RE-EVALUATING TRADITIONAL ENDURANCE TRAINING METHODS
BASED ON CONTEMPORARY FATIGUE RESEARCH
MATT GITTERMANN

THE ‘HOLY TRINITY OF TRAINING’
VO2 Max, Lactic Threshold and Running Economy: These three modalities of training have formed the basis of training programs of coaches and runners for more than a half a century. The prevalence of the use of the term ‘lactic acid’ in our lexicon can be traced as far back as studies from 1907 (Fletcher and Hopkins 1907), which in turn served as the foundation for another study that suggested a limit to oxygen use (VO2 Max) during exercise and a further examination of ‘lactic acid’ as seen in the work of Archibald Hill in the mid 1920’s (Hill et al. 1924a, 1924b). While examinations and critiques of VO2 Max and Lactic Threshold continued through the remainder of the century to present times, their prominence through practical application was disseminated to the masses via the Daniel’s Running Formula (Daniels 1988) in the late 1980’s. As the principles of VO2 Max and Lactic Threshold became under more scrutiny from modern research, the catch-all equalizer of Running Economy was introduced to explain the discrepancies between experimental values and race performances deviating from predicted values (i.e. why runners with different VO2 Max values could run similar times or why runners with the same relative VO2 Max values performed at completely different levels). While strength training and altitude training seem to be the most common modalities used to enhance running economy, the full spectrum of stimuli and the resultant adaptations could fill a textbook (Saunders, et al. 2004). In the end, the traditionalists would and still do suggest that the key to running faster is all about oxygen consumption and efficiency of its use.

The practical application of this research has led to the creation of training plans based around threshold training (tempo runs, aerobic threshold, cruise inter-
vals, anaerobic thresholds, etc.) or paces determined by percentage of VO2 Max (88% of VO2 Max, Critical Velocity, heart rate training, etc.). To cover the gaps between VO2 Max/Lactic Threshold levels and actual performance we have also seen a marked increase in use of supplemental training practices (strength training, plyometrics, hill strides, etc.) coupled with staples such as altitude training (and to a lesser degree hot weather training) to increase one’s running economy.

SPECIFICITY OF TRAINING AND MULTI-TIERED SYSTEMS
While the ‘Holy Trinity of Training’ serves as the foundation of training principles, the human body is far too unique, especially individual to individual, to use such broad overarching principles to fine tune a specific individual, with a specific physiology, to perform in a specific race on a specific day. This naturally led to a specificity of training seen in the intensive multi-tiered systems of Horvill and Coe, where the training frame of an individual is created around specific race paces adjacent to their target event rather than percentages of VO2 Max. Or in contemporary systems of training in which a majority of interval work is based on percentage of date or goal pace of races at or around the target race distance.

These systems can be naturally blended with the ‘Holy Trinity’ as one can easily tune into the adaptation benefits of Lactic Threshold training (10k – HM Date Pace) and VO2 Max work (3k-5k Date Pace) into their training due to their close proximity to specific race paces. Furthermore by focusing on a specific frame of paces around a target race or a frame of paces skewed to an athlete’s muscle type distribution (fast twitch to slow twitch ratio), coaches are able to develop specific adaptations that help reduce ‘fatigue’ in a specific individual for a specific race.
DEFINING ‘FATIGUE’ AND THE RISE OF THE ‘HERECTS’

When designing training, the assumed principle is simple, what can one do in order to run faster? However, it is arguable, that a better point of view would be what can one do not to slow down as fast and thus resist ‘fatigue’ in order to continue running at a desired pace for a longer period of time? From this point of view training design should be focused on developing adaptations that either prolong the onset of ‘fatigue’, or as will be discussed later, prolonging the potential cues of ‘fatigue’.

