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Gender- and hydration-associated differences in the physiological response to spinning

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Abstract

Introduction: **There is scarce and inconsistent information about gender-related differences in the hydration of sports persons, as well as about the effects of hydration on performance, especially during indoor sports.**

Objective: **To determine the physiological differences between genders during in indoor physical exercise, with and without hydration.**

Methods: **21 spinning sportspeople (12 men and 9 women) participated in three controlled, randomly assigned and non-sequential hydration protocols, including no fluid intake and hydration with plain water or a sports drink (volume adjusted to each individual every 15 min), during 90 min of spinning exercise. The response variables included body mass, body temperature, heart rate and blood pressure.**

Results: **During exercise without hydration, men and women lost ~2% of body mass, and showed higher body temperature (~0.2°C), blood pressure (~4 mmHg) and heart rate (~7 beats/min) compared to exercises with hydration. Body temperature and blood pressure were higher for men than for women during exercise without hydration, differences not observed during exercise with hydration. Between 42-99% of variance in body temperature, blood pressure and heart rate could be explained by the physical characteristics of subjects and the work done.**

Conclusions: **During exercise with hydration (either with water or sport drink), the physiological response was similar for both genders. Exercise without hydration produced physical stress, which could be prevented with either of the fluids (plain water was sufficient). Gender**

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RESPUESTAS FISIOLÓGICAS ASOCIADAS AL GÉNERO E HIDRATACIÓN DURANTE EL SPINNING

Resumen

Introducción: **La información sobre las diferencias relacionadas con el sexo en cuanto a la hidratación de las personas deportistas, así como sobre los efectos de la hidratación sobre el rendimiento, especialmente en deportes de interior, es escasa e inconsistente.**

Objetivo: **Determinar las diferencias fisiológicas entre sexos durante el ejercicio físico en el interior con y sin hidratación.**

Métodos: **Veintiuna personas deportistas (12 hombres y 9 mujeres) participaron en tres protocolos de hidratación, no secuenciales, controlados y distribuidos al azar, que incluían falta de hidratación, hidratación con agua corriente e hidratación con una bebida para deportistas (ajustando el volumen a cada individuo cada 15 minutos), durante 90 minutos de ejercicio spinning. Las variables de respuesta incluían masa corporal, temperatura corporal, frecuencia cardíaca y presión sanguínea.**

Resultados: **Durante el ejercicio sin hidratación los hombres y mujeres perdieron cerca de un 2 % de la masa corporal y mostraron una temperatura corporal (~0,2° C), presión sanguínea (~4 mm Hg) y frecuencia cardíaca (~7 latidos/min) superiores en comparación con los ejercicios sin hidratación. La temperatura corporal y la presión sanguínea fueron superiores en hombres que en mujeres durante el ejercicio sin hidratación, diferencias que no se observaron durante el ejercicio con hidratación. Entre el 42 y el 99 % de la varianza de la temperatura corporal, la presión sanguínea y la frecuencia cardíaca pudo explicarse por las características físicas de los individuos y el trabajo realizado.**

Conclusiones: **Durante el ejercicio con hidratación (ya fuese con agua o una bebida para deportistas), la respuesta fisiológica fue similar en ambos sexos. El ejercicio sin hidratación produjo estrés físico que pudo ser evitado con cualquiera de los dos tipos de líquidos (el agua corriente fue suficiente). Las diferencias en la respuesta fisiológica al spinning (temperatura corporal, presión**

differences in the physiological response to spinning (body temperature, mean blood pressure and heart rate) can be explained in part by the distinct physical characteristics of each individual.

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sanguínea media y la frecuencia cardíaca) pudieron explicarse en parte por características físicas individuales diferenciales.

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Palabras clave: *Diferencias en género. Hidratación. Ejercicio físico. Nutrición deportiva.*

Introduction

Dehydration is a common problem among athletes. The most important causes are poor nutritional education of both athletes and their trainers, environment factors, inappropriate diets before and after exercise[1,2], ignorance about the effects of dehydration on health and performance[3,4], a lack of thirst stimulus during exercise[5] and deficits in planning and organization by sports authorities[6].

