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Practical Information about Swim Training and Sports Nutrition

Swimming Research News

IS STRENGTH TRAINING GOOD FOR SWIMMERS?

It would seem that strength training would not be beneficial for endurance swimming performances, since the physiological adjustments associated with the two forms of training are so different. Indeed, some research has failed to link strength training with any benefits at all in the pool. However, several studies which have employed swim-specific strength training have been able to document improvements in factors related to swimming performances.

Can strength training boost swimming performances? At first glance, strength training and competitive swimming seem like polar opposites. Strength training reduces the density of mitochondria - the structures in which aerobic energy is created - inside muscle cells, and it fails to increase capillary density or the intramuscular concentrations of aerobic enzymes. In general, strength training improves the ability to perform high-load, low-repetition exercise; it has a significant impact on muscular strength and anaerobic power and no effect on maximal aerobic capacity (VO_2max). Endurance swimming training, on the other hand, hikes mitochondrial density, raises aerobic-enzyme levels, and hoists capillary density; it enhances the capacity to carry out low-load, high-repetition exertion and usually has little impact on maximal muscular strength and anaerobic power – but does improve VO_2max. The end results of conventional swim training and strength training appear to be completely different, and prescribing strength training for swimmers seems to violate the specificity of training principle, which states that training programs should mimic an athlete's specific exercise patterns and requirements.

Indeed, some scientific research has found that strength training has

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CAN GOOD SWIMMERS BE VEGETARIANS?

Many meat-eating athletes wonder whether a switch to a vegetarian diet might provide a performance boost, and there are logical reasons for such thinking. First, vegetarian diets tend to be high-carbohydrate regimens, which should lead to optimal glycogen storage in muscles. At the lofty intensities required for high-level training and serious competition, carbohydrate is the primary source of energy; when muscle-carbohydrate (glycogen) levels are too low, athletes experience fatigue and tend to perform poorly (1). Thus, a vegetarian diet may function as an "insurance policy" against insipid intramuscular carbohydrate storage and underachievement in races.

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no positive impact on swimming performance. In an investigation carried out by Dave Costill and his colleagues at Ball State University in Indiana, 24 male collegiate swimmers from a varsity swimming team (NCAA Division I) were divided into two matched groups of 12 athletes, a swim-training-only group and a concurrent swim-and-resistance-training group (1). The two groups were similar in terms of performance, as well as anthropometric and physiological measurements.

Both groups swam together during the 14 weeks of their competitive swimming season, with training volume gradually increasing from around 2000 meters per day during the first week of the season to 6000 meters/day within the ninth week; volume then ebbed gradually over the remainder of the season. In addition to the swim training, the swim-and-resistance-training group (COMBO) took part in resistance training three days per week, on alternate days, over the eight weeks stretching from week three to week 10. After the resistance-training phase was completed, both groups tapered in advance of an important competition during the 14th week.

The actual resistance-training program was set up to mimic the muscle and swimming actions utilized during front-crawl swimming; it utilized both weight machines and free weights. The resistance workout included dips, chin-ups, lat pull-downs, elbow extensions, and bent-arm flys, and three sets of eight to 12 reps were completed per session. Resistance was gradually increased over the eight-week period as the COMBO swimmers became stronger; overall, the resistance advanced by about 30 percent.

Percent body fat declined in both groups over the course of the season, but there was no difference between the COMBO and swim-only (SWIM) athletes. There were no changes in lean body mass for either group. Most importantly, there was also no difference in swim power (measured during tethered swims) between the groups; both groups improved power to the same extent (around 4 to 6 percent).

Interestingly enough, free-swimming sprint times, measured during 25-yard, front-crawl, all-out swims, tended to decrease over the course of the season – *to an equal extent in the two groups.* Throughout the season, the athletes in both groups were always slower in sprinting tests than they had been before the training period began! This is of course one reason why many swimming experts and exercise physiologists have contended that traditional swim training relies too heavily on a bedrock of high-volume work, rather than intense training.

During the tapering period, there was a tendency for both groups to improve their *average* distance covered per stroke (measured during an intense 366-meter swim); however, this change was not statistically significant. In fact, between the 183- and 366-meter points of these swims, a *significant decline* in the distance per stroke was observed in both groups during the tapering period (this was compensated for somewhat by an increase in stroke turnover). Note that high-quality research has shown that distance per stroke is the best predictor of swim performance, at least over distances of 300 to 400 meters (2).

