Original Article (short paper)

Heart rate responses of a master athlete during ultra-endurance swimming

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Abstract - Aim: Swimming races outside swimming pools take place all over the world, but studies focusing on their physiological aspects are scarce. In fact, rules forbid any direct contact with swimmers during sanctioned events. This case report presents heart rate responses of a master athlete during an ultra-endurance open water solo swim and analyzes results based on a prior cardiopulmonary exercise test. **Methods:** The swimmer performed a cardiopulmonary exercise test on a treadmill, following a ramp protocol, with continuous electrocardiogram recording. The athlete performed a 36 km swimming race with continuous heart rate recording. Description of swimming heart rate accordingly to heart rate training zones and correlation analysis between HR and swim speed was assessed. **Results:** The athlete swam the 36 km event in 11 hours, 16 minutes and 15 seconds. Most of the swim time was spent in training zone 3 (55%), and only 2% of race time was spent in zone 5. Swimming speed (3.2 ± 0.7 km/h) failed to correlate with HR during the event ($r^2 = 0.1334$, $p > 0.05$). **Conclusion:** Although HR did not correlate with swimming speed it successfully indicated exercise intensity during this 36 km event. These results can be used in the preparation and monitoring of other solo long-distance swimmers.

Keywords: open water, swimming, heart rate, physiology, master.

Introduction

Swimming events taking place in rivers, lakes, oceans, channels, seas, bays or alike places are considered open water swimming (OWS) events. The only OWS Olympic event is the 10 km race, but the Fe'de'ration Internationale de Natation (FINA) officially promotes 5 km and 25 km of OWS events in its championships.

Other non-official OWS races take place all over the world[1]. Nevertheless, studies focusing on OWS, especially ultra-endurance swimming, are rare[2], and most of them focused on hypothermia[1,3,4]. Information about physiological responses during ultra-endurance swimming events is scarce[2,5], as rules forbid any direct contact with swimmers during sanctioned events.

Over the few published case studies[2-5] describing open water swimmer's physiological parameters during races, only one focused on heart rate (HR) response. Judelson, Bagley, Schumacher, Wiersma[5] described that a 24-years-old female swimmer kept a constant HR (148-155 beats/min) during the 32,2 km Catalina Channel swim despite fluctuation in perceptual stressors.

When studying HR responses to exercise, special attention must be paid to the athlete's age, as maximal HR tends to decline over the years. Although long-distance swimmers competing from 26 km to 35 km usually get to peak performance in the 4th decade of life[6], FINA considers swimmers who are older than 25 years-old as master athletes.

This case report presents HR responses of a master athlete with hypertension during an ultra-endurance open water solo swim and analyzes the results in the light of a cardiopulmonary exercise test.

Case Report

2.1. Participant

A 39-years-old male swimmer with three-year experience in OWS (weight: 83 kg; height: 1,70 m; body mass index: 28,72 kg/m^2) participated in the "do Leme ao Pontal Swim" in Rio de Janeiro's coast. He had hypertension for several years and was on losartan therapy (50 mg/day). Blood pressure levels have been well controlled in the last five years, and there was no end-organ damage.

Ethics

The investigation conforms with the principles outlined in the Declaration of Helsinki. The study was approved by the IRB of Universidade Iguaçu (CAAE 14088119.0.0000.8044). The patient signed informed consent before enrolment.

2.2. Cardiopulmonary exercise testing

Three months before the event, the patient underwent a maximal cardiopulmonary exercise test (Handymet, MDI, Brazil) following an incremental ramp protocol on a treadmill (ATL, Inbrasport, Brasil). The athlete star-

ted the exercise test at 6 km/h and 1% grade and reached maximal effort at 14,1 km/h and 1% grade. Minute ventilation (Ve), oxygen consumption (VO2) and carbon dioxide production (CO2) were registered every 10 s. Derived variables were calculated online (Handymet studio software, MDI, Brazil).

The ventilatory threshold was identified by the combination of the following methods[7]: at the point of the first upward inflection of the ventilation vs. time curve; at the beginning of a consistent increase in the ventilatory equivalent for O2 (minute ventilation/oxygen consumption) without a concomitant increase in the ventilatory equivalent for carbon dioxide (minute ventilation/carbon dioxide production); and at the beginning of an increase in expired oxygen fraction. The ventilatory threshold was considered as the point identified by at least two of these three criteria.

