

A first look into the influence of triathlon wetsuit on resting blood pressure and heart rate variability

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ABSTRACT: The purpose of this study was to investigate the effects of wearing a wetsuit on resting cardiovascular measures (blood pressure (BP), heart rate variability (HRV)). The influence of position (upright, prone) and wetsuit size were also explored. Participants (n=12 males, 33.3±12.1 years) had BP and HRV measured during six resting conditions: standing or prone while not wearing a wetsuit (NWS), wearing the smallest (SWS), or largest (LWS) wetsuit (based upon manufacturer guidelines). Heart rate was recorded continuously over 5-mins; BP was measured three times per condition. HRV was represented by the ratio of low (LF) and high (HF) frequency (LF/HF ratio); mean arterial pressure (MAP) was calculated. Each dependent variable was analyzed using a 2 (position) x 3 (wetsuit) repeated measures ANOVA ($\alpha=0.05$). Neither HRV parameter was influenced by position x wetsuit condition interaction ($p>0.05$) and MAP was not influenced by position ($p=0.717$). MAP and LF/HF ratio were both influenced by wetsuit condition ($p<0.05$) with higher during SWS than NWS ($p=0.026$) while LF/HF ratio was lower during SWS compared to NWS ($p=0.032$). LF/HF ratio was influenced by position being greater during standing vs. prone ($p=0.001$). It was concluded that during resting while on land (i.e., not submerged in water), wearing a small, tight-fitting wetsuit subtly altered cardiovascular parameters for healthy, normotensive subjects.

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INTRODUCTION

Triathlon is a sport that combines swimming, biking, and running into a single event. Typically, the swim portion of the event is first and followed by bike and run segments, respectively. Recently, there has been an increased interest in understanding factors related to death during a triathlon [e.g., 1, 2, 3]. The risk of death during a triathlon has been reported to be 1.5 per 100,000 participants [1]. In comparison, the risk of death during a marathon is 0.8 for every 100,000 participants [4].

Unique to triathlon is that the majority of deaths occur during the swim portion of the event [1, 2, 3]. For example, there were 43 event-related deaths from 2003-2011 with 30 of the deaths occurring during the swim portion of the triathlon [2]. However, to date there is no clear explanation for the deaths since a review of the available data yielded no relationship between triathlon experience, swim experience, swim start type (e.g., mass, time-trial, etc.), length of swim, or age, for example [2]. However, based on autopsies, Harris et al. [1] reported evidence of cardiac abnormalities in athletes who had died during the swim portion of an event. Moon et al. [3] further hypothesized that immersion pulmonary oedema (IPO) is a potential cause of death with cardiovascular comorbidity factors such

as left ventricular hypertrophy being a potential marker of susceptibility of IPO.

During triathlons, athletes typically wear a wetsuit mostly because of the benefits to swim performance and thermoregulation properties [e.g., 5-10]. However, the guidelines for selecting a wetsuit size are not uniform between wetsuit manufacturers and usually rely on height and weight data. Interesting, in a medical report issued on triathlon deaths, it was recommended that athletes be sure to use a “properly fitting wetsuit” to reduce the risk of death [2]. This recommendation seems to imply that an improperly fitted wetsuit may increase the risk of death during the swim portion of the event – even though there are no empirical data to support this hypothesis. Presently, there are no established criteria for determining a properly fit wetsuit and athletes rely largely on anecdotal information when purchasing a wetsuit. Thus, it seems logical to investigate the influence of wearing a wetsuit – as well as wetsuits of different sizes - on physiological parameters that may be related to risk of cardiac event during exercise.

There are absolute and relative contraindicators that should be considered in order to minimize the risk of a cardiac event during

exercise [11]. The presence of absolute contraindicators (e.g., recent myocardial infarction, unstable angina) would indicate that exercise should not be completed. In contrast, the risk:benefit ratio of exercise needs to be considered for relative contraindicators. These factors include hypertension (systolic blood pressure > 200 mmHg and/or diastolic blood pressure > 110 mmHg). Blood pressure is an easy parameter to measure during rest and it is not clear whether or not an improperly (e.g., too tight) wetsuit could negatively influence blood pressure in a way that it would be considered a relative contraindicator to exercise. Furthermore, Moon et al. [3] concluded that left ventricular hypertrophy may be a marker of susceptibility of IPO (and therefore risk factor for cause of death during triathlon) and hypertension is a common cause of left ventricular hypertrophy. Another measure that is easy to take during rest that may be related to risk of sudden cardiac death [12] is heart rate variability (HRV). Presently, there are no data on how simply wearing a wetsuit could influence HRV.