If you are a serious swimmer or swimming coach, this original study by Costill and crew is well worth reading. Basically, the research shows that the first 10 weeks of training had no positive – and in certain cases had negative – effects on performance. It was only during the four-week taper period, with greatly reduced training volume, that the swimmers *began to regain* some of their performance capability which was lost during the season. The athletes really didn't get better over the course of the season – they simply managed (after tapering) to return to almost the level of performance of which they were capable when the whole fiasco (the high-volume training season) began. And yet – the kind of training carried out by the Ball-State athletes is very popular in the world of competitive swimming.

There is a very telling comment in Costill's paper: "…freshmen tend to increase their swim abilities more than other classes …." Shouldn't it be the other way around? That is, if the swim training carried out at the collegiate level is indeed constructed properly, one would expect steady improvements from year to year. In fact, one might reasonably argue that the senior year would be the one associated with the greatest improvement, since all of the strength, savvy, lactate-threshold improvement, vVO_2max upgrading, and efficiency enhancement accumulated over three solid years of work could be brought together in a synergistic way.

At any rate, the Costill study clearly suggested that dry-land strength training offered no advantages to competitive swimmers. This "negative" result for resistance training might at least partially be pinned on the overall training carried out by the swimmers, of course, rather than on an actual deficiency of strength training to help swim ability. There is some evidence, for example, that the strength training, on top of the regular training the swimmers were carrying out, put the COMBO group into an overtrained state (or perhaps we should say even more of an overtrained state than the one which plagued the SWIM athletes).

The resistance training, on top of the high-volume swim training, may have induced a state of mild overtraining.

For example, swim velocity (measured during an all-out, 25-yard sprint) was absolutely equivalent between the groups when the resistance training commenced. At the end of the resistance-training period, however, swim velocity was down by .08 meters per second in the COMBO swimmers, versus a .04-meter per second decrement in the SWIM athletes. For the resistance-training swimmers, this was equivalent to losing one meter of pool for each 12 seconds of sprint swimming! Both groups recovered during the tapering period (with COMBO appearing to recover more than SWIM), but both collections of swimmers ended the season about .03 to .04 meters per second slower during sprints, compared with the beginning of the season. With this kind of training, the major competitions should be held on the first day of practice, rather than after 14 weeks of work! At any rate, the resistance training in this study, added on top of the swim work which was already being completed, may simply have constituted a bolus of excessive training, on top of the grandiose work which was already being completed in the pool. As such, the study may not constitute a fair assessment of the effects of strength training on swim performance. Interestingly enough, in a separate study carried out by Costill *et al*, resistance training did upgrade swim performance by close to 4 percent, but in this investigation the strength training *was carried out by itself*, with no concurrent swim training (3).

However, other studies have also failed to link strength training with improvements in swimming capability (4 & 5). So, why do swimmers and their coaches often claim that strength training improves fatigue-resistance, distance covered per stroke, attacking ability in races, and closing sprint capacity during competitions, not to mention overall performance?

Well, research *has* shown that there is a solid connection between the anaerobic power of swimmers' arm muscles and their competitive ability. In an investigation carried out in the School of Physiotherapy at the Auckland Institute of Technology in New Zealand, researchers found that upper-body anaerobic power, as measured during a Wingate Anaerobic Arm Test, was strongly linked with 50-meter swim performances (6). 30 competitive age-group swimmers (14 males and 16 females) who normally trained about 6000 meters per day, six days per week, participated in this study. Significant relationships were detected between 50-meter performance and both the peak power and average power displayed during the Wingate Test. In addition, 50-meter speed was closely allied with race velocity at distances ranging up to 400 meters. In effect, the raw anaerobic power of the arms was a good predictor of swim performances from 50 to 400 meters. Strength training should improve anaerobic arm power, so why shouldn't it help swimmers?

Some studies have shown that strength training can improve factors which determine swimming performances.

In fact, there is a body of research which demonstrates that resistance training can have a positive impact on swimming performance, or at least on factors which determine such performance. For example, in a unique study carried out by investigators from Vrije University and the University of Amsterdam, high-resistance training carried out in the water produced significant improvements in 50-, 100-, and 200-meter race times (7). In this Dutch investigation, 22 well-trained swimmers were divided into a control group (eight males and three females) and a resistance-training group (also eight males and three females). Over the course of 10 weeks, total training load was equivalent for the groups; an average workout volume was 4500 meters. About twice a week, the control athletes carried out sprint workouts in the pool; meanwhile, the resistance-training swimmers avoided the sprint sessions, substituting "POP" (fixed push-off point) strength training for them. Total distance swum per workout was equated between POP and the sprint-swim sessions.

