Acute effects of heat on health variables during continuous exercise and their comparison with normal and cold conditions: A systematic review

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Summary

Background: There has been an increasing number of running practitioners in the last years. Although running activity involves several benefits for practitioners, it might also induce health problems when practicing under heat conditions.
Purpose: The main aim of this systematic review was to evaluate how high temperatures affect runner's health during continuous exercise.
Search strategy: The search for articles for this study was carried out in two different databases, Web of Science and Pubmed.
Study selection: The inclusion criteria were a) Studies that investigated the effects of endurance exercise, at least at 27º, on health variables, determining exercise intensity, indicating total time for exercise and presenting pre- and post-test results or compare with normal or cold conditions.
Results: 1336 articles were identified after the searching process. 333 runners were evaluated in fifteen articles that were included in the qualitative synthesis. High increases in heart rate, body and skin temperature, some urine and blood markers, blood pH, ventilation, rate of perceived exertion and sweat rate were identified during continuous activity under heat conditions, and also when comparing with normal or cold conditions. Lower values were found in body mass, eosinophil than those observed before the running activity. Lower values for oxygen consumption and plasma lactate may occur in hot conditions when comparing with normal conditions.
Conclusions: Studies analyzed conclude that an uncontrolled long-term activity in hot conditions may induce health problems related to high body and skin temperatures. Cooling strategies should be assessed after continuous exercise under hot conditions. In addition exercise in hot conditions produces greater increases in immune functions, heart rate, breathing stress, metabolic responses and rate of perceived exertion, also compared with normal and cold conditions.

Key words:
Heat. Endurance. Health. Hyperthermia.

Efectos agudos del calor sobre variables de salud durante el ejercicio continuo en comparación con condiciones normales y frías: una revisión sistemática

Resumen

Introducción: El número de corredores ha incrementado en los últimos años. Aunque la actividad de correr implica varios beneficios para los practicantes, también puede provocar problemas de salud cuando se practica en condiciones de calor.
Propósito: El objetivo de esta revisión fue evaluar cómo las altas temperaturas afectan la salud del corredor.
Estrategia de búsqueda: La búsqueda de artículos para este estudio se llevó a cabo en Web of Science y Pubmed.
Selección de estudios: Los criterios de inclusión fueron estudios que investigaron los efectos del ejercicio de resistencia, al menos a 27º, sobre variables de salud, determinando la intensidad y duración del ejercicio y se presentaron resultados previos y posteriores a la prueba o compararon con condiciones normales o frías.
Resultados: 1336 artículos fueron identificados después del proceso de búsqueda. 333 corredores fueron evaluados en quince artículos que fueron incluidos en la síntesis cualitativa. Durante la actividad en condiciones de calor, se identificaron incrementos elevados en la frecuencia cardíaca, la temperatura corporal y de la piel, algunos marcadores de orina y sangre, el pH sanguíneo, la ventilación, el esfuerzo percibido y la sudoración. Se encontraron valores más bajos de masa corporal y eosinófilos que los observados antes de la actividad de carrera. Valores más bajos de consumo de oxígeno y lactato aparecen en condiciones de calor cuando se comparan con las condiciones normales.
Conclusiones: Los estudios analizados concluyen que una actividad no controlada a largo plazo en condiciones de calor puede inducir problemas de salud relacionados con altas temperaturas corporales y de la piel. Además, el ejercicio en condiciones de calor produce mayores incrementos en las funciones inmunitarias, la frecuencia cardíaca, el estrés respiratorio, las respuestas metabólicas y el esfuerzo percibido, también en comparación con las condiciones normales y frías.

Palabras clave:
Calor. Resistencia. Salud. Hipertermia.

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Introduction

Nowadays there has been an increase in open running races where anyone can participate, even without a medical examination.

Endurance activity has several benefits on health according to a recent meta-analysis[1] that highlighted some advantages in body composition, resting heart rate (HR), maximal oxygen consumption (VO_{2max}), triglycerides or high density lipoproteins in sedentary people. Contrarily, the practice of running in hot conditions (HC) or cold conditions (CC) and high or low relative humidity can incur performance and health problems[2-5].

