Car racing: in the heat of competition

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ABSTRACT

The present study discusses the role of heat as an additional risk factor for the accident that killed the pilot Ayrton Senna. The competition car racing is a biological challenge, a stressing situation from the physical and mental point of view. The maintenance of performance depends on the oxygen and carbohydrates availability, adequate hydration and constant internal temperature, between 37 and 38ºC. The dissipation of heat produced by the metabolism occurs through the increase on the cutaneous blood flow and sweat and maintaining brain temperature constant becomes a permanent problem. It was experimentally verified that the energy required to the racecar driving is comparable to a sport such as volleyball. During a car race, the individual is exposed to a hot microenvironment in the cockpit, sometimes reaching 50ºC, generated by mechanical and environmental sources of heat. The obstruction of the sweat evaporation by the racesuit results in humidity and personal discomfort, what leads to higher mental effort to drive the car. The anti-heat measures are adopted before the race, considering the nutritional state, hydration and specially the physical conditioning through adequate and regular aerobic exercises that enable increasing the work capacity and the heat tolerance, resulting in lower fatigue during the car racing. Another important procedure should be the previous acclimation of pilots to hot and humid environments. All efforts should be done to reduce the vehicle heating and to respect the warning flag system for the risks of hyperthermia. Finally, although Ayrton Senna was an individual with higher risk of developing hyperthermia, regardless other causes, it seems not to have elapsed sufficient time of race in order to produce metabolic heat capable to increase excessively the pilot's internal temperature in the environmental conditions of the autodrome in the day of his death.

EPIGRAPH

"At the end of the race and slowly finishing the honor lap, Ayrton Senna signaled desperately to the Toleman mechanics, who were located exactly at the way that lead to the reserved area"… "Peter Gethin and Brian Hart found him fainted, with his head over the steering wheel"… "Senna was laid on the grass. The ambulance, called by Gethin arrives with the reanimation equipment. The physician soon diagnosed complete exhaustion and determined absolute rest for at least one hour. The physician gave him a dose of Valium and only then allowed Ayrton Senna to talk. "As soon as I received the car with the full tank, I advised that it was incredibly heavy. It was impossible to drive. It was a constant effort to keep the car on the racetrack. The steering wheel almost did not turn and at each curve it seemed I was letting my arm go". Ayrton did not even see the front wing fly. He only felt a collision. "I wanted to fulfill the car race, my first in the Formula 1", justified (O Globo, 4/8/84).

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INTRODUCTION

Ten years after, Ayrton Senna's death remains arousing polemic. Many doubts about the episode still remain, some of them quite intriguing, once they have been extensively well documented(1). Among the causes of the accident, the role of the heat as an additional risk factor must be discussed, once the hyperthermia is indeed a problem for pilots in some conditions.

The situation experienced by Ayrton Senna in his first race at formula 1 clearly shows the biological challenge of piloting a speed racecar, a stressing situation from the physical and mental point of view. During the race, there is a great activation of several parts of the nervous system that need to be informed of the multiple indicators of conditions of the environment, the vehicle and the conditions of the organism itself. Large amounts of continuously renewed sensorial information are integrated in the brain in order for a perfect motor coordination to occur in the definition of each gesture to be performed. All this neurological coordination is influenced, of course, by the emotional state in which the pilot is found. This intense "biological computation" may be maintained for several hours without problems since some brain conditions are fulfilled: oxygen and carbohydrate availability, adequate hydration and constant internal temperature, between 37 and 38ºC.

The carbohydrate ingestion guarantees energy required to maintain brain activity. In rest conditions, before race, this human brain energy consumption corresponds to about 23% of all energy spent by the organism(2); in other words, the brain of someone as heavy as Ayrton Senna, with about 65 kg(1), would spend about 15 kilocalories per hour in order to simply remain lying down. The source of this substrate is the circulating glucose, whose regular level is maintained by the liver, which converts the stored glycogen, as it is required. A normal liver has around 500 grams of stored glycogen and each gram of this carbohydrate corresponds to four kilocalories; in other words, the glycogen stores would be around two thousand kilocalories. Imagining that only half of this energy was to be addressed to the brain, the glycogen stores would allow the normal brain activity for tens of hours. Therefore, the source of substrate does not seem to be a frequent problem for normal-glicemy formula 1 pilots properly fed before competition.

The brain oxygen supply is also a function rigorously controlled due to its vital importance. Any minimum reduction on the brain oxygen availability elicits reactions, from the increased respiration to the loss of conscience. In normal conditions, there is sufficient oxygen in the atmosphere and dissolved in blood and tissues, in such way that no voluntary physical effort such as driving a car, for example, is capable to reduce significantly the oxygen delivery to neurons, unless respiration or circulation are blocked. Therefore, oxygen availability should not be a common problem in car racing, except if there is an obstruction in the airways or respiratory problems.

