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Triathlon Wetsuit Removal Strategy: Physiological Cost of Running with a Wetsuit

by
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Triathletes exiting the swim portion of an event have to decide on how and when to take a wetsuit off (if worn). The purpose of this study was to determine the physiological cost of running while not using a wetsuit, carrying a wetsuit, wearing a wetsuit halfway down or wearing a wetsuit fully up. Participants (n = 20, 30.9 ± 8.7 yrs, 1.71 ± 0.08 m, 71.6 ± 9.5 kg) completed four 5 min running conditions: 1) not wearing the wetsuit, 2) wearing the wetsuit fully up, 3) wearing the wetsuit halfway down, and 4) carrying the wetsuit. A rate of oxygen uptake, a heart rate, ratings of perceived exertion and stride frequency were measured and were each influenced by wetsuit condition (p < 0.05). Each variable (i.e., a rate of oxygen uptake, a heart rate, stride frequency) was lower during running while not wearing the wetsuit vs. any other condition (p < 0.05). The rate of oxygen uptake was greatest during wearing the wetsuit halfway down vs. any other condition (p < 0.05). The heart rate was not different between any of the combinations of either wearing the wetsuit fully up or halfway down or carrying the wetsuit (p > 0.05). The rating of perceived exertion was greater during wearing the wetsuit halfway down vs. carrying the wetsuit (p < 0.05). Stride frequency was lower during not wearing the wetsuit vs. wearing the wetsuit halfway down or fully up (p < 0.05). It was concluded that running with the wetsuit halfway down resulted in the greatest rate of oxygen uptake, heart rate and rating of perceived exertion.

Key words: *running economy, fatigue, race performance.*

Introduction

A triathlon event consists of swimming, biking and running segments combined into a single event. The distances of each segment vary greatly between races, but the order is typically the swim first, followed by the bike and then the run. Since athletes progress continuously between these segments, there are two ‘transitions’ between segments: swim to bike (T1) and bike to run (T2). To improve in a triathlon, athletes train for each segment as well as practice each transition.

Although there is variety of research on the influence of completing multiple segments on physiological, biomechanical and performance measures (Bonacci et al., 2010; Bonacci et al., 2013; Cala et al., 2009; Chapman et al., 2008; Gottschall and Plamer, 2002; Hue et al., 1999), to our knowledge there is no research focused specifically on transitions. Even though, transition length (and therefore time) as well as terrain can vary greatly between races, it is important to understand the physiological demands of transitions in order to benefit overall race performance.

A unique aspect of triathlon is that an athlete will typically wear a wetsuit during the swim portion of the event. As the athlete exits the water and transitions to the bike, the athlete must decide on when to take the wetsuit off as he/she runs from the swim exit to the location of the bike gear. Some triathlons will have ‘wetsuit strippers’ – these are volunteers that assist the athlete in

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taking the wetsuit off as quickly as possible. In that case, after the wetsuit is taken off, the athlete must carry the wetsuit to the transition area. In general, athletes tend to hold on to the wetsuit under the arm that is more comfortable to him/her while running through the transition area. At that point, the wetsuit is dropped off and the athlete transitions to the bike.

In many races, however, there are no wetsuit strippers and the athlete will typically take the wetsuit half-way down (i.e., pulled down to the waist) until reaching the area to change to bike gear. Another option is for the athlete to run with the wetsuit all the way up until reaching the area to change to bike gear. Presently, there are no empirical data available to the athlete that would be helpful in making the decision as to how and when to remove the wetsuit. Therefore, as a first study on this topic, the purpose was to determine the physiological cost of running while not using a wetsuit or while carrying a wetsuit, wearing a wetsuit halfway down or wearing a wetsuit fully up. It was hypothesized that running without the wetsuit (i.e., not carrying or wearing it in any way) would result in the lowest physiological cost while running with the wetsuit halfway down would be the least costly.

Material and Methods

Participants

Twenty healthy subjects (male n = 10, 33.8 ± 8.2 yrs, 1.78 ± 0.05 m, 79.4 ± 3.75 kg; female n = 10, 27.9 ± 8.5 yrs, 1.65 ± 0.06 m, 63.6 ± 5.98 kg) volunteered to participate in the study and all subjects read and signed a university approved informed consent form before participating in the study. Subjects were healthy, currently regularly exercising and capable of completing a 45-60 min run.