The special device used for the POP training was quite unique. It was constructed to fit within the breadth (23 meters) of a 50-meter pool, and it was a ladder-like structure which rested on the bottom of the pool, with vertical pads attached to the rungs of a ladder (these pads jutted up in the water, so that swimmers could reach them with their hands as they traversed the pool). The inter-pad distance was set at 1.35 meters (about the average distance covered with one arm action, i. e., one-half of a stroke cycle), and each pad was supported by two legs. Basically, there were 16 underwater push-off pads (1.35-meters apart) in the pool, and the swimmers moved from one end of the pool to the other solely by pushing against these push-off pads (their legs were supported and tied together by a small buoy). Each thrust against a pad could be recorded by means of a force transducer, constituting a so-called MAD system (system to Measure Active Drag). The basic idea underlying the use of this MAD-POP system for training is that during normal swimming the maximal force that can be exerted is limited, since the water simply gives way as the push created by the arms is made. In contrast, when an athlete swims using the MAD-POP system, the push-off is made against a fixed point, and thus higher forces can be achieved. At the same time, the actual muscular actions and movements associated with swimming are utilized (which is of course important from the standpoint of specificity of training).

At the end of the 10-week period, the MAD-POP swimmers performed better than the non-resistance-trained athletes in a variety of different ways. Force, power, and velocity all improved for the MAD-POP swimmers but failed to get better for the sprint-trained folks. In addition, the number of strokes required to swim 25 and 50 meters as fast as possible declined in the MAD-POP group but stayed the same for normal trainers. However, there were no differences in actual race times between the groups (measured during 50-, 100-, and 200-meter races).

In contrast, research carried out in the former Soviet Union has linked strength training with better performance times. In one study carried out at the USSR Research Institute of Physical Culture with female swimmers who were medalists at open and junior USSR championships, both in middle- and long-distance freestyle events, one group of athletes trained for three weeks utilizing dry-land "Mertens-Huttel" training machines which simulated stroking movements in the water, isokinetic weight machines, and "flume" training against strong current. A second group completed only traditional resistance work, relying on barbells, dumbbells, and pulley machines in the gym. Both types of resistance training were completed three times a week (8).

At the end of the three-week period, the traditional trainees improved their maximal dry-land strength (measured with the barbells and dumbbells) by 21 percent, while the Mertens-Huttel-flume athletes increased their dry-land strength by just 10 percent. In the water, however, things turned around, with the Mertens-Huttel Soviets upping max strength by 22 percent and the stay-at-home, dry-land exercisers moving max aqua-strength along by just 11 percent. Unfortunately, no performance times were measured.

In a separate study, also carried out in the former Soviet Union, 37 competitive swimmers (aged 11 and 12) were divided into two groups (9). Over a six-month period, one group carried out strengthening exercises in the water twice a week, working against the resistance provided by a stretchable rubber cord which was attached at one end to a belt worn around the midsection and at the other end to the edge of the pool. The second group performed only typical dry-land strengthening routines, also twice a week. Both the dry-land training (completed on an exercise machine) and the rubber-cord workouts were completed with an interval format, always at maximal intensity, as follows:

(1) 8 X 10 seconds, with 50 seconds of recovery,

(2) 6 X 15 seconds, with 60-second recoveries,

(3) 4 X 30 seconds, with 90-second rests, and

(4) 1 X 60 seconds.

The rest pauses between series (i. e., between the types of intervals) were five minutes in length, and total workout time was 50 minutes for each group.

At the end of six months, the rubber-cord, in-the-water trainees achieved a higher maximal swimming speed, compared with the dry-land athletes, and the rubber-cord swimmers also displayed increased stroke force during the 30th second of exertion in a maximal test. Force diagrams revealed that the hands of the rubber-cord swimmers exerted significantly more force during the entry-into-the-water phase of the swim stroke and also during the pull phase of stroke, when the hand is moving back.

Why did early investigations and the Costill study fail to link strength training with improved swimming performance, while the Dutch and Russian work seemed to indicate that resistance training could be beneficial? Bear in mind that the initial research and Costill's investigation relied on dry-land strength training to carry the load for improved swimming, and there is good evidence that dry-land resistance work, even when it is designed to mimic the movements of swimming (and even when it is completed on a "swim bench," does a relatively poor job of producing the coordination and motor-unit recruitment patterns associated with the real thing (10). Gains in strength are always specific to the movement involved in training, the speed of that movement, and the way in which motor units are activated and coordinated; if the training movement is unlike the actual athletic movement in mechanics, overall coordination, or velocity, one should not expect the athletic movement to be improved very much. Put another way, the dry-land strength gained in the early and Costill studies did not improve swimming strength and performance because of a lack of specificity.