On the other hand, as for the rest of the organism, about 80% of the energy spent in the brain functioning is converted into heat, which needs to be continuously dissipated, otherwise an increase on the brain temperature will occur, maybe resulting in brain dysfunction or unconsciousness or even in coma or death(3). The dissipation of the heat produced by metabolism occurs through the increase on the blood flow that penetrates the brain and removes the heat excess, transferring it into the skin. Therefore, maintaining the brain temperature constant is a permanent problem that should be monitored so precisely that must have been a determinant factor on the human brain development(4).

In physiological conditions, it is necessary to consider that any increase on the brain temperature (particularly at the hypothalamus) results in thermoregulatory responses proportional to the thermal stimulus in intensity and duration. In order to maintain the central body temperature constant, besides voluntary behavioral changes (to take clothes off or to seek for a shade, for example), dilation of the skin vessels occurs, thus increasing its blood content and the superficial body temperature. This blood flow redistribution from inside into the body surface results in higher thermal differences between skin and environment, what facilitates heat loss by radiation and convection when environment is found colder than skin. Furthermore, a higher sweat production simultaneously occurs that, if evaporated over the heated skin, also effectively removes the body surface heat(5).

However, the loss of water through sweat results in progressive dehydration, what may reach a limit in which the reduced blood volume becomes insufficient to maintain circulation, bringing risks to the individual's life. Thus, the adequate hydration before and during physical activities, especially in hot environments, is a basic concern for the health of athletes(6).

All adaptations mentioned above allow brain temperature to exhibits small variations even in face of great thermal challenges such as intense exercise in hot environments.

INSIDE THE COCKPIT

It has been experimentally verified that the energy required for driving a racecar ranged from 38.5 to 59.7 $mL.kg^{-1}.min^{-1}$(7); in other words, about 11 to 17 times as much compared to the rest metabolism, considered as 3.5 $mL.kg^{-1}.min^{-1}$ on average(8). Thus, the amounts of glucose and oxygen consumed and heat produced are relatively large in usual conditions, corresponding to the practice of sports such as baseball, football or basketball(7).

It is important to remind that Ayrton Senna presented exhaustion episodes in his career attributed to excessive physical effort as result of his attempt to finish races in unfavorable technical situations*. This suggests that, under some conditions, a given pilot may produce a heat quantity even higher than that observed experimentally.

During a car race, the individual is exposed to a hot microenvironment inside the cockpit, sometimes reaching 50ºC, generated by heat sources both mechanical (motor and transmission) and environmental (solar radiation and hot air mass). Therefore, the problem for a formula 1 pilot is to remove the body heat generated through the physical effort by controlling the car and to avoid heat absorption from the hot microenvironment.

The special cloth worn by pilots is capable to resist up to 700ºC during 30 seconds, what undoubtedly is an indispensable protection for survival in case of fire. Although it provides effective barrier against heat from motor and environment, the special racesuits also avoid heat dissipation because it blocks ventilation of most body surface, reducing heat loss by radiation and convection and the evaporation of the sweat produced by the pilot.

The blockage of the sweat evaporation results in 100% of humidity between skin and overalls and in personal discomfort, what leads to higher mental effort for driving the car. As the cloth gets soaked, the transference of heat from environment into the pilot's skin is increased, worsening the situation.

* In 1984 (O Globo 7/7/84) and in 1992 (Jornal do Brasil, 5/18/92).

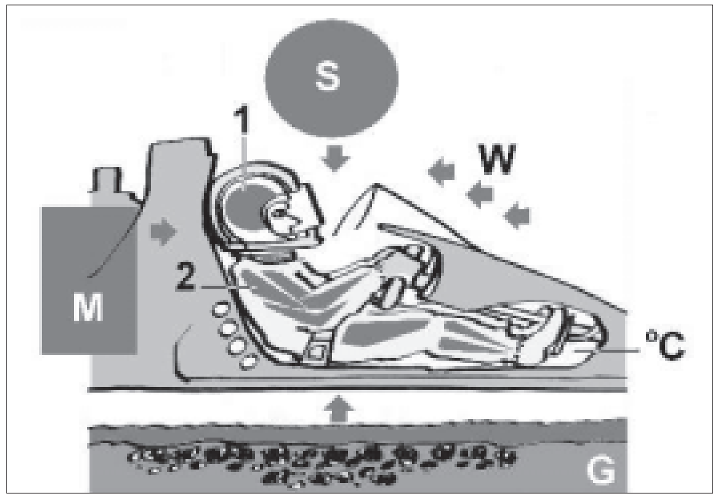

Fig. 1 – Diagram of the cockpit environment during race – External sources of heat: S, solar; M, mechanical; G, ground; W, air mass. Internal sources of heat: 1, brain metabolism; 2, muscular physical activity.