Traditionally, training has been done in such a manner that is it is attempting to either prevent the quick build-up of waste products such as hydrogen ions (acidosis) or slowing down the depletion of metabolic resources such as ATP and glycogen. Both the “build-up” and “depletion” models can be categorized as; “classic/traditional fatigue” due to them being the first prevalent view, “muscle fatigue” as per their location, “peripheral fatigue” in order to differentiate from any input from the central nervous system, and/or “catastrophic fatigue” due to notion that the body will continue to work at maximally efficient levels until it is either out of substrate for metabolism or accumulated enough metabolites to inhibit function at which point the muscles shut down. By focusing on threshold training, percentages of VO2 Max, and paces at and around pace paces, the hope of the coach/athlete is to create physiological adaptations (increase in red blood cells, increase in number of mitochondria, increase in muscle unit recruitment, buffering capacity etc.) that slow what is traditionally thought of as the causes of ‘fatigue’ and thus prevent muscle failure (i.e. rigor). See Figure 1

It is the causes of ‘fatigue’ and how it they are perceived that have become the front-lines where the debate heats up and these axioms of the past come under attack from a ‘heretical bunch’ of scientists that want to advance ‘fatigue’ away from the classical peripheral catastrophic fatigue models (build-up and depletion models) towards a new frontier of understanding.

THE CENTRAL GOVERNOR THEORY OF FATIGUE

The most familiar of the new theories is found in the works of Tim Noakes of The Lore of Running fame and his Central Governor Theory. In this theory he explains that the body has a strong desire to maintain the status quo and homeostasis of its physiological systems. As the body undergoes damage, either from training or racing, the body will protect itself from catastrophic damage through the efforts of a sub-conscious regulator (the brain) that will slow itself (the body/muscles) down to prevent such damage from occurring. Noakes continues by stating that this system is not regulating using just real time feedback (H+ ions levels, levels of hypoxia, etc.) but uses environmental conditions, experiences, mental state and other dynamic factors to anticipate the damage before it happens and begin regulating the firing of motor units (pacing) before it is actually necessary in order to maintain homeostasis and avoid catastrophic failure.

In contrast to the catastrophe (build-up/depletion) models of fatigue, the build-up of metabolites (lactate, etc.) or depletion of substrate (glycogen, etc.) are used as feedback for the Central Governor to make adjustments to the subconscious pacing strategy to prevent failure rather than being the actual cause of failure. As Noakes describes, “the linear model of fatigue suggests that exercise would continue until the muscle, for example, was completely depleted of substrate, or the system was overwhelmed by metabolite accumulation. In contrast, the Central Governor model suggests that metabolic variables are important ‘sensors’ of change themselves and initiate afferent feedback to the brain, which in turn directly resets metabolic and motor activity in a feed forward manner” (Lambert, St Clair Gibson, and Noakes 2005).

Studies regarding the Central Governor model typically revolve around the termination of exercise while there are still capabilities to not only continue but at times increase work production. For example, in a study involving a series of sprints on a stationary bike, participants show immediate and progressive decreases in power output and neural readings indicating that muscle unit recruitment and power output was decreasing even though the percentage of used muscle units were far below the maximum possible. In a homologous study, similar diminishing returns were seen however on the final sprint power output and neural readings increased, resulting in a phenomenon called the “end spurt” indicating that the facilities to maintain a higher power output through-
out were present (St. Clair Gibson & Noakes 2004). As coaches of endurance of runners, we have seen this on numerous occasions in which an athlete is dying a slow death lap after lap on the track only to be revived in the last 400 meters with a furious kick with energy they must have kept in escrow.

It is also proposed that the Central Governor is responsible for determining a pace during any sort of run or race by analyzing a variety of feedback and experiences to decide upon a pace that can be accomplished for the set duration. When the anticipatory aspect is manipulated via misinformation regarding the duration, studies have found that if duration is less than presented then performance is less than expected (similar results when no duration presented) while if the duration is longer than presented, power output greatly decreases or Rating of Perceived Exertion (RPE) greatly increases over the final portion (Tucker 2009). Tucker (2008) additionally notes that environmental conditions have an effect on pacing in an anticipatory manner, revealing that in hot conditions the human body will begin at a slower pace than normal despite a normal starting core body temperature suggesting the anticipatory nature of the Central Governor to maintain homeostasis. Furthermore, in his own study he found that when the body reaches a core body temperature of 104 degrees (40°C) it will essentially shut itself down in order to prevent catastrophic damage. Additional studies have shown that with the use of drugs, this regulation by the Central Governor can be ignored, allowing cyclists to continue beyond this critical core temperature without a full shut down suggesting that reserves were still available (Tucker 2009).