It is difficult to replicate swimming's neuromuscular patterns during dry-land training; therefore, in-the-water strength training is likely to be most effective.

In contrast, the Dutch and Russian studies used higher movement speeds and actual in-water swimming movements, allowing for greater transfer of strength from training to performance. If a swimmer can increase his/her maximal swimming strength during his/her style of swimming, the muscular tension required for each of his/her usual strokes *decreases to a lower percentage of maximal force, allowing such force outputs to be easier and more sustainable*. In addition, the reduction in percent max force probably allows an increased utilization of slow-twitch muscle fibers at various speeds (11); slow-twitch fibers tend to be more efficient than fast-twitch cells, and thus swimming efficiency would be improved. Greater strength during the swimming stroke can also be transformed into augmented swimming power, which would improve a swimmer's max velocity and ability to sprint at the end of the race.

There is also the intriguing possibility that *circuit* strength training might improve the lactate thresholds of competitive swimmers, an effect which would have a high likelihood of improving performance. In a study carried out by Dr. E. J. Marcinik and co-workers from the Exercise Science Laboratory at the University of Maryland, 10 individuals trained three times per week for 10 weeks; each workout consisted of three "circuits" of 10 different exercises, including bench presses, hip flexions, knee extensions, knee flexions, push-ups, leg presses, lat pull-downs, arm curls, parallel squats, and bent-knee sit-ups. Intensities were set at 8 to 12 RM for the bench presses, arm curls, and lat pull-downs and 15 to 20 RM for the other exertions, with 30-second recoveries between exercises. Resistance was adjusted throughout the 12-week program to accommodate increases in strength (12).

Circuit training may produce a number of positive effects in swimmers.

This kind of training was good for one-repetition-max (1-RM) strength in the participants, with 1-RM leg-extension strength vaulting upward by 30 percent, 1-RM leg-flexion ability soaring by more than 50 percent, and bench-press puissance climbing by 20 percent. Peak torque values for leg extension and flexion also took off, heading north by 31 to 35 percent during the 12-week training period. Eight control subjects failed to improve in any of these areas. As expected, neither group was able to upgrade VO_2max (maximal aerobic capacity).

Unfortunately, swimming performance was not assessed, but the Maryland researchers did look at cycling ability. After the 12 weeks of circuit training, the participants' ability to cycle for as long as possible at an intensity of 75 percent VO_2max increased by 33 percent. This remarkably improved endurance performance *was accompanied by a 12-percent improvement in lactate threshold.* Thus, the heightened performance may have been a function of both the lactate-threshold lift-off and the upgraded muscular strength, both of which were advanced by the 12 weeks of circuit training. It is quite possible that similar effects could be observed in swimmers.

And now the million-dollar question: How would a swimmer wishing to undertake resistance training actually structure and periodize his/her strength training? It makes sense to think that a general period of strengthening should come first, with an emphasis on whole-body strengthening, as well as general conditioning. Circuit training seems to work well for this, as the Maryland study suggested; it can be associated with both greater strength and lactate-threshold lifting. Twice a week for about four to six weeks or so, a swimmer could carry out a workout similar to this one:

Circuit Workout for Swimmers: Carry out a good warm-up (including at least 15 minutes of moderate-intensity swimming), and then perform the following exercises in order. Move quickly from exercise to exercise, but don't perform the drills themselves overly quickly (don't sacrifice good form to get them done in a hurry). The idea is to do each exercise methodically and efficiently – and then almost immediately start on the next exertion.

(1) Swim for two minutes at an intensity of about 8.5 to 9 on a scale from 1 to 10 (with 1 being the easiest-possible effort and 10 being maximal exertion).

(2) Do 6 chin-ups.

(3) Complete 40 sit-ups.

(4) Hit 15 elbow extensions.

(5) Perform 20 squat thrusts with jumps (burpees).

(6) Do 15 push-ups.

(7) Complete 30 body-weight squats (fast).

(8) Swim for two minutes at an intensity of 8.5 to 9.

(9) Hit 20 bent-arm flys.

(10) Do 12 squat and dumbbell presses (with 10-pound dumbbells).

(11) Complete 10 feet-elevated push-ups.