The American College of Sports Medicine considers a hot environment when temperature exceeds 27 centigrade degrees (ºC)[6]. Practicing sport under heat conditions affects negatively to aerobic performance[7]. After studying 28 marathons, positive correlations were found among non-finished runners and environmental temperature, and also between temperature and time needed to finish the races[8]. Hyperthermia, defined as an internal body temperature higher than 39.5ºC[9] may reduce VO_{2max} values up to 16% and increase heart rate (HR) between 15 and 20 beats per minute at the same intensity compared to cooler temperatures. This is due to the vasodilation process whose objective is to reduce skin temperature[10]. Fatigue might also occur as a consequence of high body temperatures even in trained subjects during prolonged exercise[11]. Although resting values for body temperature are lower in trained athletes, aerobically trained subjects can reach higher body temperatures than untrained ones when exercising at maximal intensities[12]. Skin temperature depends more on environmental conditions (temperature and relative humidity) while body internal temperature depends more on exercise intensity[13].

During sweating, a runner may lose a huge quantity of electrolytes such as sodium or potassium, inducing hyponatremia. However, hyponatremia could be also consequence of hyperhydration or a big loose of body mass (BM)[14], that ultimately might provoke death cases[7,15-17].

During exercise with high temperature exposure, there is a higher predominance of glycogen over lipid metabolism and also higher concentrations of plasma lactate[18], which induce greater fatigue. Heat acclimation can reduce muscle glycogen rate of utilization even to 50% and 60%, reducing fatigue[19]. Other benefits of heat acclimation involve greater arterial elasticity[20] or reductions of heart rate in high temperature conditions[21].

Body composition might be an important factor in exercise at different temperatures. The higher subcutaneous fat, the more efficient heat conservation is in cold environments due to a low thermic conductivity observed by fat mass[22].

Humidity is another determining factor since sweat evaporation becomes more inefficient in a heat environment making body internal temperature difficult to reduce[23]. During running, convection is less efficient in heat dissipation at lower running speeds, so this factor is identified as important in exercise intensity[23].

Continuous activity in hot conditions has less increases than variable-intensity exercise in heat storage, cardiovascular and metabolic stress[24]. Therefore, the main aim of the present systematic review was to evaluate how high temperatures affect runner's health during continuous exercise.

Method

Search strategy

Two databases were used for the searching process, PubMed and Web of Science following the search terms "Heat" AND "endurance" AND "run"; "Heat" AND "Marathon"; and "Heat" AND "endurance" AND "Cycle". The process was undertaken from May to June of 2018 and no papers were excluded based on publication date or language.

Inclusion criteria

The inclusion criteria for the studies were: a) investigating the effects of endurance exercise on health variables, at least, at 27º C; b) determining the intensity of exercise or if it was self-paced; c) indicating the value for total time of exercise when no criteria of exercise conclusion were established by the researchers (until fatigue or reaching certain body temperature). If it was necessary, authors were contacted for getting this value and d) presenting pre- and post-exercise results in hot conditions or comparing it with normal conditions (NC) or cold conditions.

Exclusion criteria

Studies that did not investigate the relationship between health variables and exercise parameters were not included. Articles were excluded if the physical activity followed by the participants was not continuous (when different activities were undertaken, only continuous exercises were taken into consideration). Those that had an animal sample were not included either. No articles were included if they only focused on performance parameters. Investigations about the effects of any substance intake were excluded as well as the post-test results of an intervention program. Previous reviews and studies where heat effects on health variables variation were not measured or were not interesting for the review were also excluded. Additionally, studies measuring races and competitions, such as ultramarathon with race times longer than five hours were excluded due to intense temperature variations. Triathlon research was excluded because of water temperature effects. Last exclusion criteria included research with unhealthy participants.

Results

A flow chart for the article identification after the searching process is presented in Figure 1. Number of records identified, screened and those chosen for eligibility and included ones are shown.

