Coaching Applications

Evidence-based recommendations for maximizing competitive swimming performance

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Abstract

Swimming coaches commonly prescribe high-distance, long workouts, which may occur more than one time per day. While it is true that this approach is an effective way to maximize the aerobic capacity of swimmers, it carries a risk of overuse injury. In addition, different swimmers specialize in different events, including different strokes and event distances. An ideal training strategy would decrease risk of overuse injury while simultaneously increasing competitive performance. We propose that a multidisciplinary, multifaceted approach may best be able to accomplish this goal. In this paper, we first discuss how muscle responds to training, and then provide examples for tailoring training to meet the needs of individual swimmers. We then review current science and recommendations in swimming technique, decreasing overuse injury risk, sports nutrition, and tapering. Finally, guidelines are provided for optimizing warm-up and nutrition on the day of competition. This work is meant to guide coaches in designing an effective training regimen to maximizing the performance of their swimmers, and to provide a context for the role of sports medicine and dietetics in a multi-disciplinary approach to swimming.

Introduction

Competitive swimming has gained worldwide popularity, and in the United States, millions of swimmers both young and old participate in a variety of organizations. Over the last several decades, changes in regulations and training techniques have led to consistent record-setting. Many swimmers are focused on improving their times to the greatest extent possible, and spend many hours in the pool to accomplish this task. Indeed, many young swimmers are now able to perform at

unprecedented levels when considering their age, and extensive training is almost invariably a central aspect of this success. In elite groups, training often includes very long-distance workouts and/or multiple sessions per day. While this training strategy may be effective for some elite swimmers, it carries a significant risk of causing overuse injuries. Furthermore, short-distance swimmers may benefit less from the thousands of meters swum during practice, compared with swimmers specializing in longer distance races. Nonetheless, long-distance workouts remain commonplace, in part due to their being ingrained in swimming culture.

Beyond workout load, many other aspects of training and health have large impacts on actual swimming performance, such as swimming technique, nutrition, tapering, and day-of-competition practices like warm-up and hydration. Different coaches have different opinions on each of these facets of swimming, often with little other than personal belief and anecdote to guide them in planning each. In addition, individual athletes frequently require each of these to be tailored to meet their needs and competitive level, making it difficult for coaches to be able to plan effective strategies in these areas.

This paper is designed to help swimming coaches to design an effective training strategy which encompasses all of these aspects. We have used data and current recommendations from the most current exercise science to support our guidelines, rather than relying on experiences or anecdotes. This paper also challenges the "more is better" dogma which is often found among swimming coaches, and instead focuses on an individualized and multi-disciplinary approach to helping any swimmer improve their times.

Role of muscle fiber structure and metabolism in performance

To understand how different training strategies affect swimmers, it is important to have some idea about how muscles work at the biological level. To begin with, muscles are made of "fibers", or muscle cells. There are three main types of muscle fibers: slow-twitch, fast-twitch, and intermediate. Each of these fiber types has a different source of energy (metabolism) which is either "aerobic" or "anaerobic". Slow-twitch fibers are used most during distance events, as they are not particularly powerful but can maintain work for a very long time; they have excellent aerobic metabolism. On the other hand, fast-twitch fibers are capable of explosive power but cannot sustain their work for long; they rely on anaerobic metabolism. Intermediate fibers are something in between; they have some aerobic and anaerobic capacity, but are not as highly specialized.

Training causes changes in muscle fibers

The relative amount of the different muscle fibers changes with specialized training, allowing a muscle to adapt to different needs. Research has shown that distance athletes have a larger proportion of slow-twitch fibers, and sprint athletes have

more fast-twitch fibers in their muscle. It is important to note that while these differences may be due in part to genetic predisposition ("born a sprinter"), training is more important in changing the build of muscle. That is, muscles will adapt to perform the tasks which are asked of them.

The importance of aerobic and anaerobic metabolism depends on distance

As mentioned earlier, distance swimmers need more aerobic (slow-twitch) capacity in their muscles to perform best, while sprinters most need the power of fast-twitch fibers. Few studies have been done in swimmers that try to determine the metabolism of muscle while swimming different races. However, this has been studied in runners, and it is reasonable to correlate the duration of the event (time) with the metabolic needs of the muscle. In order to make the data from runners applicable to swimming, a 4:1 distance ratio was used. Specifically, 400 m of running was considered to take approximately the same amount of time as 100 m freestyle swimming by an elite swimmer (Figure 1).