(12) Perform 40 low-back extensions.

(13) Do 20 bench dips.

(14) Complete 20 lat pull-downs.

(15) Swim for *three* minutes at an intensity of 8.5 to 9.

(16) Repeat steps 2-15 one more time (for two circuits in all), and then cool down with 15 minutes of light swimming.

Here are explanations of some of the exercises in the circuit:

To carry out body-weight squats, stand with erect posture and your feet directly below your shoulders. Then, go into a squatting position, so that your thighs are roughly parallel with the ground. As you do so, it's OK to let your upper body incline forward a bit. Return to the standing position, and you have concluded one rep.

To complete squat and dumbbell presses, do the body-weight squats, but hold dumbbells in your hands – directly in front of your shoulders. Your hands should be turned inward, so that the palm sides of your hands are facing each other (the grip on each dumbbell will make a straight line directly forward from your shoulder). Once you have returned to the standing position from the squat, "press" the dumbbells directly overhead, straightening your arms in the process. After you return the dumbbells to shoulder position, you have completed one rep.

Feet-elevated push-ups are normal push-ups, except that your feet are elevated (on a bench, chair, or wall).

To perform bench dips, seat yourself on a bench or chair, with your hands at your sides. Your hands should be gripping the front edge of the bench or seat. While keeping your hands in the same position, slide forward off the chair and put your feet as far forward as possible, so that all of your body weight is supported only by your hands and the heels of your extended feet. Then, simply lower your buttocks to the floor (or almost to the floor), and bring yourself back up again to complete one rep.

To do low-back extensions, lie on your stomach, with your arms by your sides and your hands extended toward your feet, with palms touching the floor. To achieve the basic starting position, contract the muscles at the back of your neck, so that you are gazing forward and upward. A rep is simply a contraction of your low-back muscles which lifts your trunk well off the ground, followed by a slow easing of your torso back to the floor.

As your general strength improves, you may increase the numbers of reps of the various exercises – and also expand the lengths of the swimming segments. During your sixth week of circuit training, you should also try three circuits instead of the usual two.

After the general phase of strengthening, it makes sense to move into swimming-specific strengthening.

After the general-strengthening period (with an emphasis on circuit training) has been completed, it would make sense to focus more specifically on swimming-specific movements and an emphasis on tethered swimming (with a stretch cord for resistance) and the use of a technique like the POP system, if possible. Again, two workouts per week would be optimal, over a period of four to six weeks or so. During this phase of training, you would of course carry out good-quality, "normal" swimming workouts as well.

In an ideal world, hill training would come next. But, since swimmers have few opportunities to swim up waterfalls, this would be an ideal time to train in a flume, working against a current which is just slightly faster than typical race speeds for extended work-interval lengths (actual work-interval length could be one-fourth to one-half of the time required to complete the race of interest).

Finally, explosive training would put the "put the icing on the cake," transforming your strength into true power and readying you for your most important competitions of the season. The explosive training could take the form of all-out and nearly all-out sprints of 10, 20, 30, and 60 seconds, with long recoveries. For the fortunate swimmer with access to a flume, the idea would be to work powerfully against very high currents for short-duration reps.

Strength training has been found to be performance-enhancing for cross-country skiing, cycling, and running, so it is no surprise that research has linked resistance training with improvements in swimming capacity, too. Be aware, though, that simple, traditional, dry-land strength-training regimens will probably have little impact on your swimming ability. It is important to periodize your strength training properly, to use a variety of movements, to emphasize in-the-water strengthening movements, and to steadily advance *the speed* with which you carry out your strengthening exercises. If you do so, you will be much stronger and more powerful when you are in the water, and your log book should be inundated with a flood of PRs. ©

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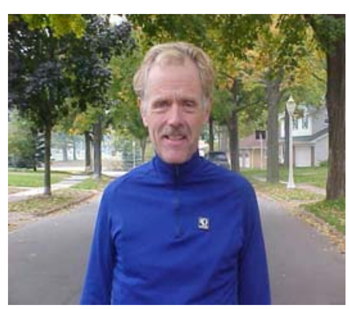
Hi Readers!