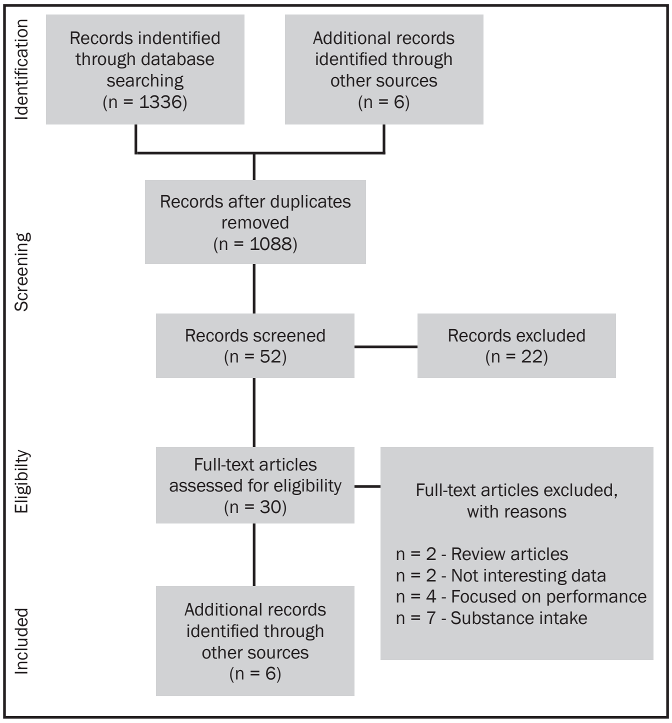
Table 1 shows an overview of articles included in the qualitative synthesis, showing the number of participants, age, exposure time to HC and its temperature and outcome measurements for each article.

A total of 333 runners (295 males and 38 females) were evaluated in the 15 articles included in the qualitative analysis once selection process concluded.

Discussion

Exposure to high ambient temperatures, reaching values of 40 ºC in core temperature can induce heat stroke[39]. This consequence can be

Figure 1. Flow chart showing the search method.



n: number of articles.

due to a high intensity exercise[40]. Aerobic fitness adaptations, related to heat dissipation, are not necessarily associated to a less health risks about body temperature[12]. Otherwise, fluid intake is an effective form to maintain lower levels of body temperature, mostly in aerobically trained athletes[41], also heat acclimation produces significant reductions in body temperature[42]. After 107.12 ± 8.85 min of exercise in HC, it was found a body temperature (BT) of 39.6 ± 0.6ºC[29], 40.1 ± 0.3ºC after 58.8 ± 3.3 min and 39.8±0,4 ºC after 59.7±2.0 min of self-paced exercise. These values were significantly higher than self-paced exercise in NC[32]. 39.2 ± 0.1ºC was the temperature reached during race-walking in HC at 10.9 Km•h^{-1} for 60 min, being 38.4 ± 0.1ºC when running at the same velocity and time, but this difference were not noticeable at skin level[28]. The increase in BT after a 30 minutes self-paced run went from 37.42 ± 0.28ºC to 39.20 ± 0.12ºC for men while for women in follicular phase it ranged from 37.42 ± 0.28ºC to 39.30 ± 0.10ºC and from 37.7ºC to 39.20 ± 0.01ºC in luteal phase[36]. At 80% and 100% of VO_{2max} intensity in cycle exercise, higher BT than CC was observed in HC[31]. Increases of 0.13 ± 0.03 ºC•min^{-1} for HC and 0.06 ± 0.03 ºC•min^{-1} for CC were detected at 80% of VO_{2max} intensity until exhaustion, considering that the time to exhaustion was approximately twice longer for CC[31]. The increases at the same conditions for a 100% of VO_{2max} intensity were 0.22 ± 0.05 ºC•min^{-1} for HC and 0.13 ± 0.03 ºC•min^{-1} for CC. At 70% of peak treadmill running speed, BT was higher for HC at 30 minutes after the start of the exercise when comparing with NC, the same difference appeared during a maximum intensity run[27]. In the same study, it was observed how the skin temperature stays always significantly higher when practicing the same exercise in HC than in NC[27]. In fact, during exercise in NC, skin temperature tends to decrease (from 30.5 ± 0.1 to 25.8 ± 0.1ºC), while in HC the skin temperature remains between 33.5 ± 0.1ºC and 34.1 ± 0.2[27]. At 75% of VO_{2max} intensity of 30 minutes running, BT was significantly higher for HC than NC[25]. Higher values for BT occurs in the first 45 minutes for HC than NC when cycling at 55% of VO_{2max}, remaining these values until the end of the 75 minutes exercise[33]. Comparing HC with CC, significant differences in BT were determined only in the first 30 minutes of cycle activity at a 65% of max power (W_{max}), but higher and significant differences were determined appear in skin temperature values from the beginning until the end of the exercise (40 minutes)[34]. Cycling at 65% of VO_{2max} in HC produced significant increases in BT during all the exercise time, being higher when practicing in the evening than in the morning, where similar results were also observed in skin temperature values[37]. A comparison between HC and NC was conducted by Lafrenz *et al.*,[38] identifying significant higher values in body and skin temperature for HC in both submaximal and maximal intensity exercises.

