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Evaluation of Triathlon Suit Characteristics Relevant to Thermophysiology of an Athlete †

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Abstract: The thermophysiological function of clothing influences athletic wellbeing and performance, particularly in outdoor endurance activities such as triathlon. However, there is very little existing research on the performance of triathlon suits relative to thermophysiological function of the wearer. This pilot study provides a benchmark for triathlon suit performance and insights into improving the suit design and material engineering. The study assessed the thermal and breathability attributes of 6 triathlon suits and concluded that while both of the attributes were similar overall, they varied in different body zones due to different design, construction and materials. Local thermal and evaporative performance were affected by fabric construction; double fabric layering in the stomach panel; the number, size, shape and material structure of rear pockets; cycle crotch pad size, shape and thickness; and panel design. The results of this study show the importance of garment design, construction and materials for the best thermal and evaporative resistance attributes of sportswear.

Keywords: triathlon; triathlon suit; thermal attributes; breathability; thermal resistance; evaporative resistance

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1. Introduction

Modern triathlon is an endurance sport that consists of a multiple-stage competition involving swimming, cycling, and running in consecutive order to challenge the stamina of its participants, much more than swimming, cycling, or running alone [1,2]. At Olympic triathlon race distance the event comprises 1.5 km swimming, 40 km cycling, 10 km running, whereas the Ironman triathlon race distance is 3.8 km swimming, 180 km cycling, 42.2 km running [3].

The triathlon suits worn during the event play a key role in supporting the performance of the athlete and facilitate fatigue recovery by providing engineered support and interface pressure on targeted sites of the athlete's body [4]. Triathlon suits are designed to remain in close contact with human skin and the functional performance of the suit is determined by complex interactions between multiple factors, such as fabric structure and physical properties, mechanical properties, heat and moisture transfer properties (relevant to the thermoregulation of human body), the size and shape of the body to which it is applied, and the corresponding dimensions of the triathlon suit. Further, the levels of physical exertion, and therefore a metabolic output of the athlete, as well as ambient environment play a role. These complex factors are known as range of physiological, psychological and physical variables and their interactions with environment and the wearer determine the comfort status of a human [5,6].

Triathlon is considered a summer sporting pursuit, and events are commonly conducted in high temperature and humidity environments [7]. Water temperature can range between 14 °C–28 °C during the swimming leg and the ambient temperature could be 32 °C [3,8] or greater during the running leg stage when the athletes are usually suffering from fatigue and are dehydrated [9]. As a result of these extreme conditions, body temperature rises considerably due to high metabolic rates, with the high potential of heat stress occurring, which will not only hinder the athlete's performance but could result in illness [10,11]. Therefore, triathlon suit must support thermoregulatory processes of the body in these hot and often humid conditions.

In this context, Troynikov and Ashayeri, (2011), evaluated 3 commercially available triathlon suits one of base level and 2 specialized suits to assess their thermophysiological comfort performance using 20 zone thermal manikin Newton. The study demonstrated that the dry thermal resistance delivered by the suits varied by body zone, with the stomach, chest and shoulders showing highest results. Further the study concluded that physiological comfort properties of triathlon suits are determined by both the fabrics and materials used and also the design and construction of the garments. The authors suggested that by altering the design, material selection and construction of the suits it is possible to improve the thermophysiological function of the triathlon suit overall as well as in targeted body zones [12].

At present, numerous brands are offering triathlon suits with little scientific and engineering evidence supporting their use or choice of particular brands [12]. Further, there is no research on the evaluation methodologies of thermal management characteristics of triathlon suits currently available in the market after Troynikov and Ashayeri, (2011) study. This is a pilot study that provides a benchmark for triathlon suit performance in standard testing conditions. The fact that there is currently a dearth in triathlon suit comfort research justifies the need to create a baseline study before embarking on further studies that include changing ambient conditions such as temperature, humidity and wind speed. Further, as many material studies are conducted using standard conditions, a study of triathlon suits using standard conditions provides an opportunity to compare material performance and the effect of garment design and panelling on comfort properties. Therefore, the present study was aimed to investigate commercially available triathlon suits for their performance attributes relevant to the physiological comfort of the competing athlete in order to further knowledge in this domain.

2. Experimental

For the present study, 6 commercially available suits were investigated for their performance attributes relevant to thermal comfort of the wearer. All suits had negative body fit, were of the same size and had body zoned design. However, the suits varied in design features with differences in rear pocket design; stomach panel design; and shaping of various panels such as the back and shoulders regions. To determine the thermal and breathability characteristics, thermal and vapour resistance (I_T and R_{eT}) of the suits were determined at different sites and compared using 20 zone thermal manikin Newton (Figure 1). In addition, the results for the suits were also compared with those of an unclothed body to determine the relative increase in potential thermal discomfort imparted by each suit.