Therefore, the purpose of this study was to determine if wearing a triathlon wetsuit influenced resting blood pressure and HRV. We extended this work to also determine the influence of wearing an improperly fit wetsuit by selecting the smallest size (following manufacturer guidelines) that could be worn. Since athletes are in the prone position during swimming, measurements were taken during standing and prone positions (on land). It was hypothesized that, while on land during rest, wearing a wetsuit that was too tight would negatively influence blood pressure and/or HRV. If this hypothesis was retained, it would highlight the importance of determining properly fit wetsuit as well as establishing appropriate warm up routines prior to an event in order to address contraindicators to exercise. If the hypothesis was rejected, then the mechanism of swim related deaths should be more focused on physiological parameters during the swim (vs. before). In either case, however, it is important to recognize that swim related deaths are multifactorial and no single experiment or parameter is likely the root cause of risk of death during triathlon.

MATERIALS AND METHODS

Subject Characteristics. Twelve male participants (mass: 79.1 ± 5.1 kg, height: 178.4 ± 2.9 cm, age: 33.3 ± 12.1 yrs) volunteered for the research study. Participant inclusion criteria consisted of male adults ages 18-55, who self-identified as healthy, and who fit into at least 2 of the available wetsuits following manufacturer's guidelines for wetsuit sizing. The study was performed in accordance with the ethical standards of the Helsinki Declaration and was approved by the university Institutional Review Board. All participants gave signed informed consent before volunteering.

Instrumentation

Four sizes of the same model of wetsuit were used in this study (size-SMT M MT ML, full-sleeved model 4 mm:4 mm thickness). The manufacturer recommendations for weight and height for each size are presented in Table 1.

TABLE I. Manufacturer recommendations for selecting a wetsuit size.

| Size | Height | Weight |
|------|--------------|-------------|
| SMT | 5'8" – 6'0" | 160-179 lbs |
| M | 5'7" – 6'1" | 159-187 lbs |
| MT | 5'11" – 6'3" | 161-190 lbs |
| ML | 5'10"–6'4" | 177-198 lbs |

Note: SMT: small medium tall, M: medium, MT: medium tall, ML: medium-large.

Blood pressure measurements were obtained using a standard in-home wrist blood pressure monitor (Omron R7, HEM 637-IT, Omron, Kyoto, Japan) since the wetsuit was full sleeved. The blood pressure cuff was always placed on the skin (i.e., not on top of the wetsuit). This instrument has been validated according to International protocol [13]. This device records blood pressure oscillometrically with a measurement range of 0–299 mmHg. Systolic (SBP) and diastolic (DBP) blood pressure are displayed on a liquid crystal digital display. The inflation was performed using an electric pumping system and the deflation by an automatic pressure release valve. A standard size cuff applicable to a 13.5–21.5 cm wrist circumference was used.

Heart rate was measured using a Polar RS800CX heart rate monitor set to R-R interval mode (Polar Electro, Kempele, Finland) along with a chest-strap transmitter. This instrument has been previously validated for the accurate measurement of R-R intervals and for the purpose of analyzing HRV [14, 15]. A sampling frequency of 1,000 Hz, providing a temporal resolution of 1 ms for each R–R period, was chosen. The first 300 sec period of each recording was selected for analysis.

Procedures

Blood pressure and heart rate were measured during six conditions with all subjects completing all conditions. All conditions were considered resting measures. The six conditions consisted of manipulating posture (standing, prone) and 'wetsuit condition'. The wetsuit conditions were: no wetsuit (NWS) and then two different sized wetsuits (small (SWS) and large (LWS)). Using height and weight measures, each participant was assigned the two sizes of wetsuits. The LWS was the largest possible wetsuit of the four sizes available that the subject could fit into according to manufacturer recommendations. The SWS was the smallest size with which the subject could fit following manufacturer recommendations. For example, a subject who was 5'10" (177.8 cm) and 177 lbs (80.5 kg) would be assigned the SMT (SWS) and ML (LWS) sizes. In all cases, subjects always wore a wetsuit that was fit.

Wetsuit blood pressure

Participants were then assigned an order of conditions (NWS, SWS, and LWS). The order of measurement was counterbalanced such that each order was used for two subjects. For each of these conditions, resting measures were taken during standing and prone postures (for a total of six conditions per subject).