Respiratory compensation point was identified at the point of the second upward inflection of the ventilation vs. time curve, which was concomitant to the beginning of a consistent increase in the ventilatory equivalent for carbon dioxide (minute ventilation/carbon dioxide production). The maximum value of each variable during the final 30 s of the exercise was used as peak variables.

During the cardiopulmonary exercise test, 12-lead electrocardiogram was continuously recorded (Xcribe, Mortara, USA) and HR registered. HR limits for each training zone were calculated as percentages of anaerobic threshold's HR (158 bpm), as follows[8]: zone 1 ($\leq 68\%$: $\leq$ 107 beats/min); zone 2 (69% to 83%: 108-131 bpm); zone 3 (84% to 94%: 132-149 bpm); zone 4 (95% to 105%: 150-166 bpm); zone 5 (> 105%: > 167 bpm). Test results are shown in Table 1.

2.3. HR monitoring

We intended to monitor HR throughout the role swim with a Polar M Vantage watch (Polar Electro, Finland) positioned in the patient's left arm. Unfortunately, the watch's power went out in the last hour of the swim (Figure 1). Nevertheless, it recorded global positioning system data, HR and swim pace each second for 10 h, 16 min. and 35 s, leaving only the last hour unrecorded.

2.4. Do Leme ao Pontal swimming event

The athlete swam 36 km from Leme to Pontal (Figure 1), in Rio de Janeiro's coast, wearing only a swimming

suit, cap, and goggles. There was no use of insulating or buoyant material, nor any unnatural assistance to the swimmer. He started at 11:04 PM with a water temperature of 23 °C. At 30-min. intervals, the athlete rested (treading water) for less than one minute, drinking water or consuming bread, fruits, smoothies or solutions with caffeine, carbohydrate and electrolytes.

Statistical analysis

Continuous variables are reported as means and standard deviations. A simple correlation analysis between HR and swim speed was assessed. A two-sided P-value < 0.05 was considered significant.

All statistical analyses were performed with STATA 14.2 (StataCorp, Texas, USA).

Results

The athlete swam the 36 km "Do Leme ao Pontal swimming event" in 11 h, 16 min. and 15 s. Monitoring was available in the first 32,629 m of the swim, with an average of 62 strokes/minute and an average pace of 1'53"/100 m. Swimming speed (3.2 $\pm$ 0.7 km/h) failed to correlate with HR during the event ($r^2 = 0.1334$, p > 0.05; Figure 2).

There were 36993 recorded HR values (one value/second). Most of them were below the athlete's anaerobic threshold (n=34420, 93% of the time; Figure 3). The athlete has started the race with an HR of 98 beats/min and the mean recorded HR was 133 $\pm$ 19 beats/minute. Maximal recorded HR was 204 beats/minute. Most of the swim time was spent in training zone 3 (55%), and only 2% of race time was spent in zone 5 (Figure 2). The higher HRs recordings occurred from 5:45' to 6:48' and can be explained by the rough sea currents at this part of the race.

Discussion

The athlete became the 25th solo swimmer to successfully complete this event. To our knowledge, this is the first report of a patient with hypertension completing an ultra-endurance swim. Most cardiology guidelines agree that, in the absence of target-organ damage, stage-1 hypertension should not prevent athlete participation in competitive sport[9].

Previous reports used age-based equations to analyze exercise intensity[5,6]. Although practical, these formulas

Table 1 - Cardiopulmonary exercise test values from the participant, three months before the open water swim.

