



Original / *Deporte y ejercicio*

Acute physiological response to indoor cycling with and without hydration; case and self-control study

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Abstract

Introduction: Oral rehydration drinks help maintain physical capacity and hydration during exercise.

Objective: Evaluate, in a case and self-control study, the effectiveness of three hydration and exercise protocols on work capacity and physical and psychosomatic stress during indoor cycling (InC).

Methods: 14 middle-aged eutrophic men participated in three controlled randomly and not sequentially hydration (~278 mL 6/c 15 min) and exercise (InC/90 min) protocols: No liquids, plain water, or sports drinks (SD). The response variables were: Body temperature (BT), heart rate (HR), and mean blood pressure (MBP). The covariables: Distance traveled (DT), ergometer resistance (R), body fat (BF), difference in body weight between tests (rBW), and age of the participants. The differences between protocols were evaluated using GLM Repeated Measures, the independence of associations by multiple linear regression.

Results: In non-liquids, the subjects showed higher BT, HR, and MBP than when they drank plain water or SD ($p < 0.01$). Work capacity was the same in the three hydration protocols. BT was the most sensitive variable detected by the hydration status of the subjects. 34%, 99%, and 21% of the associated variance to HR, MBP, and BT was explained by DT + BT, BT + BF, and $\Delta BW + \text{age} + R + DT + BF$, respectively.

Conclusions: Liquid intake with or without electrolytes does not affect work capacity, and they are equally effective as hydration sources during ≤ 90 min of InC at strong and very strong intensities. Body temperature is the most sensitive variable detected by the subject's hydration status during exercise.

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Key words: *Spinning. Dehydration. Exercise. Sports nutrition. Vital signs.*

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RESPUESTA FISIOLÓGICA AGUDA AL CICLISMO DE SALA CON Y SIN HIDRATACIÓN; ESTUDIO DE CASOS Y AUTOCONTROLES

Resumen

Introducción: Las bebidas de re-hidratación oral ayudan a mantener la capacidad física y el nivel de hidratación durante el ejercicio.

Objetivo: Evaluar en un estudio de casos y autocontroles la efectividad de tres protocolos de hidratación y ejercicio sobre la capacidad de trabajo, estrés físico y psicossomático durante el ciclismo de sala (CiS).

Métodos: 14 varones eutróficos de mediana edad participaron de manera aleatoria y no consecutiva en tres protocolos de hidratación controlada (~278 mL 6/c 15 min) y ejercicio (CiS/90 min): No líquidos, agua corriente o bebida deportiva (BD). Las variables respuesta fueron: Temperatura corporal (TC), frecuencia cardiaca (FC) y presión sanguínea media (PSM). Las covariables: distancia recorrida (DR), resistencia del ergómetro (R) grasa corporal (GC), pérdida de peso al final del ejercicio (PC) y edad de los participantes. Las diferencias entre los protocolos fueron evaluadas por GLM de Medidas Repetidas, la independencia de las asociaciones por regresión lineal múltiple.

Resultados: En no líquidos, los sujetos presentaron mayor TC, FC y PSM que cuando ingirieron agua corriente o BD ($p < 0,01$). La capacidad de trabajo fue igual en los tres protocolos de hidratación. La TC fue la variable más sensible que detectó el estado de hidratación de los sujetos. El 34%, 99% y 21% de la varianza asociada a FC, PSM y TC lo explicaron DR + TC, TC + GC, y $\Delta PC + \text{edad} + R + DR + GC$ respectivamente.

Conclusiones: La ingesta de líquidos con o sin electrolitos no afecta la capacidad de trabajo y son igualmente efectivos como medios de hidratación durante ≤ 90 min de Cis a intensidades pesadas y muy pesadas. La TC es la variable más sensible que detecta el estado de hidratación de los sujetos durante el ejercicio.

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Palabras clave: *Spinning. Deshidratación. Ejercicio. Nutrición deportiva. Signos vitales.*

Abbreviations

ΔBW: Difference in body weight between tests.
MBP: Mean blood pressure.
BF: Body fat.
BT: Body temperature.
DT: Distance traveled.
EPW: Exercise under hydration with plain water.
ESP: Exercise under hydration with sports drink.
EWL: Exercise without liquid intake.
GLM: General linear model.
HR: Heart rate.
InC: Indoor cycling.
N: Newtons.
R: Resistance.
SD: Standard deviation.
SE: Standard error.

