously. The reason lies first of all in the mechanism of creatine phosphate being a universal energy transmitter from the mitochondria to myofibrils in the cases of both aerobic and glycolytic exertions[20,21]. The glycolytic mechanism also occupies an important place in muscle energetics. At the same time, glycolytic endurance training has an important part in influencing the activity of lactate transportation proteins[22]. However, developing the glycolitic capability has to be approached carefully because the high level of blood lactate created during this type of training begins to inhibit the aerobic and creatine phosphate mechanisms and even glycolysis itself.

From the viewpoint of connecting training means and transfer of training, optimal solutions must be found for developing aerobic glycolysis and VO_2max mechanisms. Research and successful training practice have both confirmed the positive co-effect of simultaneous application of exercises based on the aerobic and creatine phosphate mechanisms in both the short and long terms. Acknowledging the inhibiting effect of anaerobic-glycolytic energy processes, one has to pay special attention to transfer from preferential development of aerobic endurance to the application of more intensive training means when developing specific endurance.

The question arises whether activities aimed at developing glycolitic capability have to be an influence at the stage of developing basic aerobic endurance or not. If the answer is yes, then what should the volume of this type of training be and with what frequency should the sessions be applied?

Developing Strength in Endurance Athletes

In competitive endurance running it is necessary to spend a lot of energy in an economical manner, sustaining a high functional activity of many organ systems while withstanding fatigue. The physiological basis of running is muscle contraction. In the direct energetic mechanism of muscle work, the main problem is restoring the ATP resources spent, which, depending on the duration and intensity of the work, takes place via aerobic or anaerobic energy production mechanisms.

In view of the efficiency of adaptation processes, one has to take into account that the higher the energetic potential of the cell, the better the possibilities to intensify protein synthesis after both endurance and strength training. Therefore it is logical that in both cases, a training macrocycle starts with increasing the energetic potential of both the organism and the muscles.

Effective development of endurance and strength capacities ensures:

- an increase in the energetic potential of the organism and muscles,
- economisation of energetic expenditure,
- an increase in the functional stability of the organism and muscles,
- an increase in aerobic and anaerobic work capacity.

If energetic processes are taken as the basis for the development of endurance, a typical fundamental development sequence in a macrocycle would be as follows:

aerobic threshold –> anaerobic threshold –> VO_2max speed –> lactic speed endurance –> alactic speed endurance

In this logical sequence, each type of load creates favourable conditions for an increase in intensity.

Another logical sequence of specific training means and methods in a macrocycle of an endurance runner is proposed by Verkchoshanskij[23]:

continuous running –> springing running –> aerobic fartlek –> uphill running –> long accelerations –> repetition running –> competition running.

This system is organised in relation to the principle of ***Superposition of Loads***. Each type of load has a more intensive and specific effect and gradually takes the place of the previous load. The previous load creates the morpho-functional basis to obtain the greatest effectiveness of the subsequent load. The subsequent load assures the realisation of the training of the previous loads at a higher functional level of the organism.

It is likely that both of these logical sequences also ensure good training transfer, owing to the presence of similar elements between the single links of the sequence.

Turning to strength development, in order to better concretise the training process and avoid confusion, the following classification has been suggested[24]:

- muscle endurance,
- strength endurance,
- general strength,
- maximal strength,
- speed strength,
- explosive strength.

If one regards strength training as a pyramid, then its base comprises exercises with an orientation towards endurance (muscle and strength endurance) and general strength with an orientation towards muscular hypertrophy. The apex of the pyramid comprises exercises requiring a high level of innervation (maximal, fast and explosive strength).

Since the classification of strength capacities can be considerably wider than the aforementioned, it is inevitable to specify, from the point of view of an endurance runner, the practical use of vital exercises of strength training with an orientation to endurance, relying on data compiled by Hirvonen & Aura[25].

