Endurance training

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Abstract

Endurance training is the act of exercising to increase endurance. The term endurance training generally refers to training the aerobic system as opposed to anaerobic. The need for endurance in sports is often predicated as the need of cardiovascular and simple muscular endurance, but the issue of endurance is far more complex. Endurance can be divided into two categories including: general endurance and specific endurance. It can be shown that endurance in sport is closely tied to the execution of skill and technique. A well conditioned athlete can be defined as, the athlete who executes his or her technique consistently and effectively with the least effort.

INTRODUCTION

Endurance training is essential for a variety of endurance sports. A notable example is distance running events (800metersupwards to marathon and ultra-marathon) with the required degree of endurance training increasing with race distance. Two other popular examples are cycling (particularly road cycling) and competitive swimming. These three endurance are combined in triathlon. Other endurance sports for which extensive amounts of endurance trained include rowing and cross country skiing. Athletes can also undergo endurance training when their sport may not necessarily be an endurance sport in the whole sense but may still demand some endurance. For instance aerobic endurance is necessary (to varying extents) in racket sports, football, rugby, martial arts and basketball. Endurance exercise tends to be popular with non-athletes for the purpose of increasing general fitness or burning more calories to increase weight loss potential.

Long-term endurance training induces many physiological adaptations both centrally and peripherally mediated. Central cardiovascular adaptations include decreased heart rate, increased stroke volume of the heart increased blood plasma, without any major changes in red blood cell count, which reduces blood viscosity and increased cardiac output as well as total mitochondrial volume in the muscle fibers used in the training (i.e. the thigh muscles in runners will have more mitochondria than the thigh muscles of swimmers). Mitochondria increase in both number and size and there are similar increases in myoglobin and oxidative enzymes. Adaptations of the peripheral include capillarization that is an increase in the surface area that both the venous and arterial capillaries supply. This also allows for increased heat dissipation during strenuous exercise. The muscles heighten their glycogen and fat storing capabilities in endurance athletes in order to increase the length in time in which they can perform work. Endurance training primarily works the slow twitch (type 1) fibers and develops such fibers in their efficiency and resistance to fatigue. Catabolism also improves increasing the athletes' capacity to use fat and glycogen stores as an energy source. These metabolic processes are known as glycogenolysis,glycolysis and biolysis. There is higher efficiency in oxygen transport and distribution. In recent years it has been recognized that oxidative enzymes such as succinct dehydrogenate (SDH) that enable mitochondria to break down nutrients to form ATP increase by 2.5 times in well trained endurance athletes In addition to SDH, myoglobin increases by 75-80% in well trained endurance athletes.

Methods and training plans

Common methods for training include per iodization, intervals, hard easy, long slow distance, and in recent years high-intensity interval training. The per iodization method is very common and was accredited to Tudor Bompa and consists of blocks of time, generally 4–12 weeks each. The blocks are called preparation, base, build and race. The goal of a structured training program with per iodization is to bring the athlete into peak fitness at the time of a big race or event. Preparation as the name suggests lays the groundwork for heavier work to follow. For a runner contemplating a competitive marathon the preparation phase might consist of easier runs of 1–4 miles 3-4 times per week and including 2–3 days of core strengthening. In the base phase the athlete now works on building cardiovascular endurance by having several long runs staying in heart rate zone 1-2 every week and each week adding slightly more mileage (using 10% rule for safely increasing the mileage). Core strengthening is continued in the base period. Once the base phase is complete and the athlete has sufficient endurance, the build period is needed to give the athlete the ability to hold a faster pace for the race duration. The build phase is where duration of runs is traded for intensity or heart rate zones 3-5. An easy method to obtain intensity is interval and interval training starts to happen in the build phase. Through interval training during the build phase the athlete can achieve higher lactate threshold and in some athletes VO2 max is increased. Because interval training is demanding on the body, a professional coach should be consulted. In the very least the athlete should do a warm up and active stretching before the interval session and static stretch or yoga after hard interval sessions. It is also advisable to have days of rest or easy workouts the day after interval sessions.[5] Finally the race phase of the per iodization approach is where the duration of the workouts decreases but intense workouts remain so as to keep the high lactate threshold that was gained in the build phase. In Ironman training, the race phase is where a long "taper" occurs of up to 4 weeks for highly trained Ironman racers. A final phase is designated transition and is a period of time, where the body is allowed to recover from the hard race effort and some maintenance endurance training is performed so the high fitness level attained in the previous periods will not be lost.

Methods of Endurance Training Part 1

In Predictors of Endurance Performance, I talked a little bit about the three primary predictors of overall endurance performance which were VO2 max, functional threshold, and efficiency. Over the next two (or possibly more depending on how verbose I am) articles, I want to look at some of the actual methods of endurance training that are used commonly to improve endurance performance.

Today I want to mainly make some introductory comments, looking briefly at some of the major adaptations that occur in response to endurance training. Also, since it gives some important background to understanding why different methods of endurance training work, I'm going to have to bore people with a bit of molecular physiology regarding something called AMPK. In the next sets of article(s), I'll look at the specific methods within the context of the information I've provided today.

