5) PRINCIPLES OF TRAINING - REVISITED

I think if you have been in the exercise game for any time at all, you know a lot about the "principles of training". But, I still want to explore this topic a little bit as a prelude to additional training articles that will follow. I will discuss four training principles. Depending on what your read, there are others. This is especially true if you happen to read "Muscle and Fitness". But, I think these main concepts are fundamental to understanding exercise induced adaptation, and encompass most everything else.

1. The Overload Principle

The Cells are Sensitive

We are biological organisms composed of an interdependent assortment of billions of individual cells. It has been said that "every cell in our body is psychological". This may sound crazy, but in a sense it is true. Every cell is in some form or another sensitive to certain forms of stress, and capable of initiating a specific **response**.

Training is a cyclical process of tearing down and building up

Part of understanding this overload principle is knowing that the adaptations we are trying to stimulate require synthesis of new biological material. This process takes time! Even as you sit reading, your body is constantly in a state of deterioration and repair. Some cells, like red blood cells are dying out completely at the rate of 2-3 milllion every second, and being replaced just as fast! Others, like muscle cells, hang around much longer, but are constantly repairing themselves from within. When we train, we do additional, specific damage to some cells, and use up cellular resources (fuel, water, and salts are 3 examples). When you walk off the track or get out of the pool after a workout, you are WEAKER, not stronger. How much weaker depends on the severity of the exercise stress. The cells always seek to maintain *homeostasis*, or the status quo, so the cellular and systemic stress of exercise elicits not just a repair to former levels, but an adjustment, or build-up, of the stressed system that serves to minimize the future impact of the stressor. For example, the depletion of muscle glycogen to low levels by a lengthy exercise session triggers a rebound increase in glycogen storage level. Another example, getting hot and bothered during a run on the first hot summer day initiates a process of adaptation whereby we, within 10 days or so of repeated heat exposures, turn on sweating faster, more intensely, and over a bigger skin surface area, but lose less salt (which means our eyes stop burning when we get that more dilute sweat in them. This **GENERAL ADAPTATION SYNDROME** was described by Hans Selye, and expanded by Yakovlev. If the stress is too small in either intensity or duration, little or no adaptation growth is stimulated. On the other hand, if the stress is too severe, "growth" is delayed or even prevented.

Maintaining homeostasis in the face of chronic stress means increasing the synthesis of specific proteins (mitochondrial enzymes for example) that enable the cell to respond to future demands with less disruption. The optimal training program would be one that maximally stimulated these positive adaptations, while minimizing the cellular and systemic stress thrown at the body in order to trigger the changes. Very hard training does damage and sometimes threatens our health by transiently lowering our resistance to infection. Not to mention the fact that it can stress our time schedules and relationships. Put in real world training terms, the double edged sword nature of the body's response to training suggests that we should try to organize training (frequency, intensity and duration) in such a way that we minimize the negative stress effects while still achieving the physiological adaptations desired. This program would then incorporate the appropriate **recovery time**; 1) long enough to allow the synthetic processes time to occur, while 2) not so long that reversion back towards the previous cellular state could begin. Finally. our overall training program would have to recognize that some cellular adaptations have a faster response time than others. For example, plasma volume increases dramatically within a week of hard training, while capillary growth occurs slowly after years of training. This knowledge will impact the relative amount of training we dedicate to achieving specific adaptations.

Thresholds and Diminishing Returns

If we put this Overload Principle into action, we are talking about regular exercise. When we train, we choose some specific **intensity and duration** of effort (or sometimes IT chooses us!). Then we repeat these efforts with some specific **frequency**. Add in the mode(s) of exercise and you have the 4 variables of a training program. Since even the most untrained body has a built-in reserve capacity to handle a substantial degree of stress, there is a minimum threshold for intensity and duration of stress that must be exceeded before additional adaptations are triggered. This is the **minimum training threshold**. For example, in untrained people starting an exercise program, we don't see significant improvements in exercise capacity unless the training intensity exceeds 50% of their maximal oxygen consumption, but this intensity isn't too difficult to achieve. If you have been doing nothing, almost anything helps. However, the threshold level (in terms of the combination of intensity and duration of exercise) for further adaptation increases as we become more fit. In elite young and older athletes, the threshold for a **positive training response** may exceed 80% of VO2 max. So does this mean that every training session should be above this intensity? No, this is an important lesson to learn, usually discovered after repeated injuries, overtraining, and staleness. Exercise at below the higher training threshold can be important for **maintaining** existing adaptations while **allowing recovery processes to occur.** What we are faced with as we continue training is a **diminishing return** on our training investment. The better adapted we are to exercise, the more difficult it is to induce further positive changes. Emerging from this fact is the use of **periodization of training**, a common training term these days. At the elite level the diminishing returns on training investment are clearly evident as athletes train 3-4 hours per day in order to be 1% faster than if they trained 1.5 hours per day. And they gamble this 1% improvement against the greatly increased risk that they will become injured or sick due to the extra training load. So, we each have to decide how important that last 1% is to us.