Exercises developing muscle endurance are performed with a high number of repetitions (20-50 and more) and low resistance (0-30% max); the total number of exercises in training is 500-1500 and the rate of performing the exercises is slow. The effect of these exercises is aimed at the slow-twitch (ST) muscle fibres and it is essentially aerobic strength training, in which the lactate level of blood does not exceed the anaerobic threshold. These exercises can also be called local muscle endurance exercises.

Strength endurance exercises are performed with a resistance of 20-50% max and the number of repetitions in a series is 10-20; the total number of repetitions in training is 300-600 and the rate of performing the exercises is fast. Owing to the latter, the fast-twitch (FT) fibres also start to operate and the effect of the exercises is aerobic-anaerobic. It is recommended to maintain the lactate values of blood at the maximum VO_2 consumption level, in order to avoid the inhibiting effect of glycolysis.

If there is a need to increase the maximum strength level, general strength exercises are suitable for the purpose. These are performed with an additional load (50-85% max), the number of repetitions being 4-12; the total number of exercises in training is 150-200 and the rate of performing the exercises is slow. The aim is to work the muscle to the point where the last repetitions of a series have a developing effect on both the ST and FT muscle fibres leading to hypertrophy.

To be clear, one should not exaggerate strength exercises at a slow rate and over 60% of max, as endurance running does not necessarily require a maximum growth in strength. What is called for is the "creation of a work-space" to perform cell functions[26] and to increase the oxidative potential of muscles. The preferred effect on the strength characteristics of ST fibres should be stressed in general and especially within the basic training period of an endurance runner. The forced strength training with a considerable application of FT fibres often found in training practice is not effective for preparation in the long perspective, thus the choice of exercises to affect ST fibres is vital.

Several research papers[27,28,29] have shown that static-dynamic strength exercises, performed at a slow rate, are considered an effective method for the development of the strength and muscle endurance of ST fibres. In the training schedules of endurance runners the so-called aerobic-strength method[30] is also widely used. This consists of training in challenging conditions – running uphill, in sand, in a mountainous landscape[31,32,33]. Exercises for fast and explosive strength in an individually optimal volume are also necessary for an endurance runner in order to stimulate speed characteristics. Alactic jumping exercises, sprinting and specialised exercises are mainly used in practice. By affecting movement speed, these exercises provide a reserve for the improvement of the mechanical performance of muscle work and a fast distance specific running rhythm.

The principal sequence of strength preparation means within a training macrocycle of an endurance runner can be the following:

muscle endurance –> general strength –> strength endurance.

Linking Endurance and Strength Exercises in a Macrocycle

The training process of a top endurance runner is complex and dependent, to a great extent, on different performance abilities[34,35,36]. In order to be efficient and achieve positive transfer of training, all the components have to be encompassed in a single system and aimed at achieving the final goal – a high-level competition result. The management of the system can be generally viewed as a rearrangement of the system elements, taking into account correspondence with objective biological and pedagogical principles. Consideration also has to be given to the fact that the human organism is a dynamic, self-regulatory and self-preserving system, in which the central nervous system is the leading sub-system.

NEUMANN et al.[37] maintain that endurance training is effective if its main components are linked to each other in such a way that a constantly operating influence spiral is created. The spiral can be visualised in the form of a cone, the base being good basic preparation and the apex being competition-specific preparation and the expected competition performance. This helps us to understand training activities and the progress of adaptation as a single and constant process in which exercises with an ever-growing training potential, together with the respective recovery measures in between separate preparation complexes, are used. This is directly related to the concept of transfer of training.

When examining training transfer mechanisms, BONDARCHUK[38] concludes that the transfer level of physical activities achieved at the end of every stage of training does not take place in the beginning, in the middle or at the end, but throughout the whole stage, i.e. as a process, ensuring a new adaptation level for the exercises to be used during the following stages. It is also evident that transfer of training is only possible in cases where the succession of the applied training means leads to specialised development exercises. If there is no succession to these exercises, there will be no transfer either. At the same time, general development and specialised preparation exercises must be used, with an indirect and balancing effect, in every stage. The ratio of the two may change, but they have to be present in all of the stages.