The practical application of the trainability of the Central Governor is as tough as one would expect with regulation being overseen by the sub-conscious part of the brain. It is likely that training in hotter weather would not only improve running economy but would create adaptations that would also prevent the rise of the core body temperature as quickly thus stopping or slowing the progression to the 104 degrees shut down point. It should be noted that the overall size of the athlete will always be a limiting factor in the heat with larger runners at a disadvantage. From a more anecdotal side, one could target the anticipatory regulation and pacing by creating workouts where athletes are ignorant of volume, distance and speed, or ones designed to put the athlete in a bad physiological spot prior to running a goal pace or a kicking simulation that might callous the body to running a desired pace in a distressed state. Even, the inclusion of a few, highly structured and restricted “spiritual” workouts where athletes are pushed to the edge of their capabilities could create the callousing effect needed to “ignore” the Central Governor. However, with the potential negative effects of such a workout (injuries, overtraining, etc.) this would be a modality which you could only access once and while. See Figure 2.

THE PERIPHERAL GOVERNOR THEORY OF FATIGUE

In a similar vein, Brian MacIntosh and Reza Shahi take the idea of anticipatory regulation and shift it from the brain (Central) to the individual cells (Peripheral) with MacIntosh and Rassler (2002) suggesting that “peripheral muscle fatigue is ‘a response that is less than the expected or anticipated contractile response, for a given stimulation’ as a consequence of repetitive or sustained contractile activity” (as cited in MacIntosh and Shahi 2010). The implication being that cells regulate the use of muscle units by individually adjusting the rates at which ATP is supplied and hydrolyzed, thus affecting the rate and force of muscle contractions (MacIntosh and Shahi 2010).

In their review, “A Peripheral Governor Regulates Muscle Contraction”, MacIntosh and Shahi analyze a study (Bigland-Ritchie et al. 1986a, as cited in MacIntosh and Shahi) in which participants were asked to voluntarily contract their quadriceps to maximal levels every 30 seconds until the force production was less than 50 percent of the maximally achieved level. During the voluntary contraction an electric stimulation was applied in order to remove the central nervous system from the equation, resulting in two items of note. The first is from the very beginning there was a decrease in force with each subsequent contraction despite glycogen, ATP and lactate levels remaining relatively unchanged, which implies a regulation of muscle unit firing. Furthermore, there was very little to no difference in the force production between voluntary and electrically stimulated contractions, implying that the regulation was occurring peripherally, potentially at the cellular level, rather than from a Central Governor.

In regards to practical application, this theory can be integrated into traditional training methods fairly easily as specific endurance training can bring about various adaptations that would increase ATP production or improve the efficiency of use of calcium ions thought to be one of the items responsible for regulation. While it would not prevent the anticipatory regulation it could in theory slow the regulation down and thus extend the force of muscle contraction further into the race. See Figure 3.
THE PSYCHOBIOLOGICAL THEORY OF FATIGUE

Emerging research from Samuele Marcara, Walter Staiano and associates is returning the regulation of exercise, and thus fatigue, back to the brain, but in a conscious format. In their research they have found that there is a strong relationship between Rating of Perceived Exertion (RPE) and fatigue, while suggesting that mood and mental fatigue greatly affect RPE (Marcara and Staiano 2010), such that one should train (and rest) the brain in order to reduce RPE in order to increase peak performance. In contrast to the Central Governor theory, the implication is that performance can be “consciously regulated,” and as a result performance can hopefully be improved by “using psychological and psychobiological interventions” (S. Marcara, personal communication, April 24th, 2014).