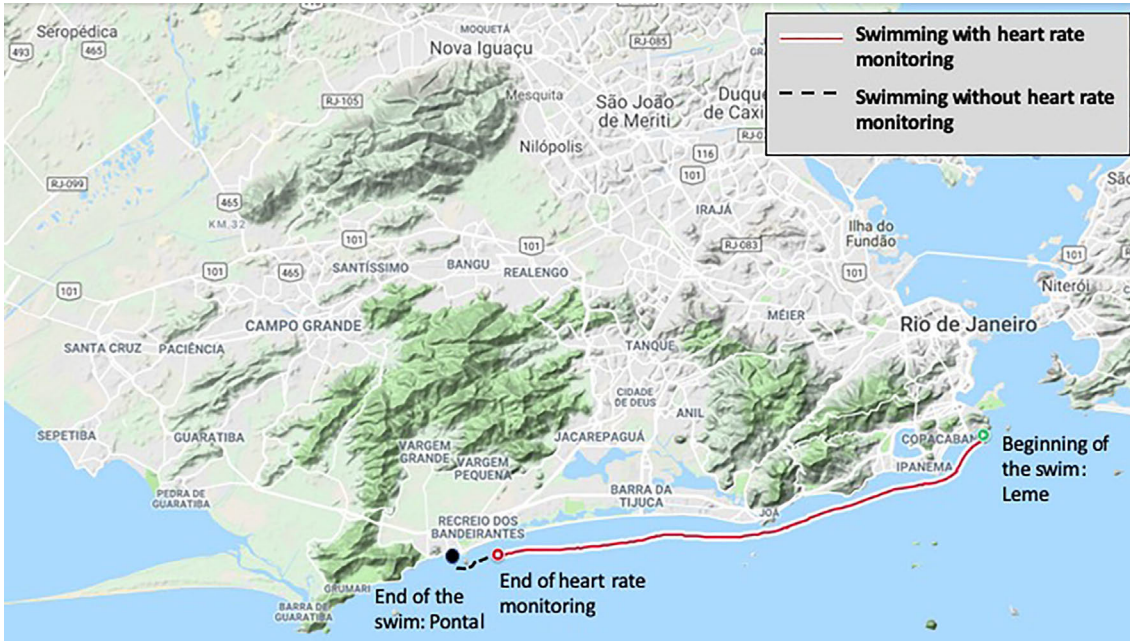| Parameter	Anaerobic threshold	Respiratory compensation point	Peak exercise
Heart rate (beats/min)	158	176	190
Oxygen uptake (mL/kg/min)	27.7	34.1	37.4
Oxygen uptake (%)	74	91	100

Figure 1 - Rio de Janeiro's coastal map showing global position system tracking of the monitored period.
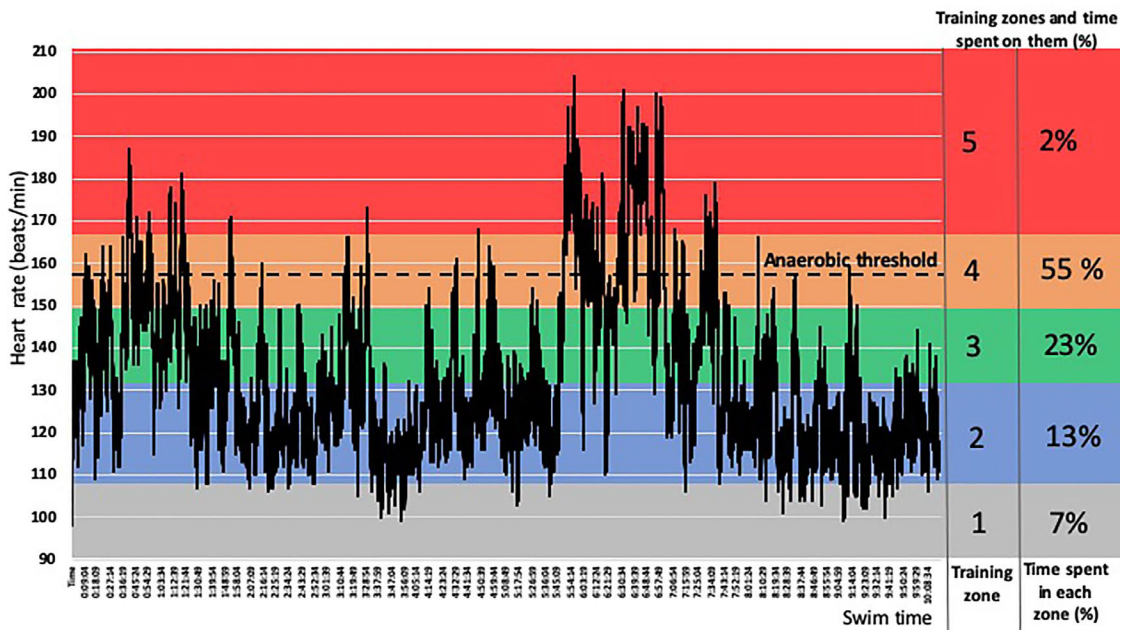

Figure 2 - Heart rate and swimming speed of the athlete during the event

may present errors and don't show the exact condition of the athlete. In the present study, we analyzed exercise intensity by comparison of recorded HR during the race and the HR from the cardiopulmonary exercise test, showing that aerobic metabolism was predominant during the event.