After an 80% and 100% of VO_{2max} intensity during cycling exercise higher blood pH under HC than CC was observed, a difference that remained along the recovery time at 80% of VO_{2ma}[31]. There were not significant lactate concentration differences between HC and CC after cycling exercise until exhaustion at 80% of VO_{2max} intensity[31]. However, at a 65% of W_{max} significant differences in lactate concentrations were observed in the first 20 and 40 minutes of cycling when comparing between the same conditions[34]. Additionally, differences in lactate concentration were found after 60 minutes of race-walking and running at same VO_{2max} percentage, but not when running at same speed in HC[28]. In the present study, there were not differences in plasma volume after any of these trials. After a 30 minutes of 70% of peak treadmill running speed, urate were higher for HC when comparing with NC[27]. After running at maximum effort, there were also higher values for plasma ammonia concentrations in HC, but lower values in lactate concentrations[27]. Anyway, the difference between pre-exercise urate concentrations in these three variables compared to those observed after running at maximum effort showed significant increases. Furthermore, there were not any significant differences in plasma volume and lactate in submaximal cycling exercise when comparing HC to NC, observing same results for plasma volume in maximal intensity, but lower values in plasma lactate in HC comparing with NC[38].

According to the research about immune system, at the end of 78 minutes of a self-paced race[6], there were significant increases of total leucocytes number (from 5.52x10^3 ± 0.2x10^3 cell/µL to 9.31x10^3 ± 2.4x10^3 cell/µL), neutrophils (from 2.90x10^3 ± 0.6x10^3 cell/µL to 7.64x10^3 ± 3.4x10^3 cell/µL) and hematocrit percentage (from 43.16 ± 3.0 to 46.68 ± 3.2). At the same time, there were significant decreases in lymphocytes (from 1.67x10^3 ± 0.3x10^3 cell/µL to 1.34x10^3 ± 0.3x10^3 cell/µL) and eosinophil (0.36x10^3 ± 0.2x10^3 cell/µL to 0.22x10^3 ± 0.1x10^3 cell/µL). Data obtained after a mean time of 107.12 ± 8.85 min of self-paced running in HC, revealed that leucocyte count and plasma Lipopolysaccharides increased by 66.2% and 31.6% respectively, as well as granulocyte, which increased from 4.1x10^9 ± 1.0x10^9/L to 9.0 ± 3.2x10^9/L. Same authors[29] also observed a significant increase in cytokines (IL-6, IL-10 and IL-1ra) after a running competition. On the other hand, lymphocyte count decreased 25% after running activity. In addition, no significant changes before and after the race in TNF-α and IL-1β were identified[29]. After a Marathon race with a mean time of 229 ± 38 minutes in HC, increases

Table 1. Overview of articles included in the review.