2. The Principle of Specificity

I think it is safe to say that the media and shoe makers have combined to confuse many young and older athletes about the Principle of Specificity. Nike, and all the folks who sell exercise equipment would like you to believe that "Cross-training" is a key to peak performance. The concept sells more sports shoes and exercise machines, but is it true? Well, no. Any sport you pursue places highly specific demands on your body in at least two major ways. First, the exercise will have a **very specific pattern of joint and muscle coordination**. For a rower, there is absolutely no substitute for rowing. Ditto for swimming. Even when we try to duplicate the basic movement of a sports skill with strength training exercises, the transfer of increased strength to the actual sports movement is often small or absent. In the worst case this type of training can detract from performance of the real skill due to disruption of technique. Second, the **exercise will place high metabolic** demands on a very specific group of muscles. For example, running and cross-country skiing appear to involve many of the same muscles, used in a similar movement pattern. Yet, several research studies have demonstrated that there is NO relationship between VO2 max measured by treadmill running and VO2 max measured by cross-country skiing in a group of elite-trained skiers. In contrast, there is a strong relationship between on-snow skiing and performance on a skiing specific test such as the double poling test.

A high endurance capacity in a specific sport requires both 1) high oxygen delivery (cardiac output) and 2) high local blood flow and mitochondrial density in the precise muscles used. The only way to **optimally** develop the second component of endurance is to train those exact muscles by doing your sport!

Is there ever a place for cross training?

The answer to that question is definitely yes! BUT, we need to understand as athletes what the limited purpose and value of the alternate exercise modes are. For example, I work with some world class speedskaters from Holland on training issues and physiological testing. After a couple of years of observations, it is clear to me that they just cannot skate every day, at least not in a good competitive skating position. The stress on the legs is just too great. So, in order to achieve the training volumes that we think are necessary for success at that level, the skaters also do a lot of cycling, even during times in the year when ice is available. Our choice of cross-training is an effort to combine the needs for highly specific loading with the need of these elite level athletes to train at high volumes (20 hours per week or more during the preparation period). Take note though that during the racing season, essentially all hard training is performed on the ice, with low intensity and recovery workouts performed on the bicycle. So even when we use cross-training, we are keeping our eyes on the real goal. Or, take me, a 40 year old masters rower for example. During the Spring and Summer back in Austin, Texas, 90% of my endurance training was performed on the water, rowing. However, in the late fall and winter (non-competitve period), I rowed less on the water than I could have (no ice in Austin), probably half as much. Why? Mostly because I was mentally tired of rowing, but also because of weather and time constraints. Sometimes I would row on the indoor machine, by no means a perfect substitute for the technique of rowing, but a good simulation for developing basic rowing endurance. But to be honest, on most days, I hate being on that machine for more than about 45 minutes. Embracing the expression "the mind needs rest, but the body needs work", I would often mix in running or cycling on an ergometer with my rowing to increase my total aerobic exercise volume without growing mentally stale. A little bit of cross-training helped maintain my general aerobic base, while allowing me to mentally recharge my batteries in anticipation of another cycle of intense training on the water with my rowing partners.

Another reason to "cross-train" is to avoid injury and maintain muscular balance DURING a period of intense sport specific training. One of the keys to success in sport is staying healthy over the long haul. Weight training by itself will almost certainly do nothing for a runner's 10k time, but if weight training maintains muscular balance in her abdominal wall and low back, preventing injury, then it is contributing to her becoming a faster runner. Why? Because it keeps her running! And, cycling isn't running. But if cycling takes the pressure off tired knees and hips on a recovery steady-state day, then it will probably make the next running workout better. Cross training should always be limited to those activities that allow us to do our event-specific training workouts with greater enthusiasm and intensity, or less risk of injury. It is a cautiously administered **supplement, not a substitute**!

3. The Reversibility Principle

If people were as economical as their bodies, we would not have problems with personal debt and excess world waste production. The human body is nothing if not thrifty! The iron and protein in those millions of blood cells that die each day is almost completely re-used to build new blood cells! The body does not **build** proteins it doesn't need (except maybe those that make up the appendix?), and it doesn't retain proteins that are no longer needed! For the athlete, the unfortunate consquence of this thriftiness is the rapid reversibility of training adaptations if training is stopped. In general, I think it is fair to say that those adaptations that occur fastest when we start training fade away fastest when we stop training. So, a week in bed with the flu will result in a substantial loss in blood plasma volume, but little change in mitochondrial enzyme concentration, and essentially no change in capillary density. Once over the virus, a couple of good traiing bouts will have blood volume back up to normal levels, and cardiac function back to normal as a result. However, take 3 months completely off from your training routine due to a big project at work and you will lose a lot of the adaptive foundation gained over the previous year of regular workouts. If you were highly fit before the break, it may take 6 months to come all the way back. What is clear is that training adapatations are always transient and dependent on chronic stress to the system. However, it does seem that people who have been really fit, and take a break, often seem to be able to return to high fitness levels FASTER than those who have not been highly trained before. Whether this is a function of good genetics for training responsiveness, a certain "muscle memory" in the brain or muscle cells of the detrained athlete, or just past knowledge of how to train is unclear, but it does seem to be real.