Welcome to the first issue of *Swimming Research News*, and thank you very much for your interest in our publication. Teressa and I hope that you enjoy *SRN* and that you find it to be very useful for your training. We promise to provide you with the most current information about swim training, strength training, and injury prevention. Please send your comments to me at info@rrnews.com



Owen Anderson, Editor

Swimming Vegetarians continued:

In addition, it is possible that vegetarian eating might enhance *the recovery process* following tough workouts and competitions. The reasoning goes this way: High-intensity or prolonged effort generates increased levels of "free radicals" within an athlete's body, potentially enhancing the breakdown of cell membranes, including the membranes which wrap around muscle cells (2). An athlete's own physiological systems can synthesize antioxidant enzymes to stem this free-radical onslaught, but an additional line of defense is provided via the consumption of antioxidant nutrients. Vegetarian diets revolve around fruits, vegetables, and whole grains – the kinds of food which are high in antioxidants. Thus, vegetarian eating may do a better job of protecting muscle cells during hard training, compared with dietary plans which are more biased toward meats.

Of course, the "coup-de-grace" pro-vegetarian argument in the running community relies on the fact that Kenyan distance runners, at least when they are "coming up," are basically lactoovovegetarians, depending on corn, beans, and the various fruits and vegetables found in Kenya, along with dabbles in milk and eggs, to fuel their achievements. Since the Kenyans perform better as a group than any other runners in the world, it would seem that vegetarian diets, or at least lactoovovegetarian ones, go hand-in-hand with top performances.

While those are rational and reasonable points, it should be noted that a meat-eating athlete's diet is not necessarily low in carbohydrate. Evidence now strongly suggests that an athlete who trains between 60 and 90 minutes per day should ingest about eight to 10 grams of carbohydrate per kilogram of body weight daily (approximately 3.6 to 4.5 grams of carbs per pound of body weight per day). Even an athlete who consumes a nightly T-bone steak is not prohibited from attaining such lofty carbohydrate heights; while the T-bone might take up room in the tummy which could be better filled with carrots, brown rice, and passion fruit, there is nothing about meat-eating *per se* which automatically produces a carbohydrate-consumption failure (the needed carbs could be ingested throughout the day, for example). Even an athlete whose diet is 70-percent carbohydrate has to fill that other 30 percent with something, after all. Take in a grandiose T-bone at every meal, and you've got a problem; take in meat in prudent amounts, and it is relatively easy to ingest adequate levels of carbs, too.

The Kenyan reliance on lactoovovegetarianism also provides rather shaky support for the idea that athletes should shun meat. After all, elite Kenyans increase their consumption of chicken, goat, and even beef after they have won a major race or two, with no noticeable fall-offs in performance.

Critics of vegetarian eating for athletes have a long list of "problems" associated with the practice.

Finally, although the story about vegetarian eating and muscle recovery is a nice one, there is *no strong scientific evidence* to support the tale. It would be nice for supporters of vegetarianism if there were some positive data here, because there is actually a laundry list of "knocks" against the practice of refraining from meat consumption during heavy training. For example, there is a concern that a vegetarian diet high in fiber and phytic acid (a compound found in whole grains) might actually reduce the absorption and availability of zinc, iron, and a few "trace" minerals. Fears have also been expressed that vegetarian diets tend to be too low in protein for athletes, and that female vegetarian competitors are at increased risk of impairment of menstrual function. Finally, there is a belief that vegetarianism gradually lowers muscle-creatine concentrations, thus diminishing the power outputs of vegetarian athletes during strenuous efforts.

What does science have to say about all of this? Are vegetarian diets good for performance – or bad? Does vegetarian eating enhance the health of athletes – or does it lead to potential problems?

Let's take a look at the performance side of these questions first. In a unique study, venerable exercise scientist Mel Williams examined the effect of a vegetarian diet on running performance, using 5- and 8-K test runs as the performance variables (3). The athletes in Mel's study completed their tests before and after a two-week vegetarian diet and then again two weeks following the resumption of a carnivore's diet. There were no differences in performance between the trials, suggesting that vegetarian eating was neither harmful nor beneficial for performance. However, two weeks is a particularly narrow "window" through which one might attempt to examine the potential performance benefits of vegetarian eating. Longer periods would certainly be necessary to understand how meat-free eating might alter the recovery process during strenuous training, for example.

In research which did proceed for a longer period of time, eight well-trained Danish athletes swallowed a Kenyan-style lactoovovegetarian diet for six weeks and then a meat-lovers' regimen for an additional six weeks (4). Both of these eating plans contained 57 percent of total calories as carbohydrate, 14 percent as protein, and 29 percent as fat. Interestingly enough, a plethora of variables – VO_2max, endurance time to exhaustion, muscle-glycogen concentration, and muscular strength – were all unaffected by the changes in the athletes' diets.

A reliance on vegetarian eating did not produce any problems for athletes in a million-meter competition.