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Adaptations to Endurance Training

There are a number of adaptations that occur with regular endurance training that work to improve performance. In no particular order these include (but are probably not limited to):

1. Changes in heart function (notably an increase in how much blood is pumped per stroke).
2. An increase in the oxygen carrying capacity of the blood (through both increased blood volume and increased hematocrit).
3. An increase in capillarization around skeletal muscle.
4. Increases in both mitochondrial number and density.
5. Increases in levels of enzymes involved in energy production.
6. Increased buffering/utilization of acid.

Now, something to keep in mind is that the above adaptations tend to not only occur at different rates (in terms of how long training needs to be carried out to generate/maximize them) but tend to be affected to a greater or lesser degree depending on the type of training that is done. This is one of several reasons that the occasionally argued idea that there is a single optimal intensity for endurance training can't be correct. No single intensity can possibly stimulate or optimize all possible adaptations.

Practically speaking, endurance athletes use a variety of training zones (of varying intensity and duration combinations) to achieve different sets of adaptations as required by the specifics of their sport and their individual needs (e.g. to fix weak points that are limiting current performance). Endurance, VO2 max, efficiency, lactate threshold, acid buffering can all be 'targeted' with specific combinations of intensity, duration and frequency.

Conceptually this is no different from strength athletes using a variety of training zones and intensities to achieve different things. Extensive, moderate intensity methods may be used to generate hypertrophy which provides a base for increased strength gains through higher intensity 'neural' training; heavy slow training may be combined with lighter speed/power work to generate still other adaptations. At some point in the future I'm going to look at specificity vs. variety and discuss this in more detail.

However, and somewhat confusingly, it does look like acid (specifically H+) is a cause of fatigue. It's simply not coming from lactate production or dissociation of lactic acid into lactate and H+. As it also turns out, one of the major determinants of how well the skeletal muscle can deal with this acid is…the size of the aerobic engine. It's turning out that mitochondria can metabolize the acid. Simply put, the bigger your aerobic engine, the better your 'anaerobic' performance. And with that out of the way, I want to get a bit molecular and talk about one of the major skeletal muscle 'sensors' that triggers endurance type adaptations. While this may seem unnecessary detailed, it actually provides a basis for some of the different types of training I want to talk about.

AMPk: The Master Metabolic Regulator

As I mentioned in the section above, today I'm going to focus primarily on the skeletal muscle adaptations that occur with regular endurance training so I want to look a little bit at what drives those adaptations (e.g. what the molecular stimulus actually is). Now, as is always the case, there are a whole bunch of them. Calcium levels in the skeletal muscle, fuel utilization (e.g. fatty acids and glycogen), and free radical production are all turning out to play a role in the stimulus that occurs from endurance training. The last one is interesting as some studies are suggesting that high-dose anti-oxidant supplementation may actually impair some of the endurance adaptations that athletes are seeking.

However, one of the primary effectors of adaptation is something called AMPk (which stands for adenosine monophosphate kinas). Now, I wrote an article about AMPk: The Master Metabolic Regulator several years ago and, since that time, research has simply continued to mount on the topic. For the details you can read the article, I'll simply recap below.

In essence, AMPk is a cellular energy sensor, it reacts to changes in the energy state of the muscle cell and this has a number of effects. For example, when AMPk is activated, the muscle will burn fatter for fuel, it will take up glucose from the blood stream, it will become more insulin sensitive. It's worth mentioning that AMPk activation also inhibits protein synthesis by inhibiting another molecular sensor called mTOR. This explains a whole bunch of other things (such as why doing a lot of endurance training after you lift is a bad idea) which I'm not going to get into in this article.

Relevant to this article, AMPk activation is a big part of what stimulates mitochondrial biogenesis (that is, the creation of new mitochondria). If you remember hearing about the couch potato rat that was turned into a marathon running rat, that was done by over-expressing AMPk in the skeletal muscle.

This is critically important to endurance performance (and, as it turns out, 'anaerobic' performance) because mitochondria are where oxygen is processed. And, as I mentioned above, mitochondria are also involved in buffering acid accumulation during higher intensity/anaerobic activities. Having a bigger aerobic engine ends up having two impacts:

1. You can produce more power without producing acid in the first place
2. When acid is produced, the body can metabolize it better

Which is why even seemingly 'anaerobic' sports end up doing a fair amount of basic endurance work? Even in the 400m (an event lasting 45 seconds), the aerobic contribution is about 50% or so, by the time you get to the 800m, it's even more significant. Athletes in the 400m do a fair amount of aerobic work as part of their total training; it can comprise half or more of the total training volume for an 800m runner depending on their strengths and weaknesses. A speed based runner may do more endurance work; an endurance based runner does proportionally more speed work. But they all do a good bit of aerobic work. But I digress.