Introduction

Indoor cycling (InC) or spinning is one of the most practiced aerobic exercises around the world. To date, more than two hundred thousand instructors in this discipline have been certified in more than 35,000 gymnasiums and club chains in 80 countries.¹ In addition, there are many noncertified gymnasiums where this sport is provided and people practicing it at home. This means that every day several millions of people in the world are using this discipline to exercise. Given the intrinsic characteristics of this exercise (e.g. oxygen demand), the environmental conditions where it is commonly done (e.g. closed spaces with insufficient ventilation and environmental pollution) are usually unhealthy² exposing individuals to respiratory diseases³ and excessive physiological stress². On this fact and in spite of the effort of sports medicine colleges to educate people and sports federations about the healthy way of exercising, a harmful trinomial, which is constantly reproduced in gymnasiums, continues to be seen: scarce or no ventilation, insufficient hydration, and the use of inappropriate clothing. This trinomial considerably affects electrolyte balance and muscular and hepatic glycogen,⁴ thus the general health and effectiveness of InC as an aerobic exercise. Therefore, dehydration and excessive stress are two factors which must be watched and eliminated in all sports practice.

On the other hand, dehydration rates and loss of electrolytes as factors of stress during physical exercise greatly differ between people and sports.^{5,6} In turn, they increase with the use of inappropriate clothing, room temperature > 33.5° C, relative humidity > 60%, and the intensity of the exercising, or they decrease with air conditioning and drinking liquids with or without electrolytes.^{5,6} In order to improve physical performance and hydro-electrolytic balance, currently, a large amount of sports drinks, with or without electrolytes, are being sold offering different benefits in sports

performance. However, many athletes are not in the habit of drinking liquids during exercise; moreover, sports drinks with electrolytes are a second option for hydration to plain water.⁷ Even though the usefulness of drinks with electrolytes vs. those without them during exercise has been demonstrated, their use has been evaluated, in their majority, during intense long duration exercise, done in extreme temperature and humidity.^{5,6} In view of this, few studies have been done on moderate duration and moderate intensity exercise, realized under temperate climates with low relative humidity, where both types of drinks being able to provide similar benefits in these latter cases.

It is a known fact that when physical activity is done in open spaces, body water loss tends to be between 0.5-2 liters/hour;⁸ however, in closed, non air conditioned spaces where heat loss by convection and evaporation are compromised by a lack of ventilation, perspiration and dehydration rates can be higher which means more physical and mental stress^{9,10} and, at least theoretically, lower work capacity. In view of this, the purpose of this case and self-control study was to find out if during 90 minutes of indoor cycling, without ventilation, work capacity and physical and psychosomatic stress are affected by dehydration and/or the type of liquids consumed (water with or without electrolytes). Namely, there are very few studies on the subject, evaluated in a case and self-control design.

Methods

Subjects

14 male, amateur cyclists participated (table I) in a case self-control study. All subjects exercised for one hour or longer three to five days per week. The subjects were called in to the laboratory between 9:00-14:00 h and three to five hours after eating (*ad libitum*). The subjects were also asked not to change their exercise and diet habits, or drink alcohol or caffeine during the studies or engage in physical activity 48 hours prior to the studies.

Table I			
Descriptive characteristics of subjects			
Parameter	EWL	EPW	ESD
Age (years)	32 ± 8		
Height (m)	1.75 ± 0.05		
BMI (kg•m ²)	25.6 ± 4.8		
Weight (kg)	78.6 ± 15.7	79.0 ± 15.5	79.0 ± 16.0
Body fat (%)	18.4 ± 5.9	18.1 ± 6.2	18.4 ± 6.1
SBP (mmHg)	110.5 ± 11.8	110.5 ± 11.2	109.9 ± 11.5
DBP (mmHg)	68.3 ± 5.8	68.5 ± 8.6	66.9 ± 4.8

Exercise without liquid intake (EWL), exercise under hydration with plain water (EPW) or exercise under hydration with sports drink (ESD). The results are shown as mean ± standard deviation (SD). n = 14; BMI = Body mass index; SB = Systolic blood pressure; DBP = Diastolic blood pressure.