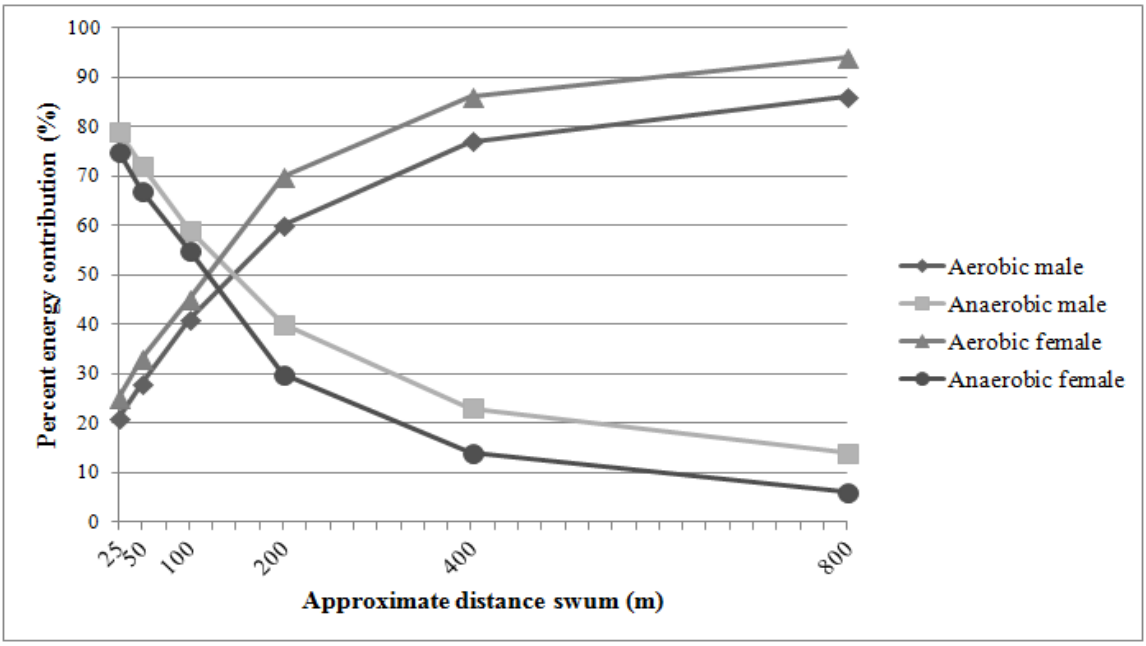

Figure 1. The percentage of aerobic and anaerobic metabolism used by muscle during race events of different duration. Data is from track athletes and converted to meters swum using a 4:1 distance ratio. This data shows that during a 50-meter race, most of the energy comes from anaerobic metabolism (fast-twitch muscle), and vice-versa for an 800-meter race. Interestingly, the two forms of metabolism are equal at approximately 150 m of swimming by an elite swimmer (approximately 75 seconds of intense exercise).

A training strategy for maximizing swimming performance

Maximizing aerobic capacity

As aerobic metabolism begins to predominate in events 200 m and longer (Figure 1), it is important that swimmers who swim these events have excellent aerobic capacity. Swimming long distances at a medium pace is an intuitive way to increase the aerobic capacity of muscle. However, current research shows that an even more effective method may be to include some amount of high-intensity training (HIT) along with long-distance sets. This is because both long-distance and HIT can boost aerobic capacity, and when alternated, they have an even stronger effect.

Maximizing anaerobic capacity

Sprinters have been shown to have muscles composed mostly of fast-twitch fibers, and anaerobic metabolism dominates during 50 and 100 m short events (Figure 1). As a result, swimmers specializing in short sprint events would benefit from maximizing their anaerobic capacity. High-intensity training (HIT) and resistance training can improve anaerobic capacity, especially when the exercises performed reflect the nature of the competitive event. Specifically, sprint events should be included during practice, which correctly reflect the type and distance of the race to be performed. It is also important to include adequate rest, as would occur in a real race scenario, allowing maximal effort to be given during practice sets.

Optimizing technique

The technique of swimming stroke, start, turn, and finish are sometimes neglected at the elite level. These are all important aspects of the swimming race, and optimizing each will help improve race times. There is limited evidence to support specific techniques in these areas, however. A central theme in improving each of these is the need for an observant and thoughtful coach, who is able to identify areas for improvement and give feedback to swimmers. Gliding after starts and turns is an efficient means of propulsion when coupled with proper timing of the kick, and should be optimized for all swimmers. Additionally, individual swimmers must work together with their coaches to determine what aspects of the swim stroke, start, turn, and finish may be altered to achieve improvement in race times.

Decreasing overuse injury risk

Injuries to the shoulder, knee, and spine related to overtraining are surprisingly prevalent in swimmers, particularly at the elite level. Studies on swimming-related overuse injury have shown that swimming more than 15 hours or 35 km (21.8 miles) per week significantly increases risk of shoulder injury. Additionally, overtraining can lead to decreases in immune system function, potentially harming competitive performance. In order to minimize overuse injury risk, an effort should be made to contain workouts to these figures. There is significant concern that such restrictions will be detrimental to swimming performance at the elite level, particularly for distance swimmers. However, at least for short-distance swimmers, these distances are adequate to achieve the proper balance of HIT and endurance training. Spending time improving technique may decrease distance swum per

week, but will also provide a potentially therapeutic effect for swimmers already suffering from overuse injury. A mix of stretching and recovery activities may also help to decrease injury risk in swimmers, regardless of distance swum per week.