Data obtained from simulated races presented energy expenditure between 11 and 17 MET, what could require from 1.5 to 2 liters of sweat produced per hour in a microenvironment at 50ºC with the use of the typical overalls. These sweat rates (about 16 $g.m^{-2}.min^{-1}$) are comparable to the training of the Brazilian volleyball team in a thermo-neutral environment(9) and smaller that the highest rate ever registered (34 $g.m^{-2}.min^{-1}$) during a marathon(6). If these high sweat rates are maintained without adequate ingestion of liquids, the dehydration situation may occur, leading to the decrease on the circulatory capacity and consequently the decrease on the body heat removal capacity, what may anticipate the fatigue state.

The symptoms of heat accumulation in the pilot's body may start as a headache and dizziness. As the body temperature reaches 39ºC, the individual becomes even more disorientated with reduced motor coordination. If the internal temperature exceeds 40.6ºC (situation known as insolation or hyperthermia), it may lead to coma and to shock state and if the individual is not treated seriously, it generally leads to death(10).

THE PSYCHOMOTOR PERFORMANCE

Some studies have demonstrated that the hot environment generated by the motor increases the reaction time and produces higher incidences of driving mistakes(11). Laboratory observations also showed that the slight increase on the internal temperature (up to 0.6ºC) usually increases the vigilance level(12) and the physical performance(13).

On the other hand, the increase on the central temperature of 0.8ºC above normal values results in deterioration of cognitive and psychomotor performance, for example, in the eye-hand coordination and in the decision making. Studies performed in military pilots that could be compared to formula 1 pilots indicate that, as the heat stress is developed, there is a tendency for the pilot to reduce his attention to the center of the visual field, partly despising side occurrences(14).

In other words, in heat situations, the pilot would pay more attention to the main tasks to conduct his own car, while less attention would be addressed to the other moving vehicles. Besides, the body heat seems to reduce one of the most important cognitive abilities of the pilot, which is to anticipate and to perform correctly the movements required to overtake in a curve.

In short, one may conclude that if the transference of heat from environment or from the own vehicle into the pilots' body is increased, this condition may result in higher internal and brain temperature elevation, causing deterioration of the pilot's efficiency along the car race.

AVOIDING PROBLEMS WITH HEAT

With pilots

The measures against heat initiate long before race. The pilots should be considered as athletes[7] and submitted to medical examination within standards adequate to all other athletes[15].

As already mentioned, the previous nutritional state should provide plenty carbohydrate availability for the race. The pilots' hydration is one of the most important preventive aspects for them to present good cardiovascular conditions in order to endure the physical effort associated to heat. Generally, a good hydration state is reached with the ingestion of half liter of water two hours before competition in addition to volumes of water or carbohydrated electrolytic beverages equivalent to the volume of sweat lost each 15 minutes or whenever possible[16].

The physical conditioning obtained through regular aerobic exercises is adequate and vital for pilots to increase their cardiovascular work capacity, enlarging the available blood volume and the heat tolerance, resulting in less fatigue during the race. It is interesting reminding, for example, that Ayrton Senna joined regular exercises under the orientation of a personal trainer, although the declared purpose for the physical training was "to spend the adrenaline injected into blood during races"*.

Other important procedure should be the previous acclimation of pilots to hot and humid environments by regularly submitting them to the exposition to hot environments for the development of their heat dissipating mechanisms to develop (capacity to sweat and to dilate the skin vessels, besides higher fatigue tolerance in heat). In this context, the performance of at least 10 sessions of exercises in hot environments is a safe acclimation method[17].

It is known that individuals deprived of sleep exhibit lower thermoregulatory capacity[6], therefore, a good sleep quality prior to races should be guaranteed.

There are several drugs that may influence the thermoregulatory capacity and the use of any medication should take this possibility into account. Generally, all remedies that speed up the heart increase hydric losses (urinary or intestinal) or that inhibit sweat should be rigorously supervised.

Of course, it is inconceivable for a pilot the use of alcoholic beverages and illicit drugs of any type: the alcohol, besides the depressor effects on the nervous system, also induces dehydration. On the other hand, most stimulating drugs interfere on the thermoregulation system including the hyperthermia, which is one of the death mechanisms of some of them.