Instrumentation

All participants ran on a treadmill while wearing a mouthpiece that the subject breathed through in order to determine the rate of oxygen uptake (VO_2) (Moxus modular metabolic system, AEI Technologies Inc., Pittsburgh, PA). VO_2 was measured breath-by-breath and recorded every 15 s for each condition. Subjects wore laboratory provided running shoes (Adidas adiPRENE) and a telemetry heart rate transmitter (Polar Electro Inc., NY) to record their heart rate. Prior to testing, subjects were assigned a wetsuit size selected following manufacturer guidelines (HUUB Design Limited, size-SMT M MT ML, Aerious full-sleeved model 4:4, Derby, UK).

Procedures

Each participant completed four running conditions consisting of manipulating carrying or wearing the wetsuit. The four conditions were: 1) running without wearing a wetsuit (NWS); 2) running while carrying the wetsuit (WS_{carry}); 3) running with the wetsuit fully on (WS_{full}); and, 4) wetsuit worn halfway down (WS_{half}) (Figure 1). During WS_{carry} participants generally gathered up the wetsuit in a way that they would carry a ball; they were allowed to change the wetsuit from one hand to another. Each condition lasted 5 min with participants given time for a self-directed warm-up on the treadmill prior to any testing.

Treadmill speed was controlled across conditions and set to each participant's preferred running speed (PRS_{test}) while running without the wetsuit (i.e., NWS). This speed was determined following the warm-up (and prior to testing) by instructing the participant to run on the treadmill and select a speed he/she could sustain for a 30 min training run. The speed display was hidden from the participant. Once the participant indicated the preferred speed was reached (usually within 1-3 min of running), that speed was recorded, the treadmill stopped and the process repeated for a total of three times. This process usually takes about 1-3 min (i.e., the subjects do not run 30 min) and follows a protocol used by the laboratory for selecting a preferred speed. The PRS_{test} was the average of these three speeds. In addition to determining PRS_{test}, the preferred speed for each condition (PRS_{cond}) was determined using the same process; however, all measurements were always done while participants ran at PRS_{test}.

During each running condition, rating of perceived exertion (RPE, 6-20 point scale) (Borg, 1970) and stride frequency (SF) data were collected at the beginning, middle and end of the 5 min time interval while VO_2 and HR data were collected breath-by-breath and recorded at 15 s intervals throughout the 5 min condition. Stride frequency was calculated by measuring the time to complete 20 strides. Time was allowed between conditions as needed to prepare for the next condition (e.g., put the wetsuit on). Order of testing was always NWS, WS_{carry}, WS_{full} and then

WS_{half}.

Statistical Analysis

VO_2 and HR data were averaged over the final 3 min of each condition. SF, RPE, and PRS_{cond} were averaged across three measures taken for each condition. Each dependent variable (VO_2, HR, SF, RPE and PRS_{cond}) was analyzed using a 1 x 4 (NWS, WS_{carry}, WS_{half}, WS_{full}) repeated measures ANOVA (IBM SPSS Statistics, version 22; $\alpha = 0.05$). If the omnibus F-ratio was significant, planned comparisons were conducted to compare conditions to each other. Data from one participant (male) was dropped from analysis due to instrument error. Also, HR data from two specific participant conditions (one male, during WS_{carry}; one female during WS_{full}) were dropped from the analysis due to the HR transmitter not operating. However, data were run with and without these data with no change in the statistical outcome.

Results

HR ($p = 0.001$), VO_2 ($p < 0.001$), SF ($p = 0.002$) and RPE ($p < 0.001$) were each influenced by wetsuit condition (Table 1) while PRS_{cond} was not ($p = 0.756$) (Table 1). Using planned comparisons, VO_2 was lower during NWS vs. any other condition (i.e., WS_{carry} ($p < 0.001$), WS_{half} ($p < 0.001$), WS_{full} ($p < 0.001$)) as well as during WS_{carry} or WS_{full} compared to WS_{half} ($p < 0.001$, $p = 0.002$, respectively).