In undoubtedly the most physically challenging of all the studies which have looked at the effects of vegetarian diets on performance, 110 runners competed in a 1000-K (one-million-meter) race carried out over a 20-day period (5). During the race (and also before it), 60 of the competitors ingested a conventional, meat-rich, "Western" diet, while 50 harriers took in lactoovovegetarian fare. During the race itself, both groups had a similar total intake of carbohydrate (60 percent of total calories). As it turned out, there was no connection between diet and performance in the race, with half of each group actually finishing the event and total performance time absolutely equivalent between groups.

So, the available research tells us that a vegetarian diet is neither beneficial nor detrimental to endurance performance (one caveat, of course, is that there have been no good *long-term* studies on this topic with serious athletes). There is a legitimate concern, however, that vegetarian practices might hurt high-power performances by lowering muscle-creatine levels.

Recall that creatine is found in large quantities in muscles, where it combines with phosphate to provide a significant source of "quick energy." High levels of muscle creatine ("phosphocreatine") have been linked with improved performance during high-intensity interval workouts (for example, five 30-second "reps" of very fast running, with one- to four-minute recoveries) (6). The estimated daily requirement for creatine is thought to be about two grams; a typical meat-eater gets about one gram from the animal muscle he/she ingests and probably synthesizes the other gram in his/her liver, kidneys, and pancreas. The vegetarian athlete, on the other hand, gets essentially no creatine in his/her diet, and there is strong evidence that his/her internal organs are not up to the task of creating two grams of creatine per day, leading to a situation in which vegetarian competitors are "low" on creatine. One study found that basal plasma creatine levels in vegetarian athletes were about 50-percent lower, compared with concentrations in meat-eating sportspersons (7).

In another investigation, 16 healthy men who normally consumed an omnivorous diet were placed on a lactoovovegetarian diet for 21 days, while 16 other men remained on the omnivorous regimen (8). Although the two groups had similar muscle-creatine levels at the beginning of the study, just three weeks of lactoovovegetarianism was enough to significantly reduce creatine concentrations in the meat-free group, compared with the omnivores. However, the good news was that when the two groups subsequently engaged in creatine supplementation (.3

grams of creatine per kilogram of body weight per day) for five days, the meat-free and meat-rich athletes ended up with exactly the same level of creatine in their muscles. In other words, vegetarian power athletes concerned about low intramuscular creatine levels can probably boost creatine to meat-loving levels with just five days of creatine supplementation.

In truth, while there is little doubt that vegetarians have less creatine in their muscles and plasma than omnivores do, there is actually little strong evidence that such creatine displacements put them at a major disadvantage, even in high-power competitions. In fact, one of the few pieces of research which has looked at this question (a randomized, double-blind study) found that creatine supplementation failed to have a uniquely positive effect on muscular power output in vegetarian athletes (9). The bottom line is that there is at present no strong reason for vegetarian athletes to be worried about losses of muscular power; if they are worried, they can simply stoke in creatine for five days and attain the same lofty levels enjoyed by the meat-rich crowd.

Other worries about vegetarianism also tend to fall by the wayside when inspected closely. Take the case of iron, for example (one argument is that since the "non-heme" iron found in plant foods is more poorly absorbed than the heme iron found in meat, an endurance-athlete's risk of developing anemia rises when he/she adopts a vegetarian diet; in line with this, a serious endurance athlete may already be at higher-than-usual risk of developing an iron deficiency because of exercise-induced iron losses (via sweat, urine, and feces), which exceed the losses associated with watching television or sitting around on the couch).

In one scientific study, nine female runners who consumed a "modified-vegetarian diet" (with less than three ounces of meat per week) were compared with nine other female runners who ate red meat regularly (10). Dietary iron intake was actually the same for the two groups (about 14 mg per day), but the bioavailability of the ingested iron was about 50-percent greater in the meat-eating group (at least partially because of the presence of heme iron). Serum ferritin values were lower in the modified-vegetarian group, but the bottom line was that there was absolutely no difference between the groups in terms of ability to train or maximal aerobic capacity.

Contrary to popular belief, low ferritin levels are not an indicator of iron-deficiency anemia.

Blood ferritin was also lower in the vegetarian runners in the *1000-K* race mentioned earlier in this article, but the vegetarian competitors fared just as well as their carnivorous peers. Bear in mind that reduced ferritin concentrations, although a potential warning sign, are not by themselves a bad thing. Running a race or hard workout with moderately low serum ferritin values is a bit like driving your car with less than a half-tank of gas; the car still operates in great fashion, and you can run PBs with less-than-half-full ferritin stores, as long as your blood hematocrit and hemoglobin are OK.