For each condition and position, heart rate was measured for 5 minutes while blood pressure was measured 3 times over the 5 min period at equal intervals between each measurement (t=100 sec, 200 sec, 300 sec). In accordance with the standards of measurement for blood pressure, participants held their left wrist, where the blood pressure cuff was placed, across their chest at the height of their heart [16].

Data Analysis

Data obtained from the heart rate monitor were transferred to Polar Pro Trainer 5 software (Polar Electro, Kempele, Finland) and then further analyzed using Kubios HRV Analysis Software (version 2.1, The Biomedical Signal and Medical Imaging Analysis Group, Department of Applied Physics, University of Kuopio, Finland). Heart rate was analyzed in both the time and frequency domains. The frequencies analyzed were: low (LF: 0.04-0.15 Hz) and high (HF: 0.15-0.4 Hz). LF and HF were reported in normalized units which represent the relative value of each power component in proportion to the total power minus the very low frequency (<0.04 HZ) component. Also included in the frequency analysis was the ratio of LF/HF. In the time domain, the standard deviation of all normal to normal (SDNN) R-R intervals was calculated as another measure of HRV.

Blood pressure data were further analyzed by calculating the Rate Pressure Product (RPP) and Mean Arterial Pressure (MAP). RPP was calculated as the average heart rate over the time period multiplied by the average systolic blood pressure. MAP was calculated using

systolic and diastolic blood pressure as well as heart rate ($MAP = DBP + [\frac{1}{3}(SBP-DBP)]$).

Statistical Analysis

Dependent variables (SBP, DBP, RPP, MAP, SDNN, LF, HF, LF/HF ratio) were each analyzed using 2 (position) x 3 (wetsuit) repeated measures analysis of variance (ANOVA) ($\alpha=0.05$) (SPSS Statistics 20 software; IBM, Armonk, NY). If an interaction was present, planned comparisons were run to compare the dependent variable between wetsuit condition (i.e., NWS, SMS, LWS) within a position. When 'wetsuit condition' was a main effect (and no interaction), simple effects post hoc test were run comparing the NWS to SWS and LWS.

RESULTS

The means and standard deviation values for each dependent variable for each condition are presented in Table 2. MAP was not influenced by the interaction of position and wetsuit condition ($p=0.706$), nor was it influenced by position ($p=0.717$). MAP was, however, influenced by wetsuit condition ($p=0.041$) with MAP for NWS less than the SWS ($p=0.026$) but not different than LWS ($p=0.268$). Systolic blood pressure was not influenced by the interaction of position and wetsuit condition ($p=0.260$). Furthermore, SBP was not influenced by position ($p=0.243$) but was influenced by wetsuit condition ($p=0.003$) such that SBP was greater while wearing the small wetsuit vs. no wetsuit ($p=0.004$) but not different between no wetsuit and the large wetsuit ($p=0.068$). Diastolic pressure was not influenced by the interaction or main effects of position and wetsuit condition ($p>0.05$).

RPP was not influenced by the interaction of position and wetsuit condition ($p=0.388$), nor was it influenced by wetsuit condition ($p=0.948$). RPP was influenced by position ($p<0.001$) with RPP

TABLE 1. Means and standard deviations for each dependent variable while.