Figure 1. Manikin in triathlon suit B.

3. Materials and Methods

3.1. Materials

Suits comprised of up to three different fabrics (Table 1).

Table 1. Experimental triathlon suits.

Triathlon Suit	Fabric Composition *
Suit A	Fabric 1: 64% Polyester, 36% Elastane Fabric 2: 56% Nylon, 44% Elastane Fabric 3: 77% Nylon, 23% Elastane
Suit B	Fabric 1: 75% Nylon, 25% Elastane Fabric 2: 88% Nylon, 17% Elastane
Suit C	Fabric 1: 68% Nylon, 32% Elastane Fabric 2: 84% Nylon 16% Elastane Fabric 3: 83% Nylon, 17% Elastane
Suit D	Fabric 1: 80% Nylon, 20% Elastane Fabric 2: 80% Nylon, 20% Elastane
Suit E	Polyester/Elastane
Suit F	Polyester/Elastane

* Fabric composition as given by manufacturer label.

3.2. Methods

For the present study, the manikin [13] was operated in constant skin temperature (CST) mode. Temperature of each zone was set at 35 °C during each experiment. Ambient temperature was set at 23 °C with 50% relative humidity (RH) during assessment of thermal resistance of experimental ensembles. For the determination of vapour resistance, ambient temperature was set at 35 °C i.e., same as the skin temperature of manikin, with 40% relative humidity (RH) to ensure that there is no dry heat loss during these tests and only vapour resistance would be measured. Air velocity in climatic chamber was controlled and maintained at no greater than 0.20 m/s (i.e., negligible) during both experiments.

To ensure direct comparison, a group "tri suit" (TS) comprising the manikin zones covered by triathlon suit when dressed was created to enable determination of thermal and evaporative resistance of the suits. In this group the zones are: upper arm, chest, stomach, hips, thighs, shoulders and back (Figure 2). In addition, as the suits had differences in fabric composition, construction and design, I_T and R_{eT} of each individual zone were also determined, as differences in results of these individual zones may provide opportunity for improvements in fabric composition, structure and also in garment design.

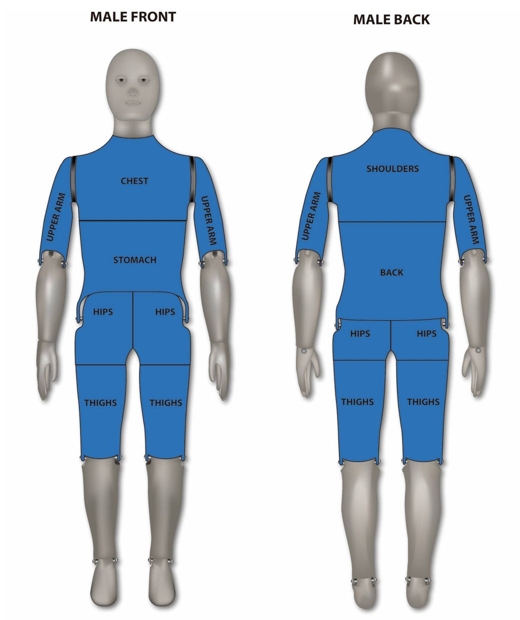

Figure 2. Manikin Group TS and individual zones.

Calculations of total thermal resistance values (I_T) including thermal resistance of boundary air layer (Ia), were carried out in accordance with the corresponding ASTM F1291-10 using parallel method [14]. Total evaporative resistance (R_{eT}) including evaporative resistance of boundary air layer (Rea), was calculated in accordance with the corresponding ASTM, F2370-10 using parallel method [15].

Each experiment was repeated three times and mean values were presented using bar charts with error bars indicating the standard deviation. To determine the statistical significance of the differences between the mean I_T and R_{eT} analysis of variance (ANOVA) was applied [16].

4. Results and Discussion

Figure 3 shows that the I_T of all triathlon suits is 20–30% higher compared to the I_T of nude manikin in group TS ($p = 0.00 < 0.05$). This indicates that the thermophysiological impact of the suits has an important effect on the athlete.