It is known that athletes must be euhydrated (280-290 mOsm/kg) to have good physical performance during exercise. However, there are several environmental conditions that provoke a considerable loss of water (1-5% of body mass) and electrolytes (10-80 mEq/L Na^+, 3-15 mEq/L K^+, and 5-60 mEq/L Cl^-)[7,8], including intense sun light, high temperatures and high relative humidity, as well as a lack of ventilation and proper clothing. At a certain threshold, the higher body temperature and physical stress of dehydrated athletes lowers physical performance compared to their euhydrated counterparts[5,7,9].

While some authors propose that the rate of sweating is lower in female than male athletes[10,11], others pose that women take more time than men to start sweating[12]. Since there is scant information on the relation between physical performance and hydration of sports persons, and because these differences could affect the homeostasis and performance of females, it is necessary to gain insights into this subject.

Most of the studies on male and female athletes have evaluated the effects of dehydration on exercise performance outdoors, especially under extreme environmental conditions (temperature > 30°C; relative humidity > 60%)[7,8], however, there are few reports on sports persons practicing indoor sports. Since the latter activities are generally carried out with poor ventilation, and in some cases require clothing impermeable to air flow, the problem of dehydration tends to be worse indoors than outdoors in spite of *ad libitum* drinking. For example, a loss of water representing more than 2% of body mass has been reported during judo[13], nearly 3.4% during indoor soccer[14], between 1-2 kg of body mass/h during badminton[10] and tennis[15].

Dehydration is a problem with the aforementioned indoor sports even though they involve displacement of the involved person, leading to a certain degree of ventilation and therefore heat loss by convection and evaporation. Hence, dehydration becomes an even more serious problem with spinning, an activity in which sports person are stationary, i.e., Mora-Rodríguez et al. (2007)[16] reported a mean body mass loss of 2.3% after 60 min of spinning. When adding ventilation (air flow: 2.55 m/s), dehydration was lower by 0.5% and body temperature by 0.5°C. According to Coyle (2004)[5], physical performance is not affected during spinning provided that sports person are well hydrated and the body mass loss is below 2%. Although these guidelines have been established for spinning, to the best of our knowledge there is only one report that explore the different hydration status of male sports person of this sport[17]. This factor is important because it may affect performance. Thus, here we study the gender-related physiological response during 90 min of spinning exercise with and without hydration in healthy young adult volunteers.

Methods

Subjects

Twenty one amateur spinning sports persons (12 men and 9 women) volunteered to participate in a case series study (each subject is its proper control) (table I). All sports persons were accustomed to practicing spinning 3 to 5 days per week, in sessions lasting at least 1 hour. They were asked not to smoke, drink caffeinated beverages or consume alcohol during the entire study, not to exercise 48 h prior to a session, and to arrive to the physiology lab between 9:00 am and 2:00 pm. All participants were found to be in good health, corroborated by a medical check-up (University medical service) and an electrocardiogram before the tests. The study was carried out with the approval of the institution's Ethics Committee, and each volunteer signed an informed consent letter in accordance with the Declaration of Helsinki of the World Medical Association Ethics Code.

Anthropometry

Height (stadiometer Seca Model 206, Mexico) and body fat (Quantum X RJL, USA) were determined immediately before the first exercise session. Body mass *(Bame* Aut model O.C.N. 5282; *Torrey,* Mexico) was measured before and after each session, weighing the sports person with an empty bladder (at the end of the exercise the individuals did not want to urinate) and no clothing, and when completely dry.