Optimizing nutrition during training

Health and sports professionals agree that proper nutrition is a key to good athletic performance. However, in practice, not enough attention is paid to getting proper nutrition for swimmers. In general, 6 to 10 g/kg of carbohydrates is needed for most high level athletes to maintain glycogen stores and recovery; protein needs range from 1.2 to 1.7 g/kg per day, which is usually achievable without supplements; dietary fat requirement is not based on weight, and is ideally between 20-35% of total energy intake. To meet these needs, a total of 5 or more meals/snacks may be needed, as long as caloric balance is maintained. Furthermore, intake of some carbohydrate before a strenuous workout may help the immune system and top off fuel stores. It is important to note that complex carbohydrates, particularly those containing fiber, are superior to simple sugars for maintaining energy and a balanced diet. Swimmers should work with their coaches to design a nutrition plan which meets their nutrition needs and helps them to feel their best. A sports dietitian is an excellent resource in optimizing nutrition plans, and should be consulted when designing the diet of elite athletes.

Effective tapering

The taper is designed to increase the energy level of the athlete while maintaining overall fitness, a combined effect resulting in improved times. There is little consensus among coaches regarding the duration and nature of the taper. Studies in swimmers have shown that the most important elements of the taper are: (1) a progressive decrease in training load to 41-60% of maximum; (2) no change in training frequency; (3) duration of 2-3 weeks; and (4) inclusion of high-intensity training (Table 1). The most central themes in studies on tapering are that training *frequency* and *intensity* should be maintained during the taper. The optimal decrease in distance/workload and overall duration of the taper often varies between swimmers, thus, tapering plans need to be tailored to individual athletes based on personal experience, performance results and the athlete's own impressions.

Recommendation	**Rationale**
Plan out a progressive decrease in training distance over time	Start at 100% and end the taper at 41-60% of normal. Decrease some each day; this helps prevent fatigue while maintaining fitness.
Begin taper 15-21 days before competition	This appears to be the most effective taper length for swimmers.
Maintain training intensity	Including high-intensity sets has been shown to play a key role in maintaining fitness even as total swim distance is

	decreased.
Maintain training frequency of 4-6 session per week	Maintaining multiple practice sessions per week helps maintain fitness during a taper.

Table 1. Guidelines for generating an effective tapering strategy. Rationale is provided for each recommendation.

Day-of-competition practices

Activities on the day of competition, including warm-up and nutrition, play a significant role in performance potential. There is considerable variability in warm-up practices preferred by different coaches and swimmers. Available evidence in swimming and other sports has shown that a too-long warm-up may be detrimental due to development of fatigue. Warm-up should be approximately 1000-1500 m total, include stroke technique drills and limited sets approaching race pace. Warm-ups between races should also occur approximately 8-20 minutes prior to the event. Regarding nutrition, carbohydrate is the most important source of energy during the day of competition, and longer events require more energy. A recovery snack with carbohydrate and good quality protein after a race may also speed muscle recovery. Finally, it is centrally important to achieve proper hydration through a mixture of water and electrolyte-containing beverages throughout the day of competition. Keep in mind that swimmers must be mindful of how they feel during the day, and tailor nutrition to meet their needs. Guidelines for the day of competition are summarized in Table 2.

Recommendation	**Rationale**
Initial warm-up should be 1000-1500 m total, at moderate intensity, include technique drills, and short sets approaching race pace	Some studies suggest that longer warm-ups cause fatigue. Drills may allow swimmers to get comfortable in the water. Very short spurts at high intensity may maximize muscle blood flow and performance.
A warm-up should occur 8 - 20 minutes before each race	Even short warm-ups before a race may help muscle blood flow and maximize performance.
If no pool space is available before a race, brief dry land exercises using the large muscle groups may be effective	Designated warm-up space is sometimes limited or absent during competitive events.
Warm-up should be customized for individual swimmers based on what plan works gives the best competitive result	Data regarding the effectiveness of warm-ups in swimming are conflicted. Individuals may have best results with different warm-up designs than those described in this document.
Snacks or meals during the day of competition should be based on swimmer preference, comfort, and best competitive results	Swimmers should eat enough to be comfortable throughout the day of competition, and should consume calories in proportion to the amount of swimming to be done.

Stay properly hydrated throughout the day of competition using a combination of water and electrolyte-containing drinks	Athletes perform best when properly hydrated, both with enough fluid volume and electrolytes. Swimmers should also consume amounts which make them most comfortable.

Table 2. Guidelines for day-of-competition strategy, encompassing several important aspects, which may impact performance. Rationale is provided for each recommendation.

Conclusions

Aerobic and anaerobic metabolism both contribute to the energy supply of muscle, but their relative contribution depends on the length of the race. Training should be tailored to the type of event(s) which the swimmer is most likely to pursue. Importantly, overtraining must be avoided, as injury is a significant source of disappointment for swimmers and coaches. Time should be devoted to the maintenance of stroke technique and optimization of starts, turns, and finishes. Nutrition is of utmost importance in allowing swimmers to maximally benefit from training and to perform at their peak. Finally, day-of-competition strategy may be of great importance, and must not be neglected. Coaches should work with swimmers individually to develop a multidisciplinary training strategy which best suits their needs and competitive goals.