In the case of the described a structure of cycles, an athlete acquires a sporting condition simultaneously during that general development, special preparation, special development and competition periods, the final outcome of which is a certain level of competition result by the end of the last stage. This type of training transfer is called "current" by BONDARCHUK, differing from "distant" transfer. Current transfer is simpler, as the athlete acquires a sporting condition during exercises, which are used simultaneously.

The endurance runner's competition result in his or her main competition distances is affected by the results in distances that are shorter or longer. The tests made by BONADARCHUK[39] demonstrated that the range of the transfer of motor abilities for 3000m steeplechase runners begins from the 600m distance and ends with the 10,000m distance, whereas the most transmittable are the results in the 3000m and 5000m distances (r = 0.7-0.8). In 5000m and 10,000m runners the range of the transfer of motor abilities also begins with the 600m distance. In the 5000m runners the most transmittable results are in the 3000m and 10,000m distances. In the 10,000m runners the longest distance of favourable transfer is the marathon.

The wide range of the transfer of motor abilities in endurance running is evidently related to the mutual relations of the training effect system and the adaptation systems of the organism. For the coach it is clear that a wide range of aerobic, anaerobic-alactic and anaerobic-lactic training means ought to be considered for producing the desired training effect. The short and long-term adaptive changes in the organism ensure the acquiring of a sporting condition and an oriented transfer of motor abilities. The adaptive reactions can be either general or specific.

Generally, the cardiovascular system and the respiratory system reflect the functional state and any specific reactions are related to adaptive changes in the optional peripheral nervous-muscular structure. The share of the latter in the competition results of endurance runners is of utmost importance and an effective morphofunctional specialisation of the muscle system requires a considerably long period of time.

In sports theory, the prevailing point of view is that aerobic loads create a foundation for lactic and alactic anaerobic loads. While this can be highly regular for general adaptive reactions, it is insufficient to affect the muscle system. This is especially true of top-level endurance runners whose results in races shorter than their main competition distance are very high. However, those results occur due to lactic and alactic training means creating a single bioenergetic spectrum and a full spectrum of adaptive rearrangements. According to a hypothesis by BONDARCHUK[40], it is probable that not only aerobic loads create a basis for greater anaerobic lactic and alactic loads, but these latter loads also increase the capacity for even greater loads of the same types. A scientific fact in support of this idea is discussed above (mechanism of phosphocreatine as a universal energy transfer, the role of glycolytic mechanism in affecting lactate transport proteins). The role of anaerobic and lactic processes in acquiring a maximal level of aerobic capacity, and therefore top condition for endurance running, is also generally recognised. The complex use of aerobic, lactic and alactic training loads induces specific mutual relations, leading to positive results, providing their relations are optimal.

A vivid example of a very high level of complex development of individually suitable relations when developing aerobic and anaerobic abilities can be seen in one of the most versatile runners of all time, the 1984 Olympic 5000m champion Said Aouita (MAR). He repeatedly improved world records in the 1500m, 5000m and 2 miles and was very near to the record in the 2000m, 3000m and mile. His versatility is proved by results in other distances: 200m – 22.8; 400m – 46.9; 1,000m – 2.15:16; 3,000m steeplechase – 8.21:92 and 10,000m – 27.26:11. There is basis to believe that Aouita's training system ensured positive training transfer and his extraordinary range of top-level results.

It is possible to give several examples from world running training history of well developed training systems that were highly successful in their eras, for example Arthur Lydiard's training system used with a number of champions including Peter Snell (NZL) and Murray Halberg (NZL)[41,42], Rolf Haikkola's training system, which served as a basis for the success of Lasse Viren (FIN), and Peter Coe's scientifically grounded training system used on his son Sebastian Coe (GBR)[43]. Analysis of these and other successful systems from the point of view of transfer of training helps to understand their essential nature, solve several principal issues, find innovative approaches and maximally individualise top-level training.