| | Position | Wetsuit Condition | | |
|---------------------------------------|----------|-------------------|----------------|---------------|
| | | No Wetsuit | Small Wetsuit | Large Wetsuit |
| Mean arterial Pressure (mmHg) | Standing | 88.4 ± 7.4 | 94.6 ± 9.6* | 91.2 ± 8.1 |
| | Prone | 89.7 ± 6.8 | 95.5 ± 12.3* | 91.1 ± 8.7 |
| Systolic Blood Pressure (mmHg) | Standing | 114.0 ± 9.1 | 126.2 ± 12.3* | 120.6 ± 10.4* |
| | Prone | 120.0 ± 10.0 | 128.6 ± 18.0* | 122.0 ± 6.9* |
| Diastolic Blood Pressure (mmHg) | Standing | 75.6 ± 7.1 | 78.8 ± 10.2 | 76.6 ± 8.6 |
| | Prone | 74.6 ± 6.3 | 79.0 ± 10.2 | 75.6 ± 10.4 |
| Rate Pressure Product (bpmxmmHg) | Standing | 9698 ± 1312 | 9890 ± 1046 | 9417 ± 1316 |
| | Prone | 8009 ± 997 | 8013 ± 2664 | 8282 ± 1097 |
| High Frequency (HF) (n.u.) | Standing | 11.7 ± 6.5 | 18.7 ± 12.3 | 16.3 ± 9.5 |
| | Prone | 33.6 ± 14.1 | 39.5 ± 12.3 | 38.5 ± 16.7 |
| Low Frequency (LF) (n.u.) | Standing | 88.3 ± 6.6 | 81.4 ± 12.1 | 83.6 ± 9.5 |
| | Prone | 66.3 ± 14.3 | 60.3 ± 12.3 | 61.4 ± 16.6 |
| LF/HF Ratio | Standing | 10.864 ± 8.397 | 5.927 ± 4.711* | 7.529 ± 5.815 |
| | Prone | 2.500 ± 1.440 | 1.841 ± 1.169* | 2.093 ± 1.341 |
| Standard Deviation Normal-Normal (ms) | Standing | 55.5 ± 23.4 | 55.1 ± 18.6 | 54.4 ± 18.0 |
| | Prone | 73.8 ± 35.5 | 63.1 ± 34.3 | 59.2 ± 31.4 |

Note: * indicates SWS was different than NWS ($p<0.05$).

during prone position being less than during standing position ($p < 0.001$) regardless of condition (i.e., NWS, SWS, LWS).

HF was not influenced by the interaction of position and wetsuit condition ($p = 0.970$) nor was it influenced by wetsuit condition ($p = 0.071$). HF was influenced by position ($p < 0.001$) with HF in the standing position less than the prone position ($p < 0.001$) regardless of the wetsuit condition.

LF was not influenced by the interaction of position and wetsuit condition ($p = 0.974$), nor was it influenced by wetsuit condition ($p = 0.072$). LF was influenced by position ($p < 0.001$). LF while standing was greater than while prone ($p < 0.001$).

The ratio of LF and HF was not influenced by the interaction of position and wetsuit condition ($p = 0.80$). However, this ratio was influenced by position such that it was higher during standing vs. prone regardless of condition ($p = 0.001$). The LF to HF ratio was influenced by condition ($p = 0.028$) such that the ratio during SWS was less than the ratio during NWS ($p = 0.032$), while the ratio for NWS was not different than the ratio for LWS ($p = 0.140$). There was no significant difference in this ratio when comparing LWS and SWS ($p = 0.070$). SDNN was not influenced by the interaction of position and wetsuit condition ($p = 0.090$), nor was it influenced by position ($p = 0.127$) or the wetsuit condition ($p = 0.068$).

DISCUSSION

The most important observation of this study was that MAP was greatest and the LF/HF ratio was least when the smallest wetsuit was worn compared to not wearing a wetsuit. The increase in MAP is attributed primarily to an increase in SBP which was greatest for the smallest wetsuit condition. It was also determined that body position was shown to influence resting values – but, most importantly, there was no interaction between wetsuit condition and body position. Therefore, it seems that resting parameters can be taken in either position. Therefore, the hypothesis that wearing a too tight wetsuit influences physiological parameters at rest was retained.

Although there are no other published data on the parameters measured in this study while wearing triathlon wetsuits (either during resting or exercise), our resting data during the NWS condition are similar to other published studies. For example, MAP was 88.4 ± 7.4 mmHg in the standing position and 89.7 ± 6.8 mmHg in the prone position during NWS. Sesso *et al.* [17] reported similar resting values of MAP for men under the age of 60 years old. They observed the average resting MAP in this population to be 92.3 ± 6.7 mmHg, with the highest and lowest quartiles being > 97 mmHg and < 88 mmHg, respectively.

Normative resting values for RPP have also been established. Hui *et al.* [18] studied a population of 230 males who reported normative values of resting RPP to be 9635 ± 2159 . Another study [19] reported that resting RPP for males ages 19-34 years old was 8242.58 ± 1267.70 , while males ranging from 35-54 years of age were slightly higher at 9313.14 ± 1699.33 . In the present study, RPP ranged from 8009 to 9890.

Watanabe and colleagues [20] utilized similar methods to the present study in measuring and analyzing HRV. They compared resting HRV measurements between different postural positions, specifically: supine vs. prone, and prone vs. sitting. They observed that in the prone position compared to sitting upright, HF was greater while LF and LF/HF ratio were lower. The results from the present study are similar when comparing the prone position to a standing position for these same variables. Overall, the BP and HRV data that we recorded are comparable to published data.