Furthermore, many studies of long-term vegetarian athletes report that iron status (as measured in blood, urine, and hair) is just fine (11). It is important to note that although inhibitors of iron absorption are present in plant foods (for example, phytates in grains and tannic acid in tea), plant products also possess compounds which stimulate iron absorption, including vitamin C and citric acid. As long as vegetarian athletes do not go to dietary extremes, it appears that their iron status will usually be adequate; iron-deficiency anemia is rare among vegetarian sportspeople (12).

Research has shown that very strenuous training leads to an uptick in urinary zinc excretion (13). This is potentially of concern to the serious vegetarian athlete, who already has a reduced bioavailability of dietary zinc and who may be losing more zinc, compared to the couch potato, in his/her feces and sweat. The good news is that most studies have failed to demonstrate impaired zinc status in vegetarian athletes; it is possible that the bodies of athletic vegetarians may be able to adapt by enhancing the absorption of zinc across the small-intestinal wall.

David Nieman, Ph. D.

Dr. Nieman's research has shown that vegetarian diets can be completely compatible with top-level athletic performances.

This may not be true in *adolescent* vegetarian athletes, however, who actually have higher zinc requirements, compared with adults. One reasonable dietary practice for vegetarian athletes is to consume ample amounts of foods which are rich in zinc, including fortified breakfast cereals, legumes, nuts, and seeds. If you are a vegetarian and you decide to supplement your diet with zinc tablets, it is important *not* to take in more than 100 percent of the recommended dietary allowance (15 mg per day for men and 12 mg daily for women) – in order to avoid potentially negative interactions with the absorption of other nutrients, including iron (the same is true for iron supplementation, which in excess can interfere with zinc absorption). Doses of zinc only a few milligrams above the recommended intake, especially when ingested regularly over time, can also interfere with copper absorption and lower the body's total copper content, which may weaken the heart; high intakes of zinc may also diminish the concentration of protective HDL in the blood.

Protein is another concern for vegetarians, since plant foods can be considerably lower in protein, compared with meat. Research indicates that endurance athletes probably need to take in approximately 1.2 to 1.4 grams of protein per kilogram of body weight per day – and that strength athletes might need as much 1.4 to 1.8 grams per kilogram daily. While such intakes might seem rather expansive, they are actually fairly easy to meet when athletes – including vegetarians and meat-eaters - simply keep their protein intakes at around 15 percent of total calories (14). As Dr. David Nieman points out in an excellent review article (15), even totally vegan athletes can enjoy optimal protein intake by emphasizing the consumption of protein-rich plant foods, including legumes (beans and peas), nuts, seeds, and whole-grain products.

Straying away for a moment from performance to the topic of health, it is worthwhile noting that vegetarian eating has been linked with a variety of health benefits, including a lower risk of mortality from heart disease, diabetes, and certain forms of cancer (16), along with a reduced chance of developing abnormal blood-fat profiles, obesity, and high blood pressure (17). Interestingly enough, regular exercise is also associated with many of these same advantages. Is there any evidence that vegetarianism and regular training, when practiced together, produce greater health benefits than either factor taken alone? As you might expect, the evidence suggests that this is indeed the case. In two different studies, a combination of recurrent physical exertion and vegetarian eating produced lower mortality rates, compared with a vegetarian diet alone or exercise by itself (18 & 19). From a health perspective, it is hard to argue against combining regular physical training with a vegetarian eating pattern.

So what is the bottom line about vegetarian eating and athletic performance? As Dr. Nieman points out, the available evidence indicates that a vegetarian diet has neither a demonstrably positive nor significantly negative effect on physical capacity. Although vegetarian diets are definitely "endurance-athletes' diets," in the sense that they are high in carbohydrate, usually adequate in protein, and low in fat, it is possible for meat-eaters to consume just as much carbohydrate as vegetarians do; when this happens, meat-lovers and vegetarians perform in similar fashion during endurance activities. There has been some concern that vegetarian female athletes are at increased risk for menstrual dysfunction, but Nieman indicates that low energy intake, not vegetarian eating *per se,* is the actual culprit in this area. Finally, vegetarian athletes do not seem to be at higher risk for impaired nutrient status, either in terms of protein or various minerals. As Dr. Nieman concludes, "…a varied and well-planned vegetarian diet is compatible with successful athletic endeavor."

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