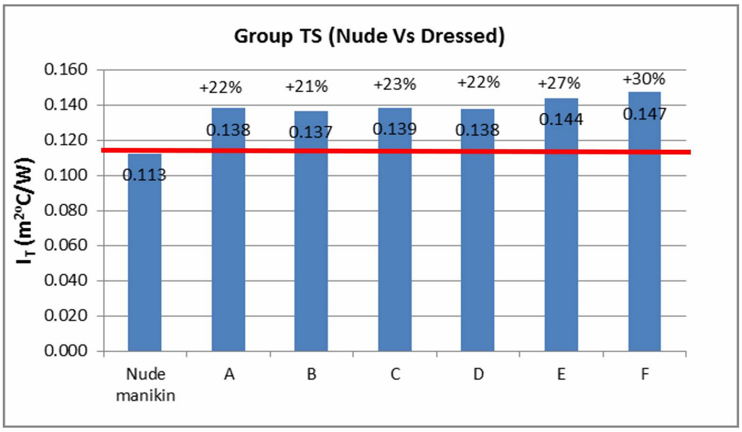

Figure 3. IT of triathlon suits and nude manikin in Group TS.

When results of each suit are compared with each other, they show that I_T of the triathlon suits have some differences in thermal resistance. Triathlon suits A, B, C and D show lower I_T than those suits E and F.

For example, the suit A has an I_T 6% lower than the suit E and F which is statistically significant ($p = 0.03 < 0.05$). In terms of thermal resistance, with this lower result it could be expected that the overall physiological impact of suit A would be less than suits E and F for the wearer.

The results (Figure 4) show that suit A has the lowest I_T for chest and shoulders, for example, 14–18% lower than D ($p = 0.00 < 0.05$), due to differing body zone design and construction of the suits.

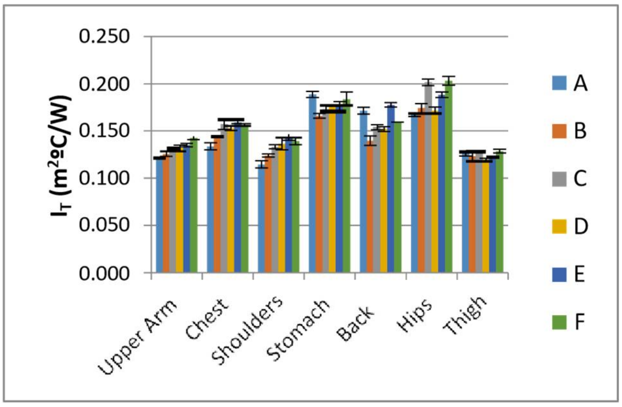

Figure 4. IT of triathlon suits by zones.

However, in suits where design features result in double layering of fabrics in the stomach and back zones, suit A shows the highest results, for example, 6–13% higher than suit D which only has double layering in the rear pocket panel ($p = 0.00 < 0.05$). Further, suit E showed 15% higher I_T in shoulders than suit B and is statistically significant, which could be due to differences in fabric structure. Thermal resistance of suit D is the lowest at thighs compare to the other triathlon suits. The variation in I_T of all suits at thighs ranges between 4–6% which is considered statistically insignificant.

In the hips zone where the influence of the cycle crotch pad is determined, suit D showed the lowest thermal resistance compared to the other suits due to the thinner design and smaller size of the pad.

Further, suit C and F demonstrate 17% higher I_T ($p = 0.00 < 0.05$), compared to suit D. Suit E showed 7% lower I_T than C and F ($p = 0.02 < 0.05$).

The R_{eT} results of triathlon suits (Figure 5) show 16–27% higher compared to the R_{eT} of nude manikin in group TS ($p = 0.00 < 0.05$), which indicates that the thermophysiological impact of the suits may have a substantial negative effect on the athlete.

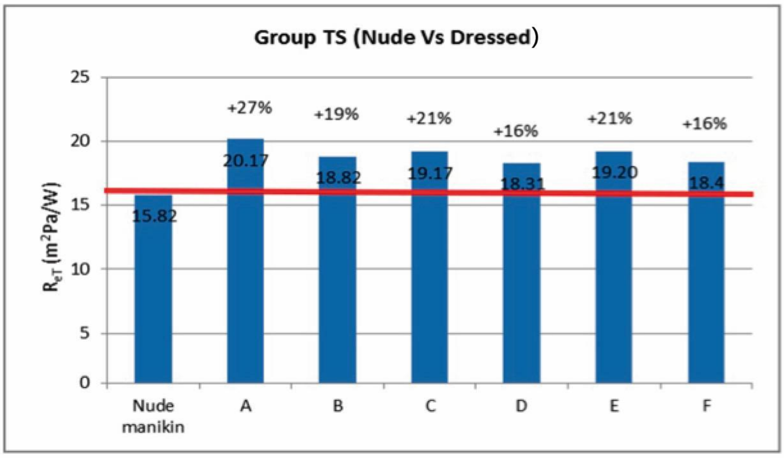

Figure 5. R_{eT} of triathlon suits and nude manikin in Group TS.