So what, you ask, turns on AMPk? Basically, AMPk is activated when the energy status of the cell is disrupted. So under normal conditions, the body is using ATP for fuel but can make as much as it needs. When you start exercising, the body can't make ATP quickly enough and you get an increase in something called ADP (adenosine diphosphate, it's just ATP with a phosphate stripped off of it). ADP is further metabolized to AMP (adenosine monophosphate which is ATP with both phosphates stripped off of it).

And this shift in the ATP/AMP ratio is what turns on AMPk; basically the cell 'senses' that it's energy levels have been disrupted so it turns on other stuff to try and combat that;

AMPk activation is a big part of 'what happens'. And when you activate AMPk along with doing a bunch of other stuff you get an adaptation. Mitochondria proliferate, aerobic enzymes increase; endurance improves.
If you think about what's happening, this should make sense. Increasing endurance simply means that the body is better able to produce sufficient energy to keep continuing without fatigue. So the stimulus for this is related (at least partially) to an imbalance between energy production and energy requirements. The power output or endurance duration that had previously caused the energetic imbalance no longer does due to the adaptation.
This also explains why training has to progress in either intensity, duration or both depending on what's trying to be achieved. At a fundamental level, an improvement in 'endurance' means that the body has improved its ability to maintain ATP levels during exercise; this means that the same training load will no longer activate AMPk in the future and no further adaptations will be stimulated.

Devices to assess endurance fitness

The heart rate monitor is one of the relatively easy methods to assess fitness in endurance athletes. By comparing heart rate over time fitness gains can be observed when the heart rate decreases for running or cycling at a given speed. In cycling the effect of wind on the cyclists speed is difficult to subtract out and so many cyclists now use power meters built into their bicycles. The power meter allows the athlete to actually measure power output over a set duration or course and allows direct comparison of fitness progression. In the 2008 Olympics Michael Phelps was aided by repeated lactate threshold measurement. This allowed his coaches to fine tune his training program so that he could recover between swim events that were sometimes several minutes apart. Much similar to blood glucose for diabetes, lower priced lactate measurement devices are now available but in general the lactate measurement approach is still the domain of the professional coach and elite athlete.

Muscular Endurance Training

Guidelines for a Muscular Endurance (Short-Term) Training Program	
Load	40 - 60% 1RM
No. exercises	4 - 8
Time per station	30 - 60 seconds
No. circuits per session	2 - 4
Rest interval between sets	60 - 90 seconds
Rest interval between circuits	2 - 3
Speed of execution	Medium - fast
Frequency	2 - 3 x week

Muscular endurance is a muscle's ability to work continuously against resistance over a long period of time. To build muscular endurance, an athlete must train her muscles to overcome fatigue. Gains in muscular endurance are not made by increasing the weight lifted, but by increasing the amount of time a muscle spends contracting against resistance. A muscular endurance training program should come after a maximum-strength building phase (high weights, low repetitions), because the greater a muscle's strength, the more force it can exert during muscular endurance training. Muscular endurance training should not be done to muscle failure.

Specificity

To improve athletic endurance, exercises must mirror the challenges that an athlete expects to encounter in competition. There are several kinds of muscular endurance, each used by different athletes according to the demands of their sport. The best muscular endurance programs train muscles in the same movements used in competition. For example, a swimmer may practice his stroke using resistance bands, while a cyclist would train on the leg press machine.

Power Endurance

Power endurance is required for sports where a powerful movement is repeated over and over with little or no rest. Power endurance athletes include boxers, racquetball players and baseball pitchers. To train power endurance, lift about 50 to 70 percent of your one-rep max (1 RM, the maximum weight you could lift for one repetition). Choose three or four sport-specific exercises and complete them all, one after the other, before returning to the first exercise. Doing your workout as a circuit allows one muscle group to recover while another works.

Short-Term Endurance

Activities that require 30 seconds to 2 minutes maximum effort, such as 800-meter sprints and team sports combine aerobic and anaerobic energy metabolism. They require that muscles cope with fatigue and high levels of lactic acid. To train your short-term muscular endurance, use light loads of 40 to 60 percent of your 1 RM and lift for a specific period of time (i.e. one minute) or a high number of repetitions (i.e. 50 repetitions). Like with power endurance, doing a circuit of four to eight exercises will ensure your muscles recover adequately between sets.

"Long-term" Endurance

Activities lasting more than two minutes, such as distance running, 500m freestyle or backpacking require that a muscle fire hundreds of times at a small fraction of its maximal capacity. In the weight room, training with 30 to 40 percent 1 RM improves long-term muscular endurance, but many athletes can improve their long-term endurance outside the gym. Runners and Nordic skiers use hill repetitions to improve long-term muscular endurance, for example.

Continuous Tension

Sports like rock climbing, acrobatics and men's gymnastics require that an athlete remain immobile against resistance. This type of muscular contraction is an isometric contraction. Strength gains made through isometric training are specific to the joint angle trained, so athletes interested in improving their continuous tension endurance should hold the position that they plan to use in competition while holding a weight.

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