Exercise and hydration protocols

Environmental indoor conditions during the exercise sessions were kept constant, with a temperature of 23°C, relative humidity of 23%, barometric pressure of 659 mmHg, and no ventilation (it is important to notice that in Ciudad Juarez, few gyms have ventilation). Participants wore sports clothes commonly used in cycling and were free to have their habitual breakfast 3 to 5 hours before the exercise sessions. On the first day they were given 15 min to adapt to the stationary bicycle of the lab (Monark 828E, Vansbro Sweden), during which time they learned about the modified Borg scale (from 0 to 10)[18]. Afterwards, they were programmed for three exercise sessions, each with a distinct hydration protocol: exercise without fluid intake and exercise accompanied by hydration (either with plain water or a sports drink). In every session the participant exercised continuously for 90 min and maintained the psychosomatic perception of effort between six and seven (heavy to very heavy exercise) on the modified Borg scale. With this in mind, they were allowed to freely increase or reduce both ergometer resistance and pedaling revolutions and a member of the team monitored her/his perception of the Borg scale.

During the first session (48 hours after the 15 min adaptation period), the protocol for all participants was exercise without fluid intake. The order of the other two protocols was randomized. Based on the loss of body mass during the first protocol, we determined the amount of fluid, either plain water or the sports drink (Gatorade®: 324 mmol/L of carbohydrates, 19.9 mmol/L of Na^+ and 3.2 mmol/L of K^+), that each participant needed to prevent dehydration. In accordance with the literature, this quantity of fluid was divided into six equal parts and supplied every 15 min during the respective exercise protocol[5,19], and was kept in refrigeration at 4°C. The time elapsed between the three exercise sessions was two weeks for men and three month for women. This protocol was established for women so that each exercise session would be in the middle of their follicular phase of menstruation, since hormonal changes within the menstrual cycle affect body temperature, corporal water retention and physical performance[20].

Physiological parameters measurement

Physical stress was evaluated by body temperature (Digital infrared Ear 424 USA), heart rate (Polar RS100, Finland), blood pressure (Aneroid Baumanometer and EM Rescue stethoscope, USA), and mean blood pressure [diastolic blood pressure + (systolic blood pressure – diastolic blood pressure/3)][21]. Psychosomatic perception of effort (fatigue) was evaluated by the modified Borg scale. The distance traveled was calculated in km, and the resistance applied to the bicycle ergometer was measured in N. Only one person was in charge of recording blood pressure, one for body temperature, one for heart rate and one for psychosomatic perception of effort (Borg scale) every 15 min during exercise (without stopping the exercise) and at rest.

Statistical Analyses

Differences in physical characteristics between genders were analyzed by the Student's *t* test of independent samples. Differences between hydration protocols, time and sex were analyzed by the General Linear Model (GLM). Repeated measurements and comparisons between factors were evaluated by the Sidak test. The homogeneity of variances on Student's *t* test and GLM analysis was checked by Levene's test. The independency of associated parameters on changes in heart rate, body temperature and blood pressure was analyzed by multiple linear regression analysis through the stepwise method. The Statistical analyses were carried out with the 18.0 PASW program. Data are presented as the mean ± standard deviation (SD) in tables and ± standard error of the mean (SEM) in figure. The significance was set at $p < 0.05$.

Results

Body mass was constant for both men and women during the hydration protocols

Men showed higher values in relation to age, height and body mass than women; contrarily, men had a lesser percentage of body fat. At rest, men had higher blood pressure (systolic, diastolic and mean) and a lower heart rate ($p < 0.01$; table I). During the exercise session without fluid intake, the loss of body mass was slightly higher for men (2.2% ± 0.9) than women (2.0% ± 1.2), but the difference was not statistically significant (table II). Accordingly, men needed more fluid than women to prevent dehydration. During the exercise sessions with a sports drink, the consumption for women versus men was as follows: 72 ± 40 *vs* 103 ± 38 g of carbohydrates, 564 ± 312 *vs* 807 ± 298 mg of Na^+, and 154 ± 85 *vs* 220 ± 81 mg of K^+. While both genders lost body mass during the exercise sessions without fluid intake, this parameter was stable (± 0.2 kg) for both men and women during the two hydration protocols (table II).