0	Nothing at all	4	Somewhat strong
0.5	Very very weak	5-6	Strong
1	Very weak	7-9	Very strong
2	Weak	10	Maximal
3	Moderate		

*Borg's Modified Scale, 1982.

Anthropometry

In the first session the body mass (*Bame Aut* model *O.C.N.* 5282; Torrey, Mexico) and height (*Seca Modelo* 206 height rod, Mexico) were measured, and body fat percentage (%BF) was determined by bioimpedance (Quantum X RJL, USA). In each of the three exercise protocols assigned (as will later be explained) the subject was weighed before and after exercising, naked, completely dry, and after urinating (none of the subjects needed to urinate at the end of the exercise in any of the protocols).

Exercise and hydration protocol

The environmental conditions of the laboratory were the same that are founded at the spinning gyms in urban environments: temperature 23° C, relative humidity 23%, barometric pressure 670 mmHg, and no ventilation. In the first session, the subjects were familiarized with the protocols, measuring equipment, and for 15 minutes of InC on a stationary bicycle (Monark 828E, Vansbro Sweden) trained to use the Borg scale¹¹ modified from 0 to 10¹² (table II). This scale measures the perception of effort or psychosomatic stress of the subjects during exercise). Later, three hydration protocols were applied for 90 minutes of continuous exercise on a bicycle with the subjects wearing sports clothes commonly used in cycling; 1) without consuming liquids, 2) consuming plain water, 3) consuming a sports drink (Gatorade®: 324 mmol/L of carbohydrates, 19.9 mmol/L of Na⁺, and 3.2 mmol/L of K⁺). In the first protocol (without consuming liquids) the amount of liquids to be consumed by the subjects in the remaining two protocols was established in accordance with the amount of weight lost at the end of the exercise. In the hydration protocols, the loss of body liquid caused by dehydration was replaced, either by plain water or by the sports drink, according to what the literature recommends.^{13,14} The drinks administered (mean: 1679 ml, range: 900-3000 ml, median 1,550 ml) were divided into six equal parts and supplied every 15 minutes in such a way that the subject would continue drinking the same amount of liquid in the same time. In order to improve the administration of the liquids, they were kept in refrigeration at 4° C, since the participants complained of nausea when drinking liquids at higher

temperatures. This last indication is, additionally, recommended as one of the best ways of administering drinks during exercise.¹⁵ The order of participation of a same subject in the protocols with consumption of liquids was random. The time between each protocol was one week.

Variables response

Physical stress both at rest and every 15 minutes during exercise was evaluated by body temperature (BT) measured with a digital thermometer (Digital infrared Ear 424 USA), by heart rate (HR) (Polar RS100, Finland), and by blood pressure (BP) taken on the right arm of the subject (*Anaeroide* Baumanometer and EM Rescue stethoscope, USA), also calculating the mean blood pressure (MBP) [diastolic blood pressure + (systolic blood pressure-diastolic blood pressure/3)].¹⁶ During exercise, psychosomatic perception of effort (fatigue) was also noted by the Borg modified scale as explained above. The distance traveled in km was calculated, and the resistance applied to the bicycle ergometer in Newtons (N) was measured. BP, BT, HR and psychosomatic perception of effort were noted by just one person. The subjects were allowed to freely increase or reduce both the ergometer resistance and the pedaling revolutions, maintaining at all times the psychosomatic perception of effort between six and seven on the mentioned Borg scale. The protocol of the experiment was approved by the Ethics Committee of the Universidad Autonoma de Ciudad Juarez after having corroborated that the subjects were in good health by a medical study and a resting electrocardiogram, and after signing the informed consent letter in accordance with the Helsinki guidelines.¹⁷

Statistical analyses

The search for differences between hydration protocols were analyzed by the general linear model (GLM) Repeated Measures and comparisons between factors by the Sidak test. The independence of the variables that would explain the changes in HR, BT, and blood pressure was analyzed by multiple linear regression analysis through the Stepwise method. The statistical analyses were carried out with the version 18.0 PASW computer program. The differences were considered significant when the value of $p < 0.05$.

