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"Dear coach, why is it so difficult to run off the bike in a triathlon?"

Factors affecting the ability to run effectively during the run phase of a triathlon; a review of recent and relevant research.

Introduction

The first recorded triathlon events combining swimming, cycling and running were held in Mission Bay, America in 1974. In 1978 the first Hawaii Ironman Triathlon took place, with competitors racing over a 3.8km sea swim, a 180km cycle and a 42km run. 1983 saw the first UK triathlon and the founding of the national governing body. 1989 saw the establishment of the sports international governing body, the International Triathlon Union. 1994 was the year that the standard distance triathlon, (1500m swim, 40km bike, 10km run) was accepted into the summer Olympics programme; triathlon becoming an Olympic sport at the 2000 Sydney Olympics. Triathlon can be described as one event encompassing three sports and two transitions; swim, transition (T1), bike, transition (T2) and run. There are a number of recognised formats as shown in Table 1.

Table 1. Various Race distances & formats of triathlon races.

	Swim distance (m)	**Bike distance (km)**	**Run distance (km)**
Super Sprint	400-600	<20	<5
Sprint	750	20	5
Standard (Olympic)	1500	40	10
Middle Distance	1900-3000	80-90	20-21
Ironman™	3800	180	42
Decaman™	38000	1800	420

Factors affecting an athlete's running ability in triathlon.

Chapman, Vincenzino, Hodges, Dowlan, Hahn, Alexander and Milner (2009) state that triathletes report impaired coordination when running after cycling. Observation and anecdotally evidence show this is a problem for triathletes. An analysis of current literature may provide considerations that can be applied by the coach. This review has, where possible, focussed on research articles pertaining to Standard distance of 1500m swim, 40k bike and 10k run.

Morphology & Physiology.

Bloomfield and Sigerseth (1965) claimed longer lever lengths were advantageous in swimming: previous studies (Sleivert & Rowlands, 1966; Tittle & Wutscherk 1988) state that long limbs allowed for greater stroke and stride length; greater stroke or stride length is more efficient that increasing cadence. Landers, Blanksby, Ackland and Smith (2000) studied the morphology of elite athletes and reinforced the aforementioned studies showing that athletes with longer limbs tend to perform better in the swim and cycle phases of triathlon. Landers et al. stated that body measurements are directly related to stride length and running cadence. Landers et al. hypothesised that the variance in the pace the 10km run was completed at, could be due to fatigue. Atwater (1990) showed that to be efficient as a runner a lower body fat was required.

How the swim can affect the run.

Given the continuous nature of triathlon the impact that the swim and swim equipment has on the overall event must be taken into account.

Parsons and Day (1986) research came about from a health perspective, as at the 1985 British National Championships 41% of the athletes competing were forced to withdraw having suffered from hypothermia. The participants swam over a set time period rather than a specific distance and their study showed that a wetsuit provided a 7% reduction in swim times. Cordain and Kopriva (1991) showed that leaner athletes benefit from wearing wetsuits in cooler temperatures, competitive swimmers swam over 400 & 1500m. This study showed that the 400m times were reduced by 4.96% and the 1500m times were reduced by 3.32%.

Bentley, Millet, Vleck and McNaughton (2002) study showed that whilst a wetsuit may reduce the incidence of hypothermia, the wetsuit may cause the body core temperature to rise thereby affecting performance, re-emphasising how the swim and body core temperature can affect the athlete’s power output on the bike phase.

Millet, Dreano and Bentley (2003) studied elite athletes’ physiological characteristics and concluded that whilst standard distance triathletes swam faster but there was no submaximal or maximal physiological difference in either cycling or running between standard and long-course triathletes.

In 2005 Peeling, Bishop and Landers showed how the intensity of the athlete’s swim phase can affect the overall triathlon. They studied participants over a sprint triathlon. They concluded that in a triathlon it was more effective for the participants to swim at approximately 80-85% of their maximum swim velocity and to cycle between 80-95% of their maximum power outputs. They concluded that a training and racing strategy focussing on sub maximal swim and bike pacing will benefit the overall triathlon performance.