Table I
Physical characteristics of participants

	Women (n = 9)	Men (n = 12)
Age (years)	24.1 ± 4.5	30.0 ± 6.2[a]
Body mass (kg)	62.2 ± 2.4	77.4 ± 16.7[a]
Height (m)	1.65 ± 0.05	1.75 ± 0.05[a]
Body fat (%)	33.9 ± 4.2	18.0 ± 6.2[a]
BMI (kg/m^2)	22.9 ± 1.7	25.2 ± 5.1
Heart rate (beats/min)	69 ± 9	58 ± 7[a]
Systolic blood pressure (mmHg)	107 ± 9	124 ± 12[a]
Diastolic blood pressure (mmHg)	67 ± 5	74 ± 7[a]
Mean blood pressure (mmHg)	80 ± 5	91 ± 8[a]

Values are the mean ± SD. BMI: Body mass index. [a] $p < 0.01$. Differences evaluated by the Student's *t* test.

Hydration prevented physical stress, but did not change physical performance

Men traveled a longer distance and applied greater resistance to the ergometer than women (distance, ~50.0 *vs* ~43.4 km; resistance, ~19 *vs* ~14 N). There was no statistical difference in these values between any three exercise sessions (with and without fluid consumption) for either men or women (table II). However, the increase in body temperature ($p < 0.01$), mean blood pressure ($p < 0.01$) and heart rate ($p < 0.01$) was higher for both men and women during the exercise session without fluid intake than during the sessions with hydration. This corroborates that there is an increase in physical stress when sports person are deprived of hydration; furthermore, there was no statistical difference in these values between the two exercise sessions with hydration (table II), suggesting that this protocol prevented physical stress regardless of the composition of the fluid.

Men had higher body temperature and mean blood pressure than women during exercise, but similar heart rate

During exercise (after 30-40 min and on) men had higher body temperature ($p < 0.01$) and mean blood pressure ($p < 0.001$) than women (fig. 1); however, women had a slightly higher heart rate than men, even at rest, but this difference was not significant ($p = 0.12$; table II). Analysis of the associations between parameters showed that: (a) 42% of the variance in body temperature could be explained by differences in age, heart rate, Δ body mass and resistance applied to the ergometer ($p < 0.001$); (b) 74% of the variance in mean blood pressure could be explained by gender and differences in heart rate ($p < 0.001$); (c) 99% of the variance in heart rate could be explained by differences in body temperature ($p < 0.001$; table III).

Dehydration increases physiological parameters independently of gender

Exercise with no fluid intake yielded higher numbers in all parameters evaluated, independently of gender (fig. 1), which were maintained throughout the 90 min spinning period. It is worth to mention that, even though statistical significance was obtained for body temperature in men ($p < 0.05$), no difference was set in the blood pressure and heart rate among sexes but they were higher when no hydration consumption was the protocol. Furthermore, hydration yielded similar results despite it was plain water or sports fluid (fig. 1).

Discussion

The results of the present study show that the dehydration provoked by 90 min of spinning, performed in comfortable environmental indoor conditions (23°C and 23% relative humidity) but without ventilation, did not

Table II
Physiological and performance changes for women and men caused by hydration protocols

	Women (n = 9)			Men (n = 12)		
	EWF	EPW	ESD	EWF	EPW	ESD
Loss of body mass (kg)	-1.21 ± 0.72	-0.05 ± 0.35[a]	0.16 ± 0.25[a]	-1.69 ± 0.68	-0.17 ± 0.50[a]	-0.03 ± 0.61[a]
Loss of body mass (%)	-2.0 ± 1.2	-0.08 ± 0.6[a]	0.3 ± 0.4[a]	-2.2 ± 0.9	-0.2 ± 0.7[a]	0.0 ± 0.8[a]
Distance travelled (km)	45.0 ± 3.6	44.1 ± 3.0	43.3 ± 3.1	49.3 ± 5.6[b]	50.1 ± 5.6[b]	51.4 ± 6.5[b]
Resistance applied to the ergometer * (N)	13.4 ± 2.1	14.3 ± 2.0	14.1 ± 2.2	19.6 ± 4.1[b]	19.8 ± 2.8[b]	18.2 ± 3.3b
Body temperature* (°C)	36.9 ± 0.3	36.7 ± 0.5[a]	36.7 ± 0.3[a]	37.3 ± 0.5[b]	36.9 ± 0.3[a,b]	37.0 ± 0.4[a,b]
Mean blood pressure* (mmHg)	94 ± 5	91 ± 4[a]	88 ± 6[a]	114 ± 8[b]	112 ± 10[a,b]	111 ± 7[a,b]
Heart rate* (bpm)	154 ± 16	145 ± 19[a]	145 ± 17[a]	147 ± 12	141 ± 14[a]	142 ± 16[a]