When linking endurance and strength exercises with transfer of training, the system of VERKHOSHANSKIJ[44] for middle and long distance runners deserves attention. This system foresees an organic and interdependent connection between the steady development of the adaptation process and the competition activity. Competitions and the immediate preparation for them are included in an uninterrupted process of the organism, morphofunctional specialisation being a factor of its adaption to the specific work regime. There are no preparation and competition periods, as in the traditional concept. The general strategic line of training can be summarised in the following sequence of actions:

development of local muscle endurance –> improvement of the organism's capacity to work for prolong time at an optimal speed regime –> increase in the top speed to cover the competition distance.

The planning of training in an annual cycle has to begin with special strength preparation: specific aims, means, methods and load volumes, all directed not only towards strength improvement but the intensification of the organism's work regime in order to improve the local muscle endurance of the muscle groups involved in competitive distance running. Overload exercises prepare the organism for high intensity distance running work and assure that this work is carried out under favourable conditions. A gradual passage from special strength preparation to specific competition speed running occurs.

In connection with linking strength and endurance abilities, MJAKINTSHENKO & SELUYANOV[45] maintain that when preparing athletes for endurance sports, one should begin with strength-related preparation, rather than aerobic endurance abilities. They hold that the aerobic preparation is fundamental and result determining at the same time and the sporting result depends immediately on it. The problem lies in the dilemma – whether or not fatigue is conditional primarily on "central" or "peripheral" factors. The conclusions and recommendations given in the monograph are primarily true of athletes in a long-term special training process, whose capability is limited by peripheral or muscle factors.

It would be logical to assume that the development of local muscle endurance helps postpone the formation of fatigue, while decreasing the load on "central" factors, which may also lead to the formation of fatigue. Thus a vital object of training effects should be the structural and enzymatic protein complexes of the muscles, creating favourable preconditions for further increase of speed over a distance. In addition, the formation of active muscle mass creates an energy deficiency in a muscle fibre, providing a stimulus for triggering adaptive synthesis processes for energy reproduction. At the same time, strength capacities would also serve as basis for endurance abilities. MJAKINTSHENKO & SELUYANOV's principal macrocycle planning scheme highlights the following issues:

increasing the elasticity and reactivity of leg muscles connective tissue elements –> increasing the strength abilities of ST muscle tissues –> increasing the aerobic potential of both types of fibre –> integral preparation –> competition. The duration of one or another effect in relation to the respective morphological structures is determined by the formation of a plateau in their growth. That may vary on a very wide scale and depends on the individual particularities of the athlete.

It is likely that hypertrophy of muscle fibres is necessary not only to counterbalance the mechanical load (especially in running events), but also as a factor to increase the aerobic capacity of muscles. Thus a larger "morphological space" is created for growth of the level of both aerobic and anaerobic enzymatic proteins in muscles[46] and improvement in local muscle endurance.

Research by NEMIROVSKAJA[47] shows that in the case of optimum compatibility, the characteristics of myofilament content and oxidative capacities (density of mitochondria, myoglobin content and capillarisation) of the muscle fibre of a top athlete can increase simultaneously, thus ensuring the maximum work capacity of these muscles. Excessive muscle hypertrophy increases inert muscle mass and its scarcity can lower the anaerobic threshold. Consequently, it is necessary to find optimal ratio of strength exercises and aerobic exercises.

The strategy to increase the functional capacities of muscle fibres consists of the hypertrophy of the ST fibres followed by their oxidative potential being taken to the maximum for the competition period. When developing local muscle endurance, the coordinated development of the contractile and oxidative characteristics of the muscles have to be taken into account in order to obtain optimum development of aerobic work capacity. Research by MANTSEVITSH & SMIRNOVA[48] showed that with a small increase in strength (up to 1.5%) the anaerobic threshold and the contractile characteristics of muscles developed practically synchronously. With greater increases (over 2%) in muscle strength, work capacity diminished in the anaerobic thresehold zone. Thus, in the latter case, there are reciprocal relations and training transfer is likely to worsen. One possibility for control would be to monitor the endurance level during strength training. If the speed of the anaerobic threshold decreases, the share of strength exercises has evidently been too high.