It is important to note that HR responses may differ accordingly to exercise modality. We have previously found no differences in maximal heart rate during progressive cardiopulmonary exercise tests performed on

cycle or arm ergometers[10]. Hauber, Sharp, Franke[11] assessed swimmers' HR responses to submaximal and maximal treadmill running and free swimming and found that despite peak heart rate and oxygen uptake are mode-specific, exercising at a given submaximal oxygen uptake elicits similar HR regardless of the mode of exercise. Thus, the study by Hauber, Sharp, Franke[11] validates the use of land-based determined target HR zones while swimming[11], as done in the present study.
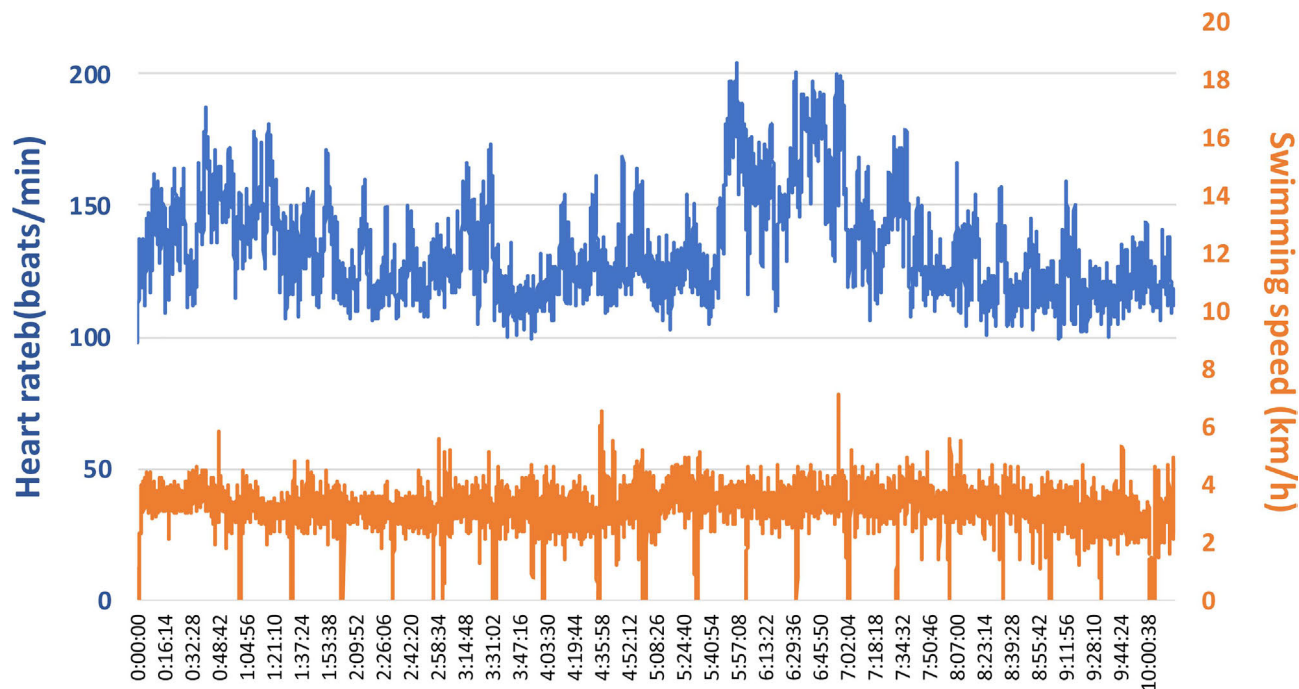
Figure 3 - Athlete's heart rate and heart rate training zones during the event.

Swimming speed was obtained from the variation in global position through time and could not account for ocean velocity and direction, which definitely influence swimming speed. Thus, depending on ocean currents, different levels of effort are needed to keep the same swimming speed[5] and this explains the lack of correlation between HR and swimming speed in our study.

Conclusion

This is the first report to continuously record HR of a master athlete with hypertension during an ultra-endurance swimming event. Although HR did not correlate with swimming speed it successfully indicated exercise intensity during this 36 km event. Most of the swimming was performed below the anaerobic threshold, indicating a predominantly aerobic event. These results can be used in the preparation and monitoring of other solo long-distance swimmers.

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