Author	N	Age (years)	Exposure time (minutes)	Outcome measures	T (ºC)
Al-Nawaiesh, *et al.* (2013)[26]	10 M	17.75±0.68	5, 10, 15, 20, 25 and 30	Body Temperature, Glycaemia, Rating of Perceived Exertion, Blood Pressure, HR, Sodium and Potassium	40
Del Coso, *et al*. (2013)[27]	114M 24F	39±8	229	Leg power, Body Mass, Urine Haematites, Leukocytes, Proteins, Ketones, Myoglobin and Bilirubin.	28
Marino, *et al*. (2001)[28]	9M	25 ± 1	31,3 ± 1,2	Body Temperature, Skin Temperature, Heart Rate, Plasma Lactate and Ammonium, Respiratory Exchange Ratio.	35
Mora-Rodríguez , Ortega and Hamouti (2011)[29]	4M 5F	22 ± 5	8, 15, 25, 30, 40, 45, 55 and 60	Oxygen Consumption, Body Temperature, Skin Temperature, Heart Rate, Rate of Perceived Exertion, Sweat Rate, Plasma Lactate.	30
Ng, *et al.* (2008)[30]	32 M	25.0 ± 3.2	107,12 ± 8,85	Leukocyte, Lipopolysaccharides and Cytokines, Body Temperature and Heart Rate.	27
Lim, *et al.* (2009)[31]	18 M (2G)	33.8 ± 7.1 33.0 ± 7.0	Until reaching 39.5ºC of BT	Lipopolysaccharides, Body Temperature, Cytokines, Ant-LPS Antibodies (IgG and IgM), Heart Rate, Sweat Rate.	35
Mitchell, *et al.* (2014)[32]	11 M	32.6 ± 4.4	To exhaustion	Oxygen consumption, Heart rate, Ventilation, Body Temperature, Blood PH, Plasma Lactate.	37
Silva-Filho, *et al*. (2016)[7]	14 M	41 ± 10	78	Body Mass, Hematocrit, Leukocyte, Neutrophils, Lymphocyte, Monocyte, Basophils, Eosinophil and Monocytes.	38,75
Viveiros, *et al.* (2012)[33]	7 M 7 M	54 ± 2 28 ± 1	58,8 59,7	Oxygen consumption, Heart Rate, Body Temperature and Sweat rate.	40
Mitchell, *et al*. (2002)[34]	10 M	24.7 ± 6.6	75	Body Temperature, Heart Rate, Glucose, Cortisol, Neutrophil, Lymphocyte and Leukocyte,	38
Romer, *et al.* (2003)[35]	7M	21.7 ± 0.8	2, 30 and 60	Body Temperature, Skin Temperature, Plasma Lactate, Heart Rate and Rate of Perceived Exertion	35
Luk, *et al.* (2016)[36]	28M 4F	49 ± 8 42 ± 12	384 ± 60	Leukocytes, Neutrophils, Monocytes and Lymphocytes	35.3 ± 5.0
Wright, *et al*. (2002)[37]	5M 5F	20.6 ± 0.8 25.0 ± 1.6	21.7 ± 1.75 20.6 ± 0.87	Body Temperature, Heart Rate, Rate of Perceived Exertion and Sweat Rate.	30
Hobson, *et al*. (2008)[38]	9M	24 ± 2	45.8 ± 10.7 40.5 ± 9.0	Body Temperature, Skin Temperature, Heart Rate, Plasma Volume, Sweat Electrolytes and Rate of perceived exertion.	35
Lafrenz, *et al.* (2008)[39]	10M	23 ± 3	15 and 45	Oxygen consumption, Plasma Lactate and Volume, Heart Rate, Body Temperature, Skin Temperature, Rate of perceived Exertion.	35

M: Male; F: Female; 2G: Two different groups; DS: Different samples

were found for hematite, leukocytes, proteins, ketones and bilirubin values through urine concentration analysis, not finding significant values in post-race pH concentrations and specific gravity[26]. Romer, Bridge, McConell & Jones[34] investigated immune cells function in HC observing significant increases of 134% in total leukocytes, 319% in neutrophils, 24% in monocytes and 53% in lymphocytes after a self-paced cycle race. A running activity in HC at 70% of VO_{2max} until reaching volitional status or a BT of 39.5ºC was conducted to examine blood markers by Lim *et al.*[30]. There were increases of 71% and 92% on plasma lipopolysaccharides concentration in two different groups. Additionally, these authors[30] did not find significant differences between pre-exercise and post-exercise in anti-LPS IgG antibodies concentrations. Similar results were found for anti-LPS IgM antibodies concentration, except for the significant increase identified between pre-exercise and 90 minutes post-exercise rest in this anti-LPS antibodies concentration. Regarding cytokines concentration, no differences between pre- and post-exercise in TNF-α and IL-1β, were detected whereas, on the contrary, increases in both IL-6 and IL-10 concentrations between pre- and post-exercise and between pre-exercise and 90 minutes post-exercise in both groups were determined[30]. Greater loss of plasma volume in HC than NC and also higher number of circulating lymphocyte (CD3, CD4 and CD8), leukocyte and neutrophil number at the end of exercise occurred when cycling at a 55% of VO_{2max}, maintaining these differences in leukocyte and neutrophil cells two hours after the exercise[33].