In their recently released study, Marcara, Staiano and Manning showed experimental data that their Brain Endurance Training (BET) program decreased mental fatigue and thus led to increases in endurance performance when used as a supplement to a traditional physical training model (Marcara, Staiano, & Manning, 2014). Additionally, Blanchfield et al (2014), showed that a structured two week self-talk program was able to reduce RPE and thus increase endurance performance (time to exhaustion). This is a big paradigm shift in how one would perceive fatigue and its potential ramifications for training as they, “propose that exhaustion is a form of task disengagement, not task failure, determined by perception of effort and potential motivation as postulated by the psychobiological model of exercise tolerance. In other words, subjects consciously decide to “give up” (i.e. disengage from the task) when the effort required by intense aerobic exercise is perceived to be maximal or exceeding the maximal effort they are willing to exert in order to succeed in the task (potential motivation)” (Marcara and Staiano 2010a).

The practical implications to training could range from very little to a large portion of your program at the coach’s discretion. A sports psychology component, which was undoubtedly already a necessity, is only more magnified in a more structured manner with occasional informal assessments of progression throughout the season. With the results only recently released or soon to be released, suggestions would only be conjecture at this point. However their work with athletes regarding self-talk has been shown to positive results, and potentially things as simple as holding team study hall before practice (creating mental fatigue) could replicate the results seen in their studies. For those cross training athletes on the bike, it would be possible to recreate the experimental results seen as a result of the BET program as it was part of the initial methods. Additionally, one might look into potentially periodization of their sport psychology component throughout the year to mirror the volume and intensity of the physiologic component.

POTENTIAL FOR AN INTEGRATED MODEL OF FATIGUE

See Figure 5. The push for all researchers...
should be an integrated model of fatigue (an unscientific attempt to summarize seen in Figure 4) that would be able to explain all aspects of fatigue within the human body, akin to String Theory in astronomy. While many of the theories are at odds with each other, there is the possibility due to the complexity of the human body to integrate portions of the models with each other or attain the very least considerations into our current training programs.

As mentioned previously, there are regulatory similarities between the Central and Peripheral governors that could imply they could be a part of a more complex regulatory system or separate systems with a redundancy of homeostatic regulation. The trainability of the Peripheral Governor is most likely addressed in current training methods, while the trainability of the Central Governor, while a bit murky in regards to physical training application has merit so long as it is done in a very structured and observable format in order not to overdo it by constantly taking informal assessments of the athletes during and a formal assessment at the conclusion of the session.

The Psychobiological and Central Governor Theories dig deep into the motivations of the athletes and thus would work well with and potentially increase the importance of sports psychology within endurance sports. The Psychobiological model alone yielded results that would encourage coaches to develop and carry out a more structured mental training aspect (self-talk, mental rehearsal, visualization, etc.) in their program, even without implementing the full BET when available. The Central Governor Theory states since the “brain uses the symptoms of fatigue as key regulators” and do not properly show the true levels of fatigue than ‘fatigue’ can be classified as an “emotion” (Noakes 2012) and thus could potentially be worked through for lack of a better term, “mental toughness.” At the very least, coaches may want to become familiar with BRUM’s Subscales (mood survey) and Borg’s Scales of Perceived Exertion to informally track the mental status of their athletes versus their training and racing performances to analyze any possible relationships that may arise.

It should be noted that many of the aforementioned descriptions were intentionally designed to be short and simplified in order to be more palatable for easy consumption in this format, and as a result the complexity (and potentially the accuracy) of the models was not reached in depth. While each theory draws its line in the sand, the human body is complex enough that it lends itself for a more integrated model, where potentially, aspects of each theory are functioning simultaneously in a complimentary and/or redundant fashion. As McKenna and Hargreaves (2008) noted, “fatigue during exercise can be viewed as a cascade of events occurring at multi-organ, multi-cellular and at multi-molecular levels. The challenge for scientists is to understand how these mechanisms work together.” The challenge for coaches is to reevaluate our reliance on traditional fatigue models and begin to incorporate aspects of these newer fatigue models to continue to improve our training programs and as a result, our athletes’ performances.

REFERENCES


27(1), 42-55.