Values are expressed as the mean ± SD. EWF = exercise without fluid intake; EPW = exercise accompanied by hydration with plain water; ESD = exercise accompanied by hydration with a sports drink. [a]Different with respect to the protocol of exercise without fluid replacement. [b]Different with respect to women. $p < 0.01$. Statistical analysis of independent variables by GLM, and of repeated measures by the Sidak test for multiple comparisons. * Mean value for the 90 minutes of exercise.

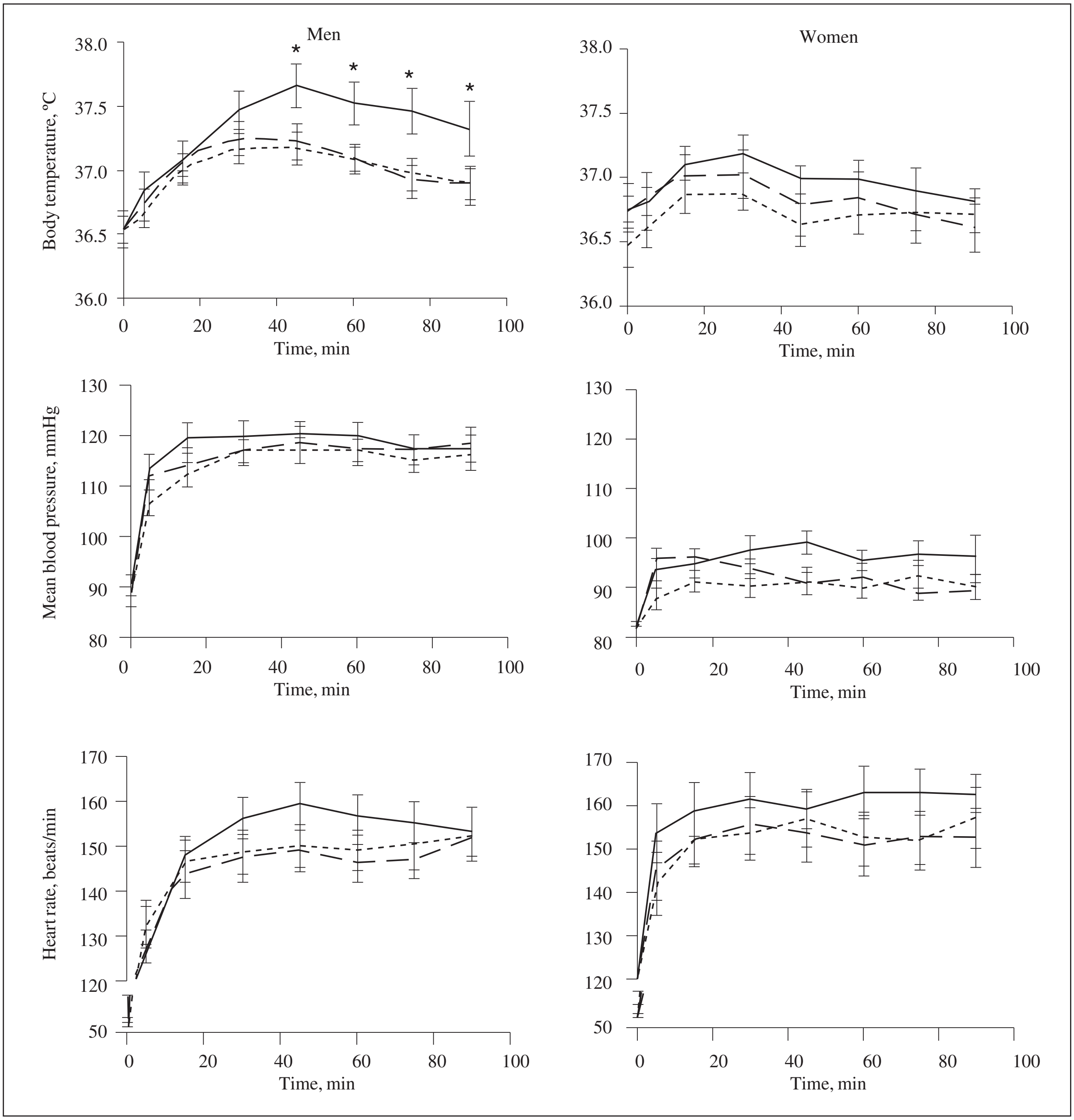

Fig. 1.—Kinetics (Time course) of body temperature, mean blood pressure and heart rate during 90 minutes of spinning. The results are shown as the mean ± SEM. (—) Continuous lines for dehydration, (---) dashed lines for hydration with plain water, (••••) Stitch lines for hydration with sports drink.

Table III
Multiple linear regression models for body temperature, blood pressure and heart rate

Regression Equations	R^2	p *level*
Body temperature = 34.3 + 0.25 age (years) + 0.01 heart rate (bpm) – 0.12 Δ body mass (kg) + 2.4 resistance applied to the ergometer (N)	0.42	< 0.001
Mean blood pressure = 62.1 + 22.7 sex (0 = women, 1 = men) + 0.20 heart rate (bpm)	0.74	< 0.001
Heart rate = 3.9 body temperature (°C)	0.99	< 0.001

diminish physical performance but increased physical stress, since all the parameters measured were higher in this condition (similar results for men have been reported previously)[17]. The physical stress apparently experienced by the sports person during the exercise session without fluid intake was absent for both men and women, when exercise was accompanied by hydration (either with plain water or a sports drink). The physiological response was similar in both genders, explained in part by the physical characteristics of the subjects.

In relation to the water balance in men and women after spinning, reported data are inconsistent. Some uncontrolled studies carried out with *ad libitum* hydration indicate that the absolute and relative rates of sweating are higher for men versus women (1.12 *vs* 0.57 L/h, and 2.16 *vs* 1.49%, respectively) during a 90 min spinning session with artificial ventilation.[11] On the other hand, in a controlled experiment, also with *ad libitum* hydration but without ventilation, no gender differences in sweating in relation to time (60 *vs* 90 min of spinning) were found, although women consumed less fluid than men[22].