The HR was lower during NWS vs. WS_{carry} ($p = 0.001$), WS_{half} ($p = 0.043$) and WS_{full} ($p = 0.002$), but not different than any of the combinations of WS_{carry}, WS_{half} and WS_{full} ($p > 0.05$). The RPE was lower during NWS vs. WS_{carry} ($p = 0.050$), WS_{half} ($p = 0.002$), and WS_{full} ($p < 0.001$) and was greater during WS_{half} vs. WS_{carry} ($p = 0.004$) and tended to be greater during WS_{half} vs. WS_{full} ($p = 0.096$). SF was lower during NWS vs. WS_{half} ($p = 0.017$) or WS_{full} ($p = 0.013$) and lower during WS_{carry} vs. WS_{full} ($p = 0.016$).

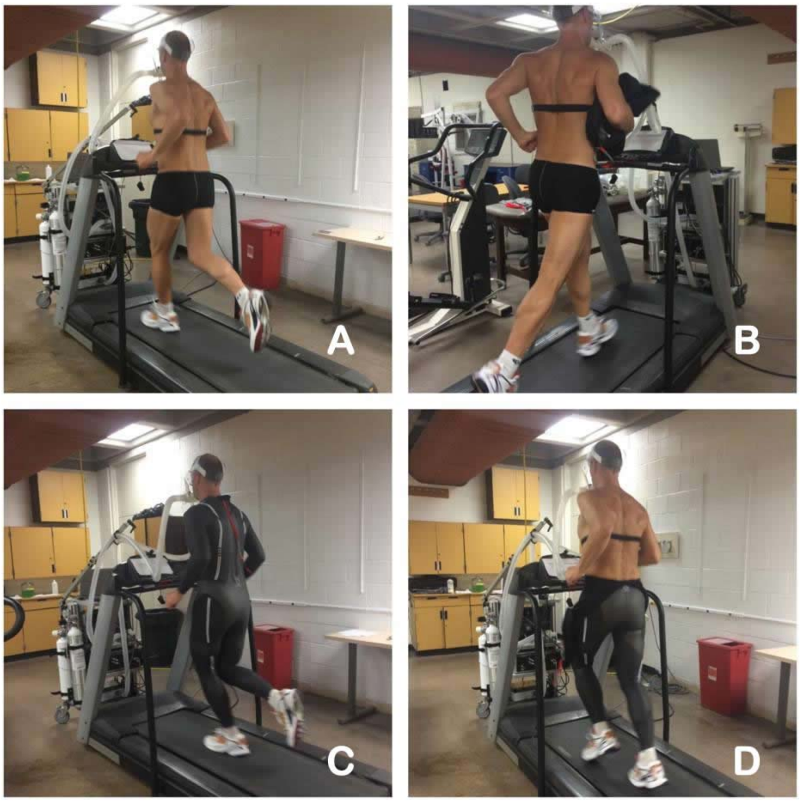

Figure 1

Illustration of the four running conditions. 1A: No wetsuit;
1B: Running while carrying the wetsuit; 1C: Running with the wetsuit fully up;
1D: Running with the wetsuit halfway down.

Table 1

Means and standard deviations for the Rate of Oxygen Uptake (VO_2), Heart Rate (HR), Stride Frequency (SF), Rating of Perceived Exertion (RPE, 6-20 point scale) and Preferred Running Speed (PRS_{cond}) during running with no wetsuit (NWS), carrying the wetsuit (WS_{carry}), wearing the wetsuit halfway down (WS_{half}), or fully up (WS_{full}). VO_2, HR, RPE and SF were all influenced by condition ($p < 0.05$).