Height-weight charts are common to use to determine wetsuit size. In the present study, that type of guideline was followed. That is, subjects always wore a wetsuit that fit as per – it is often the case that an athlete can fit in more than one wetsuit size based upon the height-weight chart. For our subjects, the majority of them fit adjacent sizes (e.g., SMT-M, M-MT, MT-ML) with seven subjects wearing the SMT during the SWS. We did not test the difference between actual wetsuit size and we did not quantify the specific construction difference between the sizes. For example, the difference between the MT-ML suits is likely in length of the suit vs. the tightness (two subjects wore this combination of suits). Nevertheless, we suspect that body type (e.g., mesomorphic, endomorphic, ectomorphic) and/or body composition may be parameters that need to be considered when setting criteria for a properly fit wetsuit. For example, in the current study there were individual subjects who did not have an increase in SBP while wearing the smallest wetsuit. This is an important observation for these main reasons: 1) too small of a wetsuit did not always negatively influence parameters such as blood pressure; 2) wetsuit fit may need to account for some other parameter(s) besides only height and weight; 3) the actual difference between sizes may be in length vs. tightness of the wetsuit.

It is important for athletes to be aware that body size can influence parameters like blood pressure if too small of a wetsuit is worn. For example, an athlete's weight may change dramatically during the course of a season (or off season) or may be influenced by hydration status leading up to a race. Another example is that an athlete may over-hydrate prior to a race start and weigh more (and have greater volume) and the wetsuit may temporarily be too tight.

Regarding hydration, plasma osmolality regulates vasopressin secretion, which in turn constricts blood vessels and increases blood pressure [21]. Varying hydration levels will change plasma osmolality. Therefore, hydration level and plasma osmolality may influence blood pressure measures in a study such as this. However, because this study utilized a repeated measures design and all measurements took place within an hour of each other, hydration status likely did not drastically differ among conditions. Also, all measurements were taken at rest (i.e., no exertion) and, qualitatively, all subjects appeared to be both well-hydrated and well-nourished. Nevertheless, future studies should examine the influence of hydration status on parameters such as blood pressure while wearing a triathlon wetsuit.

In this study, we did not assess how measurements changed over time. It may be that wearing the wetsuit for some time period (e.g.,

15 minutes) may reduce the influence on parameters such as BP and/or HRV. However, the multiple measures within each condition were inspected and it was qualitatively determined that measurements did not differ dramatically within each condition. That being said, it seems critically important to determine if a warm-up of some type (e.g., swimming, land exercises) can influence parameters like blood pressure and bring them back to non-wetsuit levels. This type of information may be helpful to the athlete in determining the appropriate amount of pre-race activity (and type of activity) to engage in as well as when to put the wetsuit on prior to an event.

Participants in this study were all male since an overwhelming majority of the victims in triathlon-related deaths have been male [2]. Thus, the results of this study cannot be generalized to females. Future studies are needed to determine whether a wetsuit has any influence on cardiovascular parameters in a female population.

It is important to recognize that we investigated only one wetsuit model and only tested parameters on land (i.e., not submerged or exposed to water) during resting conditions. Although there are many elements of wetsuit design that are common among different manufacturers, there are many elements that are unique. Nevertheless, the main point of this experiment is that wearing a wetsuit that tends to be small (but still within height-weight guidelines) likely negatively influences parameters such as blood pressure. In our experiment, this influence was subtle for healthy, normotensive subjects during rest. Although no empirical criteria exist for what is considered a 'properly' or 'improperly' fit wetsuit, it does seem intuitive that wearing a wetsuit that is too tight could cause blood pressure to increase. It therefore seems important that athletes, especially those who are diagnosed as having hypertension, consider parameters such as blood pressure when selecting a wetsuit size.