The expected overall thermal impact of suit A is the highest among all suits compared to nude manikin in group TS, with suit B, D and F adding the lowest physiological impact compare the nude manikin for group TS.

Results of Group TS for the suits (Figure 5) show that R_{eT} of the triathlon suits are similar overall. (R_{eT} of suit A is 6% higher than suits B, D and F, statistically significant $p = 0.03 < 0.05$. R_{eT} of suits A, C, and E is statistically same.). These results indicate that, in terms of the evaporative resistance of these suits, it would be reasonable to expect that the overall physiological impact of these triathlon suits would be similar for the wearer. Figure 6 shows a comparison of results for the individual zones of each suit. Suit A shows higher total R_{eT} than D in some zones, for example, 15% higher ($p = 0.00 < 0.05$) where design of the stomach panel has double layering of fabrics in the stomach zone. However, in terms of the chest, back and shoulders zones the R_{eT} results are similar for these suits.

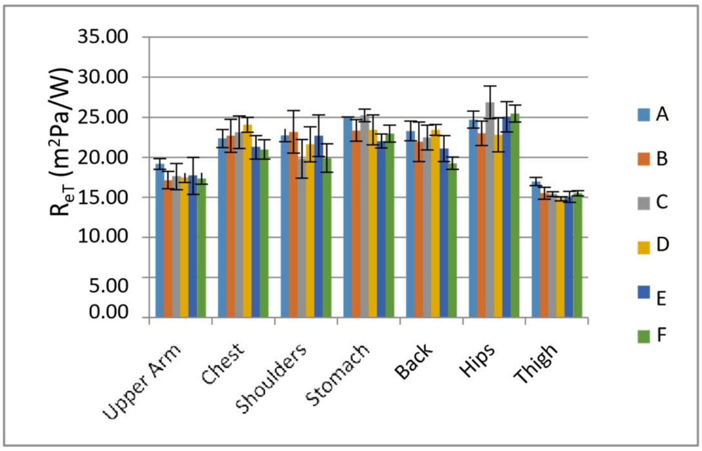

Figure 6. R_{eT} of triathlon suits by zones.

Suit B and E show similar results for all zones except the back zone, where suit B has 16% higher R_{eT} (Significant $p = 0.00 < 0.05$). Both suits have 2 rear pockets; however, suit E has mesh inserts which may provide less resistance to evaporative transfer. Results for suits C and F are similar, with suit C showing 10% higher R_{eT} in stomach (i.e., double fabric layering in stomach panel overlap) and chest zones. At thighs all suits show similar R_{eT} to each other except suit A which is higher compared to other suits.

At hips suits B and D show the lowest and similar R_{eT} to each other. Suits A, E and F show similar R_{eT} to each other and 8% higher than B and D suits at hips.

5. Conclusions

Analysis of the suits shows that in some cases, their performance overall is similar, however, when individual zones are evaluated differences in performance become more apparent, indicating that garment design, construction and fabric differences have an influence on the performance of the suits in particular zones. The suits comprise numerous differing design and construction elements, such as different panelling, material types and constructions within various zones of the garments. For example, some suits have full open zips at the front with an overlap in the stomach region, resulting in double layering of the fabrics in this area, whereas other suits have closed end full zips, with no resultant bodice overlap and therefore single fabric layering. It is reasonable to expect that having double fabric layering in some parts of the garments will adversely influence thermal and evaporative resistance performance.

Further, all suits have differing rear pockets, such as the number, size, shape and material construction, which will result in varying thermal attributes in this area. It is recommended that garment design features of all suits should be assessed, such as the stomach and back panel zones, to determine whether design changes can improve thermal regulation and breathability performance.

In addition, the size, shape, thickness and density of the cycle pads differ between garments, which can also influence thermal attributes. However, further investigation into the construction of the pads would be needed to clearly determine the significance in performance of the pads.

The fabrics used in each suit are also different in some elements; for example, construction. A number of suits comprise of fabrics of mesh or mock eyelet construction, which perform better than plain jersey or tricot constructions in some cases and can positively influence suit performance by reducing thermal and evaporative resistance.

However, it was not possible fully examine all fabrics of each suit for the present study, so a more detailed analysis of the triathlon suit fabrics will provide greater insight into possible improvement opportunities in suit performance.

The results of this study show that it is important to consider garment design, construction and materials in engineering of functional sportswear. This study provides triathlon garment manufacturers and product developers of performance apparel with insights into the influences of garment construction and material differences on performance relevant to thermophysiological comfort. Finally, this work underpins future studies where inclusion of different ambient conditions can provide further evidence of suit performance in various conditions and additional insights into improving the suit design and material engineering.

Conflicts of Interest: The authors declare that they have no conflict of interest.

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