Results

The results of the efficiency in the work and the physiological modifications during the three hydration protocols are shown in table III. The water balance of the subjects was maintained during the hydration protocols, with the sports drink being slightly better for

Table III
Physiological changes product of three rehydration protocols

Parameter	EWL	EPW	ESD
Difference in body weight (%)	-2.2 ± 0.9	-0.3 ± 0.6 ^a	0.0 ± 0.7 ^{a,b}
Distance traveled (km)	49.3 ± 4.9	49.8 ± 5.4	50.5 ± 6.3 ^a
Resistance applied to the ergometer (N)	19.5 ± 5.0	19.8 ± 3.6	18.1 ± 3.9 ^{a,b}
Heart rate* (beat/min)	137 ± 35	131 ± 35 ^a	133 ± 35 ^a
Mean blood pressure* (mmHg)	112.4 ± 15.2	110.6 ± 15.1	109.0 ± 14.2 ^a
Body temperature* (°C)	37.2 ± 0.7	36.9 ± 0.5 ^a	36.9 ± 0.5 ^a

Exercise without liquid intake (EWL), exercise under hydration with plain water (EPW) or exercise under hydration with sports drink (ESD). The results are shown as mean ± standard deviation (SD).

^aDifferent with respect to the protocol EWL.

^bDifferent with respect to the protocol EPW.

p < 0.01. Statistical analysis by GLM Repeated Measures and the Sidak test for multiple comparisons.

*Mean of the 90 minutes of exercise.

maintaining euhydration (table III). In the hydration protocol with the sports drink, the subjects consumed on average, 713 mmol of carbohydrates, 44 mmol of Na⁺ and 7 mmol of K⁺. In this last protocol a slight increase in the distance traveled was observed (~1 km); however, there was also a slight reduction in the resistance applied to the ergometer (1.5 N), so work capacity was similar between protocols.

Of the three exercise protocols, the one done without hydration (table III, fig. 1) was where the subjects showed the highest values in HR, MBP, and BT (p < 0.01). Moreover, during the protocol with the consumption of the sports drink, the lowest MBP was noted (table III, p < 0.01). BT is the most sensitive variable detected by the hydration status of the subjects during exercise (fig. 1).

As observed in table IV the associations between the variables showed that 34% of the variance in HR was explained by the modifications in distance traveled and BT (table IV) (p < 0.001). 99% of the variance in MBP was explained by the modifications in BT and body fat (p < 0.001). 21% of the variance in BT was explained by the modifications in the difference in body weight, age, resistance applied to the ergometer, distance traveled, and body fat (p < 0.001).

Discussions

The results of this paper show that 90 minutes of spinning at a constant and submaximum intensity (strong

and very strong exercise according to Borg's psychosomatic scale) under temperature controlled conditions (23° C) and relative humidity (23%), without ventilation, and with or without the consumption of liquids, does not change work capacity nor does it put healthy athletes' health at risk. In general the intensities of exercise done by the participants during the 90 minutes of InC were similar to those which are usually done in this sport. The above as the mean maximum heart rate during exercise (145-160) was similar to that reported by other authors in this sport,^{18,19} or triathletes during cycling stage.¹⁰

Just as it has already been described in other studies, dehydration increases body temperature and heart rate above the values found in protocols with hydration,^{20,21} moreover, dehydration increases mean blood pressure. On the other hand, with the exception of mean blood pressure, hydration with plain water or with the sports drink, similarly affected heart rate and body temperature. Even though there are many studies on the effects of dehydration and fluid intake in sports, namely, case and self-control studies where subjects exercise under weather and exercise intensity habitual to this sport are practically non-existent, the majority of these studies have been done at temperatures above 30° C and relative humidity over 50%.²² With respect to work capacity, it has been reported that extreme weather conditions (temperature ≥ 30° C and relative humidity ≥ 50%) during exercises at high intensity or with long duration, usually produce significant dehydration (> 2% of body weight), increase BT, and affect phys-

Table IV
Multiple linear regression models for HR, MBP and BT

	Equation	R ²	p
HR	= - 549 + 0.5*DT + 18 + BT	0.34	< 0.001
MBP	= 3*BT + 0.3*BF	0.99	< 0.001
BT	= 34.7 - 0.16* BW + 0.01 age (years) + 2.8*R + 0.02*DT + 0.02 *BF	0.21	< 0.001

Heart rate (HR, beats/min); mean blood pressure (MBP, mm Hg); body temperature (BT, °C); distance traveled (DT, km); body fat (BF, %); difference in body weight between tests (rBW, kg); resistance applied to the ergometer (R, newtons).