Since it has been shown that *ad libitum* hydration is not sufficient to prevent dehydration during and after exercise[10,11,14,15,22], we decided to replace the exact amount of fluid (euhydration) lost by each individual during 90 min of spinning. Comparing both euhydration and dehydration, we found that there are no gender differences in water balance after spinning, in agreement with other's findings[22]. In the present study, the loss of body mass was slightly but not significantly higher in men than women, which is also in agreement with Johannsen et al[22].

One possible explanation for the differences between genders found by Hazelhurst & Claassen (2006)[11], could be that women have greater body surface area/kg of body mass than men[23]. This would allow for a greater loss of heat by convection and evaporation in women than men during experiments with artificial ventilation. However, heat production without ventilation increases sweating and loss of body mass in a similar way for both genders. Hence, a lack of ventilation and displacement of the athlete[22] and the current contribution, diminishes the possibility of heat loss by convection and evaporation, and in consequence practically eliminates the differences between men and women in regard to a loss of body mass.

Besides heat production, another factor that influences perspiration during exercise is the number of sweat glands. On this question there is controversy, as some authors reported that women have a higher density of sweat glands per cm^2 than men[24], while others report the opposite[23]. However, some authors have shown that when variability in sweating is corrected by physical capacity as well as by morphological and anthropometrical characteristics, there are no differences due to gender[25].

Contrary to our findings, there is one report that women had a higher body temperature than men regardless of exercise intensity and climate conditions[26]. However, that study did not consider the variability of temperature during the menstrual cycle. It has been reported that the body temperature of women can vary as much as 0.6°C, even at rest, depending on the phase of the menstrual cycle[27]. In the present study this variation was avoided by planning all the spinning sessions for women at the same phase of the menstrual cycle.