When HC and NC were compared, a significant difference in blood sugar was detected in the first 5 minutes of exercise at 75% of VO_{2max}, that was maintained until the end of the activity (30 minutes)[25]. Similar results were observed after 75 minutes of cycling exercise in blood sugar and cortisol at a 55% of VO_{2max}[33]. In HC, sodium concentration was significantly higher after 5, 10 and 15 minutes, but lower after 20 and 25 minutes of exercise than in NC, not being significantly different after 30 minutes of exercise[25]. No significant differences were identified in sodium concentrations after 45 minutes in HC of cycling at 65 of VO_{2max}, but these differences were determined, instead, in potassium and chloride concentrations[37].

During exercise in the heat, body mass loss can induce an increase of HR[43]. Variables as HR variability decay faster than other adaptations like BT after heat acclimation during non-exposure to heat[42]. During exercise at 75% of VO_{2max}, HR significantly increases every 5 minutes in both HC and NC, observing a significant differences between both conditions at 10 and 15 minutes[25]. At 70% of peak treadmill running speed, heart rate was observed to be higher for HC from the first 10 minutes until the end of the run (30 minutes) when comparing with NC, observing similar results in the first 10 minutes during running at maximum effort[27]. After 60 minutes of 90% of self-paced running speed exercise, there were significant differences between NC and HC in HR values in young (28 ± 1 years), and middle-aged adults (54 ± 2 years)[32]. Significant higher values were identified in HR in 60 minutes of race-walking at 10.9 $Km \cdot h^{-1}$ in HC than running at the same conditions of velocity and time[28]. No significant differences were found between HC and CC at 80% and 100% of VO_{2max} in HR in cycling exercise[31]. Significant differences were observed in HR in the first 15 minutes when exercising at 75% of VO_{2max} that remain until the end of the 75 minutes activity, same differences from the first 10 minutes until the end of exercise (40 minutes) when comparing HC and CC at a 65% of W_{max}[34]. Cycling in HC at 65 of VO_{2max} produces significant increases of HR during the entire exercise time, being higher when practicing in the evening than in the morning[37]. When cycling at submaximal intensities, HR was affected by temperature, since higher values for HC than NC were observed. However, this difference was not determined at maximal intensity[38].

While in trained subjects, blood pressure values return to baseline, hypotension status appears post-exercise in trained athletes in HC[44]. Diastolic blood pressure increases with decreases of environmental temperature among elderly men[45]. Diastolic blood pressure was lower in HC than NC after 5, 10 and 15 minutes of exercise at 75% ofVO_{2max}, not being significantly different after the first 20 minutes[25]. Systolic blood pressure (SBP) was also higher in NC during the first 5, 10 and 15 minutes while after 20, 25 and 30 minutes of exercise higher values for SBP in HC were detected[25]. In submaximal intensity cycling exercise, there were not significant differences in mean arterial pressure when comparing HC with NC[38].

During cycling at 80% and 100% of VO_{2max} intensity, higher levels of ventilation in HC than CC at the exhaustion time were determined (148.74 ± 20.88 $L \cdot min^{-1}$ and 127.81 ± 15.75 $L \cdot min^{-1}$ for 80% of VO_{2max} and 164.29 ± 12.92 $L \cdot min^{-1}$ and 151.59 ± 17.39 $L \cdot min^{-1}$ for 100% of VO_{2max} in HC and CC respectively)[31]. This difference were not observed when performing at 65% of VO_{2max} cycling intensity[38].

Respiratory exchange ratios (R) were significantly higher under HC than NC at 70% of peak treadmill running speed. In HC R value was always close to 1 (1.0 ± 0.01 for the first 10 minutes; 0.99 ± 0.01 for 20 minutes; and 0.99 ± 0.01 for 30 minutes), while at the same intensity in lower values were determined (0.96 ± 0.01 at 10 min; 0.95 ± 0.02 for 20 min; and 0.93 ± 0.02 for 30 min)[27]. There were no significant differences among VO_2 parameters. In addition, significant differences were not found in R when comparing HC (0.97 ± 0.03) with NC (1.05 ± 0.04) at maximal cycling exercise[38].