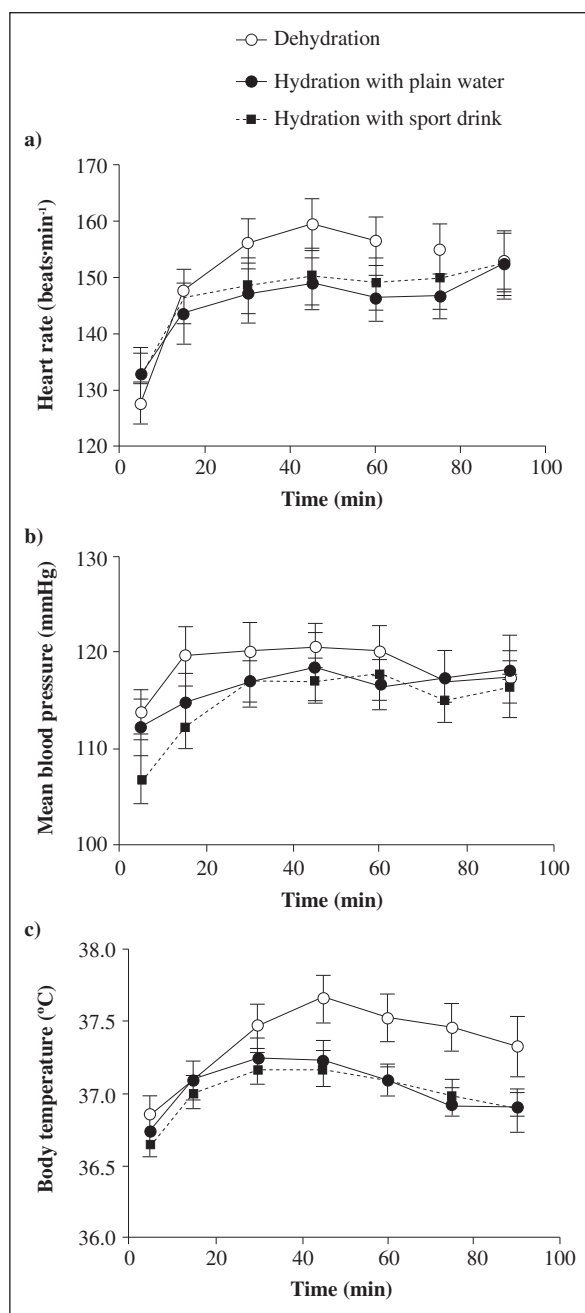


Fig. 1.—Kinetics of the mean blood pressure, heart rate and body temperature during 90 minutes of continuous exercise on a bicycle. The results are shown as mean \pm standard error (SE).

ical performance.^{5,13,21,22} On the contrary, at mild temperatures (5-22° C) and at low relative humidity (< 40%) they cause little dehydration (< 2% of body weight), and they also have little effect on BT and physical performance.¹³ With the exception of the lack of ventilation, the subjects studied here exercised in ideal weather conditions⁴ and at non-strenuous exercise intensity, so the average dehydration was kept moderate⁴ which are why no significant differences were observed between protocols in terms of physical performance.

HR, BP, and BT increase linearly with exercise intensity;^{21,23} however, as shown here, during strong or very strong intensity exercise, and with dehydration around 2% of body weight, they increased during the first 40-50 minutes; afterwards, they remained constant (HR and BP) or tended to decrease (BT). Of the main reasons for the higher increase of HR during exercise without hydration, is a reduction in blood flow and volume and, thus, in the cardiac output observed in similar studies⁹; additionally, by the higher increase of plasma concentrations of adrenaline and noradrenaline found in this type of study.⁹ Here it was found that BT and distance traveled participate equally in the increase of HR. As for BP during exercise in conditions of dehydration vs. hydration, it is mainly raised by the increase in peripheral vascular resistance and in BT;⁹ we also found that its increase is higher for higher fat mass in the subjects. The lower increase in MBP observed in the protocol with sports drink may be due to the fact that this type of drink allows for better control of euhydration and less dehydration^{4,24} and, thus, a probable lower peripheral vascular resistance.²⁵ The increase of HR during long duration exercise at a constant intensity has already been reported,^{18,26} but not together with the changes in MBP and BT during hydration and dehydration protocols.