According to Gagnon & Kenny (2012)[28], differences between genders in body temperature are related to distinct physical characteristics; also Havenith & van Middendorp (1990)[25] reported that 54 to 70% of the variance in body temperature could be explained by physical characteristics. The results of the present study disagree with these reports, since we found that the modifications in age, heart rate, Δ body mass and resistance applied to the ergometer accounted for only 42% of the variance in body temperature.

This contradiction can be explained by the distinct methods of calculating body temperature. According to the Havenith & van Middendorp regression equation [Rectal temperature = 36.7 + 0.26 (Body fat) + 82.3 (body surface area) + 0.18 (VO_2 max), among other parameters], body temperature rises with an increase in body fat, body surface area, and maximum volume of O_2 consumption (VO_2 max). However, the equation seems to be flawed, as the results it gives are not as expected. For example, a higher percentage of fat tissue implies the presence of less lean mass and therefore a lower metabolic rate, which in turn should produce less (not greater) heat. Moreover, a greater body surface area provokes higher heat dissipation, which should lead to a lower (not higher) body temperature. Finally, a higher VO_2 max indicates a better adaptation to exercise stress, which should result in a lower (not higher) body temperature. Hence, we propose the following regression equation (table III) since it sounds more adequate:

Body temperature = 34.3 + 0.25 age (years) + 0.01 heart rate (bpm) – 0.12 Δ body mass (kg) + 2.4 resistance applied to the ergometer (N)

In relation to mean blood pressure, our results are similar to studies that involve maximum intensity exercise, in which this parameter is higher for men than women, even at rest[29]. In addition, the present results show that 74% of the variance in mean blood pressure could be explained by gender and differences in heart rate.

On the other hand, it has been shown that heart rate is higher for women than men when exercise is above the anaerobic threshold[29]. In the present study, heart rate was higher for women than men, both at rest and during exercise. Moreover, 99% of the variance in heart rate during exercise was explained only by body temperature.

In the present study, dehydration did not affect physical performance, but increased physical stress since all physiological parameters augmented. This can best be explained by the fact that the participants were asked to exercise at the same subjective work intensity (6-7 on the modified Borg scale) and had a dehydration rate below 3%, which is the critical point above which sweating is reduced, body temperature increased, and there is a greater subjective perception of effort, thus affecting performance[12].

Dehydration and body temperature have an additive effect under extreme weather conditions (temperature ≥ 35°C and relative humidity ≥ 50%), increasing peripheral vascular resistance and heart rate, while decreasing systolic volume, cardiac output and mean blood pressure.[30] Together these changes lead to an enormous decrease in physical performance[31]. However, in the controlled indoor conditions of the present study (23°C and 23% relative humidity) it is understandable that physical performance was not affected; in this regard, our results agree with those by Abián-Vicén et al. (2012)[10], in relation to exercise under non-extreme conditions. The fact that the distance traveled and the resistance applied to the ergometer was higher for men than women, is probably due to the well-recognized differences in body mass and physical strength between genders.

Conclusions

Both men and women had higher values for body temperature, mean blood pressure and heart rate during the exercise without fluid replacement, confirming that dehydration provokes physical stress. Consumption of plain water is sufficient for preventing physical stress in both genders, provided that an adequate volume is consumed to replace the loss of body fluid caused by sweating. The differences found in body temperature, mean blood pressure and heart rate between women and men are due, in part to the distinct physical characteristics and work load of the subjects. Since *ad libitum* water consumption as a response to thirst has proven inadequate, the present results suggest that it would be helpful for sports person to evaluate their own dehydration rate before participating in a competition. They would then be able to program the correct intake of fluid, based on continuous drinking, to avoid dehydration, diminish physical stress, and therefore maintain a good performance level.

Limitations of the study

Is it worth to mention that participants of the study are considered Mexican mestizo and it is recommended to test this kind of experiments with other populations in order to compare results.

Competing interests

The authors declare that they have no competing interests.

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