How bike equipment, cycling cadence and cycling intensity will impact on the run.

Elite events usually feature a multi-loop, drafting course where the competitors ride in packs and need to be in the first pack to have any impact upon the race. Elite triathletes tend to ride at variable intensities whereas the amateur or Age Group races utilise a non-drafting format where athletes are not allowed to take pace or protection from the riders around them.

Cycle Geometry.

Price and Donne (1997) studied the benefits of increasing the seat tube angle (STA), the position of the saddle in relation to where bottom bracket and cranks are, from 73º to 81º. They found an increased STA produced a lower mean VO_2 and higher power outputs. Another 1997 study by Gnhem, Reichenbach, Altpeter, Widner and Hoppeler stated that increasing the STA allowed a lower body position therefore reduced frontal area and drag, which in turn meant lower energy output.

Ricard, Hills-Meyer, Miller and Michael (2006) discussed how bicycle frame geometry impacts upon the run phase of a triathlon. On a road bike the rider's posture is similar to sitting in a chair inasmuch the hips are behind the rider's feet and the crank axis (bottom bracket). When using a triathlon bike the rider's hips tend to be over their feet and the crank axis. This is a posture mimicking a running position.

They studied cyclists and triathletes, comparing bikes with a 72º and 82º STA. The conclusion was that using an 82º STA bike was beneficial for triathletes due to the there being reduced muscle activation with no reduction in athletes' power output. They hypothesised that an 82º STA also reduces hamstring tightness that allows triathletes to run with a longer stride length. This should enable the triathlete to run in a more upright position.

Cycle cadence and biomechanics.

Cycling Cadence.

In 2002 Vercruyssen, Hausswirth, Brisswalter, Bernard, Bernard and Vallier established that a cycling cadence of 73 revolutions per minute (rpm) reduced VO_2 uptake and may benefit the subsequent run phase. This cadence of 73 rpm is contrary to that recommended by Gottschall & Palmer's (2002) study that showed cycling at 109 rpm improved participant's 3200m track based run by almost a minute. This study showed that a higher cadence increased the stride rate and running speed; equally the joint kinematics at foot strike, toe-off and mid-swing phase showed no difference through the cycle cadences used. Further debate on the optimal cycling cadence is highlighted by the 2003 study by Bernard, Vercruyssen, Grego, Hausswirth, Lepers, Vallier and Brisswalter who stated that cycling cadence had no effect on stride rate during a 3000m run. This study suggested running at less than 84% VO_2 max. achieved the optimal run performance.

Vercruyssen, Suriano, Bishop, Hausswirth and Brisswalter (2005) looked at how the final 10 minutes of cycling affected metabolic responses, stride patterns and running time to fatigue. This study reported an increase in the muscle activation of the Vastus

Lateralis, Gastrocnemius and Soleus, albeit this study used a higher cadence, 94-109 rpm, than the Bine et al. study. Vercruyssen et al. concluded that the cycling cadence chosen did not change the stride pattern or time to fatigue.

Cycling Biomechanics

Hug and Dorel (2007) reviewed the pedalling action of 12 triathletes, detailing the lower muscles used and their function in pedalling. This study showed there was minimal electromyography (EMG) activity close to 100rpm at 400 Watts (W). They hypothesised that muscle activation occurs progressively earlier as cadence increases. They stated the rise in EMG activity during a constant load exercise, taken to fatigue, could induce changes to the co-ordination of the lower limb muscles.

Chapman, Vicenzino, Blanch, Dowlan and Hodges (2008) studied elite triathletes and found that the pattern of muscle activation during the run was similar to the pattern used when cycling. They suggest it is not fatigue or kinematic variations that effect the run phase rather it is the transfer of the cycling muscle patterns being used in the run phase.

Bini, Diefenthaeler and Mota (2008) studied cyclists. Their study concluded that only the ankle joint was negatively affected by cycling to fatigue; the ankle joint's reduced contribution to force transference affected the cycling effectiveness and power output. The fatiguing of the ankle joint's working muscles; Soleus and Gastrocnemius would be impactive on the athlete's running ability.