Comparing a 60 min self-paced run in HC with 50 min in NC, $VO_{2Absolute}$ and VO_{2max} were significantly higher in young and middle-aged runners[32]. $VO_{2Absolute}$ values were also significantly higher for submaximal cycling exercise in HC comparing with NC, but lower for $VO_{2Absolute}$ and VO_{2max} at maximum effort[38].

Although body mass tends to fall during endurance exercise, it is not related to decreases in performance or health troubles[46-49]. At the end of 78 minutes of a self-paced race in HC, a reduction of BM of 3,48% occurred[6]. Similarly, after a marathon race, a loss of 2.22 ± 1.2% of BW was identified when comparing to pre-race values, registering decreasing values up to 6%[26].

Regarding sweat rate, it was observed higher values when practicing exercise in HC than in NC, in both self-paced and 90% of self-paced running intensity. This results were in agreement with those observed for young and middle-aged adults[32]. Lim *et al.*[30] described a sweat rate of 2.56 ± 0.52 $L \cdot h^{-1}$ and 2.40 ± 0.48 $L \cdot h^{-1}$ when running at 70% of VO_{2max}. Sweat rate was significantly greater for men than for women in HC after 30 minutes of self-paced exercise[36].

No significant differences were found in RPE in HC before and after heat acclimation[50]. Four studies reported RPE values in HC[25,27,34,38]. There were significantly higher values for RPE in HC than NC and CC when running at 75% of VO_{2max} at 5, 10, 20 and 25 minutes of exercise[25]. Similar results were observed at 70% of VO_{2max} while running, also observing these values at maximum intensity run[27] and at a 65% of W_{max} cycle[34]. Furthermore, RPE was significantly higher in HC at submaximal cycling intensity, but not significantly different at maximal intensity[38].

Conclusions

Practicing exercise in hot conditions, produces higher values in body temperature than in normal or in cold conditions. Absolute values after exercise typically reach 39.5ºC, which means that physical activity in hot conditions induces hyperthermia. Thus, we observed that hyperthermia may occur independently of exercise intensity in hot conditions. It has been observed that skin temperate is always higher in hot conditions when comparing to normal and cold conditions, even in normal and cold conditions skin temperature can be reduced during exercise. Therefore, we conclude that an uncontrolled long-term activity in hot conditions may induce health problems related to high body and skin temperatures. Cooling strategies should be assessed after continuous exercise under hot conditions.

It has been observed that plasma lactate does not tend to be higher when the exercise is under hot conditions after identifying higher concentrations in normal conditions. Plasma volume was not affected by different temperatures. Conversely, urate and ammonia concentrations appear to be higher in hot conditions than in normal conditions. The main finding of the current review was the values attributed to immune functions. Although sometimes lymphocyte cell number tends to fell instead of increase, exercise in hot conditions typically produces great increases in cell counts. Findings on blood sugar support the meaningful increases after the exercise in hot conditions, even comparing with normal conditions.

As for heart rate, higher values in hot than in normal conditions are observed. This fact must be taken into consideration during endurance training in a hotter ambient than 27ºC if the intensity of exercise are proposed in function of percentages of maximal heart rate. It could be interesting to study how high temperatures during exercise affect to those that intake beta-blockers drugs. Similarly, in Sports Science there were few studies to conclude how temperature affects blood pressure during exercise

Although there were not many articles that investigated the effects of heat on breathing variables. Ventilation, respiratory exchange ratios and oxygen consumption present greater values in hot conditions than in normal conditions when practicing exercise.

Finally, similar results for rate of perceived exertion during exercise when comparing heat to normal conditions. We conclude that RPE is always higher for hot conditions. Thus, these findings might be interesting for those whose training programs are based on subjective effort, knowing that at same intensity greater effort is demanded when practicing in higher temperatures.

Conflict of interest

The authors do not declare a any conflict of interest.

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