Variable	NWS	WS_{carry}	WS_{full}	WS_{half}
VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	38.9 ± 7.1*	40.8 ± 7.4	40.6 ± 6.9	41.7 ± 7.4**
HR (bpm)	141.4 ± 22.4*	149.0 ± 25.3	151.0 ± 24.9	150.0 ± 27.0**
RPE	10.5 ± 1.6*	11.2 ± 1.4	12.1 ± 1.4	12.2 ± 1.9**
SF (Hz)	1.38 ± 0.07^{xo}	1.40 ± 0.04^{z}	1.43 ± 0.04^{xz}	1.41 ± 0.05^{o}
PRS_{cond} ($m \cdot s^{-1}$)	2.7 ± 0.6	2.7 ± 0.6	2.6 ± 0.6	2.7 ± 0.6

*Indicates lowest value ($p < 0.05$) and ** the greatest ($p < 0.10$) using planned comparisons; for x, o, z: like symbols indicate difference between conditions.*

Discussion

Overall triathlon race performance will be influenced not only by the athlete's swim, bike and run performances, but also by the transition performances. The present study was focused on T1 (transition from swim to bike) since there is a unique decision that needs to be made regarding when to take a wetsuit off (if one is worn).

Running with the wetsuit halfway down resulted in the greatest VO2, HR and RPE compared to during running in any of the other conditions. Furthermore, carrying the wetsuit was less costly than wearing the wetsuit halfway down, but not different than when wearing the wetsuit fully up. More specifically, VO2 was on average 2.2-2.8% greater during wearing the wetsuit half way down vs. carrying the wetsuit or wearing it fully up. On average VO2 was 7.25% greater while wearing the wetsuit halfway down than during running not wearing (or carrying) a wetsuit at all.

There is no research on the energy cost of running in a wetsuit let alone running while transitioning between swim and bike segments of a triathlon. Using the American College of Sports Medicine metabolic equation for running, on average, VO2 would have been predicted to be about 35.5 ± 7.0 ml·kg·min-1 (ACSM, 2013) which is only slightly lower than the values we observed during running without a wetsuit (38.9 ± 7.1 ml·kg·min-1). This seems reasonable given the RPE reported by participants (10.4 ± 1.7, 6-20 point scale) and is indicative of submaximal effort for the participants tested.

In three of the four conditions, participants were asked to run with the wetsuit. We considered that the weight of the wetsuit itself influenced the physiological cost of running since the relationship between body mass and VO2 is well established (Bergh et al., 1991) as well as added mass to a runner (Saunders et al., 2004). In general, VO2 has been reported to increase about 1% for every kilogram added to the trunk region (Saunders et al., 2004). In the present experiment, the wetsuits weighed 0.93 ± 0.05 kg dry. We conducted an additional statistical analysis using VO2 data normalized to total weight (i.e., body weight plus wetsuit weight) as the dependent variable. From that analysis, the statistical outcome was identical as compared to VO2 normalized to body weight only. Thus, it seems that the changes in VO2 between conditions are related more to changes in the running style vs. added weight.

To gain some insight into the mechanics of running between conditions, we measured and examined SF. On average, participants used a 1-3% faster SF while wearing the wetsuit (either halfway down or fully up). Although large changes in SF (e.g., 10-20%) can influence VO2, small changes less than 5% may not negatively influence VO2 (Mercer et al., 2008). Interestingly, it was reported that step frequency increased about 2% when upper body movements were restricted (Arellano and Kram, 2014). Although we did not measure upper body movements, it seems obvious that carrying the wetsuit would influence the arm swing. However, less obvious is the influence of wearing the wetsuit halfway down or fully up on the arm swing and any further potential negative effects on VO2. Interestingly, participants selected the same preferred speed for each condition. Additional research is needed to understand the influence of wearing the wetsuit on upper extremity kinematics as well as on SF.

From a competitive perspective, an athlete may want to consider taking the wetsuit off once exiting the water and carry the wetsuit or to wear the wetsuit fully up until the transition area is closely approached and then take the wetsuit off. Anecdotally, it is interesting to note that triathletes typically work to take the wetsuit off halfway while running from the swim exit to the bike. This makes sense since an athlete would not be moving if he/she either took the wetsuit off immediately exiting the water or waiting until reaching the bike.

Since there are no data on the physiological cost of triathlon transition, our approach was to determine the running economy while not wearing a wetsuit, wearing the wetsuit half way down, wearing the wetsuit fully up and carrying the wetsuit. Another experimental approach would be to measure VO2 while an athlete exits the water and transitions to the bike. However, it was important to first know running economy while running at a steady state before including energetic cost of taking the wetsuit off. It seems beneficial to measure VO2 in the field during transitions. Based upon the results of our experiment, it seems to make sense to delay taking the wetsuit off since the greatest VO2 was while running with the wetsuit halfway down.