4. The Principle of Individual Differences

Last but not least on the list of Training Principles is the Principle of Individual Differences.

We All Start Somewhere . . . different

It is usually practical to describe physical characteristics based on some AVERAGE. On average, American men (no offense to my international readers) are currently 5' 9" (1.75 m) tall and about 180 pounds (82kg). But, walk down a busy street and you will see that there is considerable variability! It shouldn't be too surprising that there is also a lot of variability in our internal charactersitics. Heart size, muscle mass, bone diameter, fiber type composition, position of mucle attachments on bone, fat distribution pattern, joint flexibility, etc, all vary from individual to individual. Two examples: **On average**, a 25 year old untrained man will have a maximal oxygen consumption of 45 ml/min/kg. However, there are completely untrained people who have walked into a lab, got on a treadmill and had a VO2 max of 70 ml/min/kg. I tested a fellow exactly like this myself once. I was teaching a class and he "volunteered" to perform a cycling max test. I predicted his max for the class based on his exercise history (little if any). Imagine my surprise as he kept cycling and his VO2 kept climbing and climbing as I progressively increased the workload on the bike! He didn't bother to tell me until after the test that his sister had rowed in the Olympics! There are equally "healthy" untrained young men whose max is only 35 ml/min/kg. That's a 2X difference in aerobic capacity before they do their first workout! This is a physiological gap that will not be closed, no matter how hard the "less endowed" fellow trains. If the high VO2 guy trains very hard, he **might** reach 80 ml/kg/min, a 14% increase. The low VO2 guy can train equally hard and possibly reach 50 ml/kg/min, a larger 42% increase. The gap can narrow (to 60% here), but it will not go away. Genetics place limitations on our body.

Example number two: **On average**, the fiber type distribution in the thigh muscles of a male (or female) is roughly 50% slow and 50% fast fibers. However, in a study by Simoneau et al, 1989, muscle biopsies from the vastus lateralis (outside thigh) of 418 males and females revealed a range of from 15% slow fibers to 85% slow fibers in different people. Coefficients of variation approached 30%. Again we see that there is considerable genetic variation in a variable that has significant impact on performance. So, we each have to focus on approaching the outer boundaries of OUR OWN physical potential.

Different Strokes for Different Folks

At the Laval University in Canada, the University of Texas at Austin, and three other Universities in the United States, a major collaborative project was undertaken to determine the role of genetic variability associated with individual responses to an identical training program. Fittingly, this project was called the Heritage Study. Millions of dollars were spent to quantify and understand the genetic foundations of a phenomenom that athletes already know full well. **We all respond differently to a training program.** What this major study clearly demonstrated was that not only is our physiological "starting point" highly individual, but our **training response** is also highly variable. In this study, there were some subjects who essentially did not show ANY adaptation to a very well-controlled training program (measured for example as an increase in VO2 max), while others increased as much as 40% when doing the exact same training. Some athletes can do next to nothing 3 months then train like a madman, sweat, and spew chunks for three weeks and be in racing shape (ok, maybe too graphic). Others are "hard gainers" that seem to lose everything if they miss 2 weeks of training. Some people tolerate and even thrive on, a high volume of training to reach peak fitness. Others cannot tolerate the same workload, but reach similar performance levels if they intersperse more rest days. We each have a unique psychological makeup. We have different strengths and "weaknesses" within our physiological performance machine that should influence training plan design, and we have different hormonal and immune reactivity that will influence the level of stress we can tolerate and improve under. In the field of exercise physiology, we have learned a great deal about physiological adaptations and the general methods of training that conform to known physiology. This is very valuable information for the athlete to understand whether 24 or 64 (Of course I am biased on that score). But, remember, ANY exact training program that you copy from me or someone else is destined to be, at best an approximation of what will work best for you, and at worst, a total failure.

The Bottom Line

Ok, you love your sport and are motivated to improve, but with so many possible training methods and "experts", what can you do? Well, here is what I think.

First, understand what training does to your body. Learn the physiology of the sport (hopefully the MAPP will help). Know how your engine works. This will help you critically evaluate the disparate training ideas that are thrown your way.

Next, examine and **learn the biomechanical principles that must be obeyed for performance success**. How do you maximize the efficiency of transfer of your engine power to performance velocity? There is no endurance sport that does not place a premium on good technique.

Finally, **keep a record of what you do!** Use a notebook and pencil, or a fancy computer program, but make yourself accountable to both the training you do in pursuit of your performance goals, and the results. If you do this, eventually you will have arrived at your own personal prescription for success, built from solid general principles, but fine tuned to your personal characteristics. "Success" will vary for each of you in absolute terms; completing a 10k, a new personal best, a city championship, or maybe a world veteran's record! But it all feels the same to the person who establishes the goal, develops a plan, and works diligently to achieve it! Then you can tell us about it on the MAPP!