Strength exercises used in the year-round training of an endurance runner help to maintain a favourable anabolic background in the organism, since they are natural means to maintain the activity of the hormonal and immune systems in high-volume endurance training. There are two basic approaches to this training: 1) relatively uniform use of strength exercises throughout the entire year and 2) enhanced use during certain preparation stages. Either way we cannot avoid the optimal linking of strength and endurance exercises.

Our earlier research[49,50,51] was aimed at finding compatible linking variants of strength and endurance exercises and the physiological justification and application possibilities of their positive concurrence in the training of an endurance runner. It was concluded that the exercises for the development of aerobic endurance (both at the aerobic and anaerobic threshold levels) and muscle endurance were very much compatible. This is in accordance with ISSURIN[52]. These exercises may be used for a long time, practically all year round, in order to increase or maintain threshold speeds.

Aerobic endurance and alactic strength exercises are compatible too. The latter activates the mechanism of phosphocreatine, creates favourable conditions for effective transfer of energy from mitochondria to myofibrils and the volumes of lactate forming are low in the case of both the devices. Possessing an anabolic effect, they increase the energetic potential of the organism and its utilisation capacity and may be used for a long time as fundamental means of the basic training of a runner[53]. It can be assumed that these positive linking means have a favourable effect also on training transfer as well – in energetic, coordinating and technical terms.

The conclusions of our study are very much compatible with the training system of the successful Italian coach CANOVA[54], who also emphasises the effective linking of training means with an aerobic orientation and muscle endurance in the basic preparation stage of an endurance runner. These coincidences allow us to verify the hypothesis that if the effect of endurance and strength exercises is aimed at the same muscle fibres (in this case the ST fibres), then no reciprocal relations arise between them and it contributes to the transfer of training.

The high level of basic preparation of a top endurance runner is not enough to achieve maximally high results in the competition period. What linking of strength and endurance capacities ensures maximum realisation of the basis created during the period of preparation for competitions? For the purposes of gradual intensification of the training process it would be logical to switch from the development of muscle endurance to the development strength endurance, and, from the point of view of endurance, to an increase in the lactate steady state or VO_2max speed.

From the point of view of endurance running there is a danger of forcing training here. Thus the increasing of intensity must be gradual and long enough, at least eight to 12 weeks, with a simultaneous balancing of aerobic training activities. The feasibility of this approach is convincingly verified by Canova's experience working with Saaeed Saif Shaheen (QAT), Nicholas Kemboi (KEN), James Kwalia (KEN) and others[55]. At the same, it serves as an assurance of achieving effective transfer of training using intensive training exercises.

Conclusion

When attempting to manage training transfer as a process in the development of physical abilities, one must rely on research in the areas of adaptation, genetics, bioenergetics, hormonal regulation, etc., as well as on experience yielded from progressive training practices.

A holistic approach to influencing the endurance runner's organism has been increasingly adopted in practice. This includes proceeding from the internal and external structure of the applied exercises, specificity, awareness of implications of the uniform bioenergetic spectrum and the correspondence of training exercises to competition activities.

By creating a high energy potential in a cell, better possibilities for intensifying post-training protein synthesis arise. For securing increasing distance race velocities it is essential to influence the complexes of structural and enzymatic proteins in muscles and the elastic properties in muscles and connective tissue elements.

Scientific research and the empirical experience of top coaches confirm that if the effect of endurance and strength exercises is directed at the same muscle fibres –preferentially to ST muscle fibres during the preparatory periods and preferentially to FT IIa fibres during preparation for competitions - then reciprocal relations between them do not emerge and the training transfer will be efficient.

The logical sequences of developing motor abilities in an annual training cycle recommended by different authors provide thought-provoking ideas for programming an individually suited training pattern, bearing in mind the positive transfer of training.

Further research in this area would open new perspectives and help to considerably improve the management of the training process in endurance runners leading to the realisation of top condition at a planned time.

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