Furthermore, another approach would be to determine the influence of different transition strategies on subsequent cycling and/or run performance. From our results, since the difference in VO2 between wetsuit conditions was less than 3%, it does not appear that the strategy to wear/carry the wetsuit would have a major impact on subsequent performance. Nevertheless, that small difference may be important for the elite athlete vying for an overall finish place.

It is understandable that triathlon research has focused on energetic cost and biomechanics of each segment of a triathlon since the large majority of the race time is determined by performance in these segments. However, it is important to recognize the influence of energetic cost of completing the transitions not only from a time-performance perspective, but also from the perspective of estimating caloric intake during a race. For example, some events have athletes running 1 km between the swim exit and bike mount. Even though a race may be categorized based upon segment distances (e.g., a 140.6 Iron-distance event consists of 2.4 miles of swimming, 112 miles or biking and 26.2 miles of running), athletes do not always have specific distance information of transition areas. From the results of the present experiment, decisions such as when and how to take off the wetsuit may have an influence on the energetic requirements of completing a triathlon. Albeit the transition cost is small compared to the entire event, it does seem important for athletes, coaches and race directors to consider strategies to reduce the energetic cost of running with the wetsuit.

In designing the experiment, we considered what order the conditions were presented to participants. Since each condition lasted 5 minutes, the minimum run time (without a warm up and testing of preferred speed) was 20 minutes. The specific order of conditions (i.e., NWS, WScarry, WSfull, WShalf) used was for logistic purposes when considering the time needed to take a wetsuit off and/or put it on if the order was randomized. Given the set order, we were concerned about fatigue. However, time was provided between conditions as needed and, qualitatively, subjects did not present as being fatigued at the end of testing. Furthermore, we tested athletes running in running shoes since we wanted to record VO2 during steady state running and we were concerned about minimizing the risk of injury due to the total run time (~20-30 minutes including a warm-up and a cool-down) barefoot. There are likely differences in VO2 during running barefoot vs. with shoes on, however, given the repeated measures design of the study, the difference should be consistent.

Furthermore, anecdotally athletes may leave footwear at the swim exit depending on the length of transition and condition of the running surface from the swim exit to the bike area. Related to this, we had subjects self-select a speed that could be sustained for an endurance run so that we could measure steady state physiological cost during running. It may be beneficial to record energetic cost (both anaerobic and aerobic) of running at faster speeds over shorter distances.

It is important to recognize that we did not measure the thermoregulation response to running in a wetsuit – this seems to be an important piece to consider since the wetsuit functions to retain heat even during running on land. It may be that any negative influence running in a wetsuit has on VO2 is offset by the advantage of taking the wetsuit off to avoid any additional heat load placed on the body.

Race participants have many factors to consider when putting together a race strategy. Not only are they focused on training for each segment, many participants practice the transition between segments. In line with the present research, it seems important for a race participant to consider when to take a wetsuit off as part of training and race strategy – especially when the swim to bike transition distance is long. Although anecdotally it is common for participants to take the wetsuit off halfway while running from the swim exit to the bike, participants may want to consider taking the wetsuit off entirely upon exiting the swim (if this is logistically possible). However, that decision should be made based upon how easy it is to remove the wetsuit entirely since time may be saved by removing the wetsuit halfway while running towards the bike vs. being stationary to take the wetsuit off. Another important aspect of this research is that the participant may need to account for the energetic cost of completing the transitions. For example, based upon the data from the present study, participants would have energetic cost of about 85-93 calories to complete a 1 km transition run. Although this is only a small percent compared to the calories used during any of the race segments, it does seem important for an athlete and/or coach to consider this caloric cost when designing a race nutrition plan.

In our study, it is concluded that running with the wetsuit half-way down was the most costly in terms of VO2, HR and RPE vs. running while carrying the wetsuit or wearing the wetsuit fully up. From a practical perspective, the difference in energetic cost between conditions is small so the race participant should consider which strategy of removing the wetsuit bests suits him/her individually.

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