Chapman et al's. (2009) study examined neuromuscular coordination of 30 minutes of running after a cycle. Chapman et al's. conclusion re-iterated the earlier study inasmuch as the kinematics of running remained unaffected whereas there was a direct effect upon the motor commands required for running with the altered muscle recruitment resulting in a reduction in running economy.

Cycling Intensity

Bernard, Vercruyssen, Mazure, Gorce, Hausswirth and Brisswalter (2007) concluded that maintaining a constant power output over 20km improved the running performance over 5km. These findings were echoed in Lepers et al 2008 study where it was highlighted that variable pacing led to excessive glycogen depletion and premature fatigue. This study concluded that whilst constant power output led to improved running performance this could not be explained solely due to lower limb neuromuscular fatigue.

Bine, Carpes, Diefenthaeler, Mota and Guimaraes (2008) study showed that triathletes who undertook a 40km cycle time trial to exhaustion showed no changes in lower limb activity for a 60 minute cycle at the participant's critical power output. This study showed that at a steady, constant power output there was no increase in VO_2 or muscle activity. When the participants were instructed to increase power output at the end of the time trial there was an increase in Vastus Lateralis and Rectus Femoris activation and VO_2. Bine et al. suggests the steady state observed was an attempt to prevent premature muscle fatigue; this part of the study is starting to mirror themes similar to those in the Central Governor Theory (St Clair Gibson and Noakes 2004).

Guezennec, Vallier, Bigard and Durey (1996) showed participants displayed an 8% decrease in running efficiency at the end of a triathlon 10km run compared to a stand alone 10km run despite blood lactate for both runs being the same.

Bentley et al. (2002) looked at specific aspects of triathlon and indicated that the VO_2 maintained during the running stage of a triathlon is influenced by the preceding cycle phase of the race, stating both VO_2 and pulmonary ventilation (VE) will be elevated due to the swim and bikes stages prior to the run.

Millet and Vleck (2000) showed that VO_2, respiratory frequency, ventilation rate and heart rate in a triathlon 10km run will all be increased when compared to a one off 10km run. They explain this by stating that the cycle to run transition induces leg fatigue and a redistribution of muscle blood flow between different muscle groups. They calculate the energy cost of controlled running compared to running in a triathlon, expressed as ml O_2/kg per km is 1.6% to 11.6%.

Conclusion

Given the variants in the studies it is difficult to make a like for like comparison of the research referred to. Some of the variations in the studies include participant numbers that ranged from 6 athletes upwards; the majority of the studies focused on male participants: the studies used both amateur and elite performers; studies mixed single event swimmers and cyclists with triathletes all with different history and experience in the sport. Those studies that were bike-run based appeared to use either time, velocity, cadence or power as a measure rather than specifically looking at how a 40km bike ride at a set power output would affect the run. Only a couple of the studies actually collected data from triathletes who completed a 1500m, 40km bike & 10km run. What is clear is that there is no one factor influencing running efficiency in the run phase of a triathlon. Factors to be considered are body composition; nutrition; equipment; race tactics; drafting; swim & bike velocities; swim & bike physiology and biomechanics; neuromuscular fatigue; central governor theory; sensory adaptation. Even with the limitations highlighted there are some considerations that can be implemented.

Swim

Pacing is important and athletes should swim at 80-85% of maximum velocity.

Wetsuits will benefit the leaner and slower swimmer for buoyancy and hypothermic issues, as well as improving times by 3-7%.

Bike

Geometry. A bike with an 81-82º seat tube angle appears to be more beneficial than a standard road bike.

Cadence. Still no hard and fast answer; with cadences from 73 to 109rpm showing benefits in different studies.

Intensity. The agreement on this is that a steady, constant power output is more beneficial with a target range of 80-95% of maximum power output being favourable.

Run

Expect to be running slower, at approximately 84% of VO_2 maximum as you may be 8% less efficient with an increased energy cost.

Include bike-run sessions in training.

It can be seen that whilst practical research has been undertaken, given the nature of the sport, there are opportunities to conduct additional research.

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