Resting blood pressure

It is important to understand contributing factors of triathlon-related deaths. We are not able to make any specific connections given the limitations of this experiment. There is likely no single factor that determines risk of death during triathlon. Additional work is needed to determine whether or not physiologic parameters explored in this study are influenced by wearing a wetsuit (of any size) during swimming, or after the wetsuit has become wet (or water entering inside the suit). Furthermore wetsuit elasticity will change with age of the wetsuit and how wetsuits are cut or sized is different between wetsuit manufacturers. We did not take into account the thermal effect of wearing a wetsuit on land. Taken together, there are many limiting factors that reduce our ability to generalize the results. Nevertheless, in this experiment, we focused on an easy to measure parameter (i.e., BP) during rest that is a contraindicator for exercise. Based upon an analysis of the results we report that a smaller, tight-fitting wetsuit increased resting values for MAP. Sesso and colleagues [16] established that MAP values >97 mmHg for men under 60 years of age are associated with increased risk for adverse cardiac events. In the present study, mean resting MAP values for both prone and

standing positions of the SWS condition exhibited values within this upper quartile (Standing = 99 ± 10 mmHg, Prone = 99 ± 13 mmHg). However, this was not the case for MAP during NWS or LWS conditions.

It is critically important to note that a tight-fitting wetsuit alone is not a risk factor for suffering a cardiac event. A tight-fitting wetsuit may, however, be a contributing factor when combined with all other known and documented logistical and environmental factors that are present during the swim leg of a triathlon event which include: anxiety and stress of competition, physiological stress of swimming, the large number of athletes entering the water simultaneously, cold and choppy water, and difficulty identifying and providing quick and effective medical care to struggling athletes [1, 22]. Although it seems obvious not to purchase too tight a fitting wetsuit, it is common to read anecdotal recommendations that if a suit does not feel too tight then it is too large. Overall, it seems important that athletes practice swimming in a wetsuit prior to an event and warm-up (on land and/or in water) before an event.

Heart Rate Variability

Shattock and Tipton [22] proposed a hypothesis for swimming-related triathlon deaths in that, upon immersion in cold water while engaging in physical activity, there may be a simultaneous activation of both the parasympathetic and sympathetic branches of the autonomic nervous systems; both of which regulate the cardiovascular system. This "autonomic conflict" is likely to result in a catastrophic dysrhythmia, leading to death. The autonomic response of the cardiovascular system can be measured by utilizing HRV analysis. The HF component has been shown to relate to the amount of parasympathetic activity, while the LF component is considered to be a marker of sympathetic activation [12]. Furthermore, the LF/HF ratio is considered to reflect sympatho-vagal balance and gives a good indication of sympathetic activity [23]. In the present study, it was observed that LF/HF ratio was reduced by wearing a small, tight-fitting wetsuit and that HF was significantly higher in the prone position. Reduction of LF/HF may occur in two main ways, either by increasing HF or by decreasing LF. Thus, when an individual wears a small, tight-fitting wetsuit and assumes a prone position in the water, this position alone may contribute to the autonomic conflict by increasing HF thus increasing parasympathetic activity. However, it is not known if the lower LF/HF ratio seen as a result of wearing the small, tight fitting wetsuit is a risk factor of sudden cardiac death since the research linking HRV (and components of) has been applied largely to a patient population with known disease or known cardiac events [24]. Furthermore, we did not control or measure breathing rate, which can influence HRV [12], since all measurements were taken at rest with no exercise intervention. Nevertheless, further studies should include both water immersion and physical exertion (e.g., swimming, dry-land warm up) to further evaluate the use of HRV to understand the risk of an adverse cardiac events during a triathlon.

CONCLUSIONS

Knowing what size wetsuit to purchase is challenging for triathletes. Anecdotally, many purchases are made on-line without even trying the wetsuit on. Although manufacturers often allow for exchanges at no cost, there is still a challenge to finding the right size wetsuit. For example, wearing the wetsuit on land may give a different sensation than wearing the wetsuit in the water. Also, an athlete's weight may change from the time the wetsuit is purchased. Based upon the results of this experiment, athletes (especially those with documented hypertension) should consider how a tight-fitting wetsuit could influence physiological responses such as blood pressure. The present study did not address the influence of wetsuit size on performance, which would be an insightful follow up study. Furthermore, only resting parameters were measured while on land (i.e., no submersion in

water and the wetsuit was worn dry) and only healthy, normotensive subjects were included in this study.

Of all the events during a triathlon event, the majority of triathlon-related deaths occur during the swim portion. The exact mechanism of these deaths remains unclear and the present study does not provide a direct mechanism of risk of death. It is concluded that wearing a too small, tight fitting wetsuit by healthy, normotensive subjects can subtly influence resting blood pressure measures. Further research would help in determining a time-efficient and effective warm up (on land or in water) for athletes to use before an event.

Conflict of interests: The authors are collaborating with the wetsuit manufacturer on other research projects.

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