With respect to BT, its increase during exercise is mainly due to the production of heat during muscular contraction,²⁷ secondly, by the alterations in the processes of heat dissipation and the consequent dehydration.⁵ On the contrary, as an element of protection against its elevation, the blood flow increases to the skin, thereby favoring heat loss by evaporation, radiation, convection, and conduction²⁴. This study tried to simulate the weather conditions existent in the places where InC is practiced in our city, in such a way that, from the lack of ventilation, the loss of heat by the aforementioned physical methods are generally reduced, especially the loss of heat by convection and conduction,²⁴ which is why that BT was most affected by dehydration. It has been observed that as the time engaged in exercise increases (under different degrees of hydration or dehydration), BT gradually increases until the end of the exercising.^{18,21} However, we observed that it increases only until approximately half way through the exercising and then discretely reduces until the end. As we mentioned before, the majority of the studies on exercise and dehydration have been done under extreme weather conditions, thereby impeding the loss of heat by radiation and evaporation, whereby, a constant increase is normally observed in BT, among other variables. In our study, by being done in non-extreme weather conditions, the loss of heat by radiation and evaporation remain present especially during the second half of exercising when the subjects were completely wet with sweat, and considering that perspiration improves heat dissipation capacity²⁴. We found that, in addition to dehydration, the age of the subjects, the resistance applied to the ergometer, the

distance covered, and the body fat of the subjects play a part in the increase of BT during exercise.

As for hydration status, we consider that the ~1,671 ml of liquids intake by the participants during exercise with hydration were enough to maintain euhydration. This is due, firstly, to the minimum difference in body weight observed at the end of exercising with liquid intake ($\leq 0.3\%$) as well as the compliance of the recommendations of the National Research Council: Recommended Dietary Allowances (NRCRD, 1989)²⁸ as to the consumption of liquids which must be administered during exercise (1-1.5 ml/kcal burned). According to the NRCRD, our subjects should have drunk between 1,200 and 1,800 ml of liquids since the approximate caloric expenditure during the 90 minutes of cycling was 1,200 kcal.¹² On the other hand, as for the loss of electrolytes due to perspiration and the intake of carbohydrates necessary to delay fatigue, the consumption of 44 mmol of Na⁺ and of 713 mmol of carbohydrates consumed in the hydration protocol with the sports drink were equal within the recommended range.^{5,29} It is also observed in this paper that under conditions established by protocol, the intake of plain water or sports drink had similar effects on the elevation of HR and BT but not on BP, which is why drinking liquids with electrolytes and carbohydrates is usually recommended for better athletic performance, especially when the loss of body liquids is greater than 2% of body weight.^{13,14,30} Moreover, as is also seen here, the slow continuous intake of liquids is more effective for hydration and reducing the production of urine during exercise,^{31,32} which is why our subjects did not need to urinate at the end of exercising.

As for the reasons that explain the associations between dependent and independent studied variables, to date, we find few paper that describe variables which independently explain physiological changes during exercise with or without dehydration; in this respect, this paper allows us to establish some of these associations. For example, Greenleaf & Castle (1971)³³ and Montain & Coyle (1992)²¹ find that for every 1% loss of body weight from dehydration during exercise, BT increases by 0.1 and 0.2° C. In our paper we observe values similar to the ones already reported; that is to say, for every 1% loss of body weight, BT increases by 0.16° C. We also observe the size of participation of the variables analyzed for BT, HR, and MBP. For example, the distance traveled for HR (1 beat for every 2 km traveled) and BT (0.02° C per kilometer traveled), BT on HR (18 beats/minute at 1° C) and MBP (3 mmHg at 1° C), age on BT (0.01° C per year of age turned), resistance applied to the ergometer on BT (2.8° C per unit of force applied to the ergometer), and body fat on BP (0.3 mmHg per percentage of body fat) and BT (0.02° C per percentage of body fat).

Conclusions

Body temperature is the most sensitive variable detected by the subject's hydration status during exer-

cise. In addition was also founded that ninety minutes of InC and dehydrations $\leq 2\%$ of body weight do not affect work capacity. On other hand, the intake or non-intake of water, with or without electrolytes, does not change work capacity during the 90 minutes of InC without ventilation and with dehydration of $\leq 2\%$ of body weight. Finally, the distance traveled and the changes in body weight during exercise, as well as the body fat and age, independently determine the modification of physiological variables, independently of the subject's hydration status.

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