Finally, it would be ideal if during the race, methods capable to quantify continuously the mental fatigue indicatives were developed as measures of inadequate notion of time for the control of movements or the necessity of more prolonged stimuli for the responses, signals of reduction on the capacity of anticipation and more aggressive responses against vehicle or its equipments.

With vehicles

All should be done in order to reduce the exposition of vehicle to sun before the start moment, thus avoiding the absorption of solar radiation by the car's surface. A good ventilation in shade or even the use of refrigeration blisters should be provided for all parts of the vehicle except for those that must be pre-heated, as tires and lubricating systems.

The heat from the soil radiation under the vehicle, from the mechanical transmission system as well as from eventual friction of the car's bottom with the racetrack, should be avoided with the use of refractory ceramics and other resources of thermic isolation, what has been a concern of engineers yet not fully resolved.

In most sports there is a warning flag system for the risks of hyperthermia. This warning system is based on the measure of the air temperature, on the relative humidity and on the solar radiation intensity, consisting of a thermic stress index. There are stratified levels of risk in which a match or sportive competition may be allowed or not[18]. This system should also be obligatorily employed in car racing.

In short, there is a decrease on the psychomotor performance due to the increase on the internal temperature of pilots during a car race. One may assume that the reduction of factors that lead to the heat accumulation during competition must result in better performance and higher comfort for pilots.

CONCLUSION

Although Ayrton Senna had previously been victim of probable heat exhaustion in other occasions, in other words, an individual presenting higher risk of developing hyperthermia once again, the environmental conditions of the Imola autodrome, at the day of his death, were the typical end-of-spring conditions in a subtropical region[19], and those conditions corresponded to a low-risk environment for heat problems, between 20 and 28°C[1].

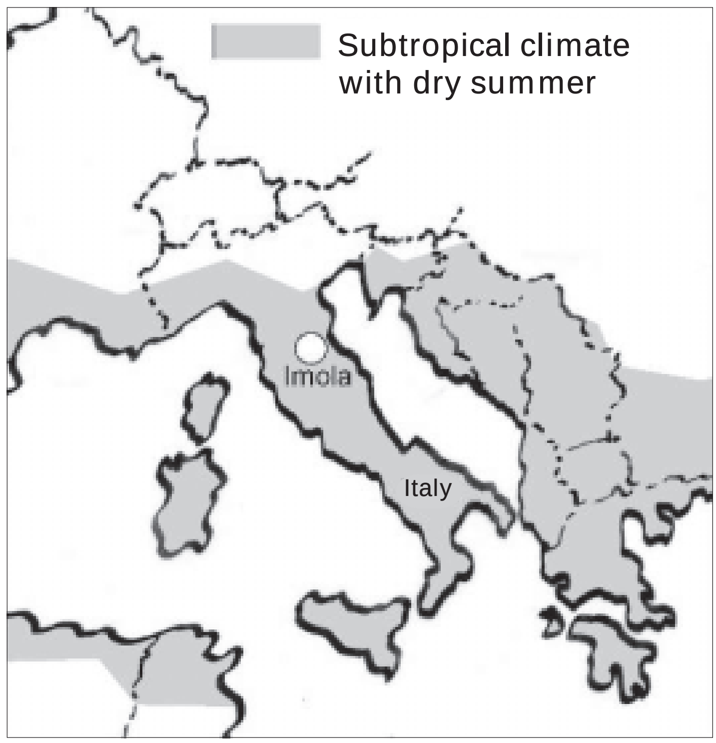

Fig. 2 *– Climatic localization of the Imola autodrome, Italy. Shaded region corresponds to dry-summer subtropical climate: Region located within latitude between 35 and 45° N and generally within longitude between 25 and 40° W (Viana, 1999) with effective temperature ranging from 0 to 10°C in winter and from 20 to 25°C in summer (Ayoade, 1986).*

Furthermore, the accident that killed Ayrton Senna occurred when the race was at the beginning: there was an accident at the start, the cars remained in movement, slowly behind the safety car during four laps, which lasted 16 minutes. The fifth lap was fast. At the beginning of the sixth lap, the accident occurred[1]. Therefore, there was not sufficient time of muscular activity in order to produce metabolic heat capable to increase excessively the pilot's internal temperature.

** Nuno Cobra in O Globo 2/26/84.

Finally, despite the hyperthermia consists of a usual risk factor for formula 1 pilots, especially when races take place in hot environments, an excessive increase on the body temperature does not seem to have contributed for the accident that, unfortunately, killed Ayrton Senna.

All the authors declared there is not any potential conflict of interests regarding this article.

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