Apunts Med Esport. 2019;54(201):5–11

apunts
MEDICINA DE L'ESPORT
www.apunts/org

ORIGINAL ARTICLE

Effects of rehydration on the physical and technical condition in soccer players

Antonella Cariolo[a], **Juan Del Coso**[a], **Francisco Manuel Argudo**[b,*], **Pablo José Borges-Hernandez**[b]

[a] *Faculty of Health; Head of Exercise Physiology Laboratory, Camilo José Cela University, Spain*
[b] *Faculty of Teacher Training and Education, Department of Physical Education, Sport and Human Motricity, Autonomous University of Madrid, Spain*

Received 29 June 2018; accepted 12 September 2018
Available online 15 October 2018

KEYWORDS
Sweating rate;
Vertical jump;
Penalty

Abstract This study aimed to determine the effect of rehydration on the physical condition and technique of twelve semi-professional soccer players (21.14 ± 1.69 years) underwent regular soccer training (129 ± 7 min). On one occasion, participants ingest water *ad libitum* or were hydrated according to standardized recommendations. In each session, temperature, three maximum vertical jump height and accuracy were measured in a four penalty kick with auditory and visual stimulus, before and after the training sessions. The dehydration achieved and the rate of sweating was greater when the players drank freely at will against a recommended rehydration (1.3 ± .8% *vs.* 0.5 ± 0.6%, $p = .01$) (730.3 ± 275.6 *vs.* 516.9 ± 111.2 ml/h, $p = .02$). The tympanic temperature of a single movement in the session where the hydration scheduled ($p = 0.06$ *vs.* $p < 0.01$), in this case and there was interaction between the treatment and the time ($p < 0.01$). Jump height after training was higher than the initial ($p < 0.01$) and also higher than *ad libitum* group ($p = 0.04$). In the case of shots there was a significant difference in the time relationship of the treatment ($p = 0.01$), indicating that hydration was effective to reduce the number of errors. These data indicate that moderate dehydration could affect muscle strength of the leg and reduce motor accuracy during a simulated football penalty kick.

PALABRAS CLAVE
Tasa de sudoración;
Salto vertical;
Penalti

Efectos de la rehidratación en la condición física y técnica en jugadores de fútbol semiprofesionales

Resumen Este estudio tiene como objetivo determinar el efecto de la rehidratación en la condición física y la técnica de 12 jugadores de fútbol semiprofesionales (21,14 ± 1,69 años) que

* Corresponding author.
E-mail address: quico.argudo@uam.es (F.M. Argudo).

https://doi.org/10.1016/j.apunts.2018.09.004

se sometieron a entrenamiento regular de fútbol (129 ± 7 min). En una ocasión, los participantes ingirieron agua *ad libitum* o se hidrataron de acuerdo con recomendaciones estandarizadas. En cada sesión se midieron la temperatura, la altura máxima de salto vertical y la precisión en 4 lanzamientos de penaltis, con estímulo visual y auditivo, antes y después de las sesiones de entrenamiento. La deshidratación lograda y la tasa de sudoración fue mayor cuando los jugadores bebieron libremente a voluntad contra una rehidratación recomendada (1,3 ± ,8 vs. 0,5 ± 0,6%; p = 0,01) (730,3 ± 275,6 vs. 516,9 ± 111,2 ml/h; p = 0,02). La temperatura timpánica de un solo movimiento en la sesión donde se programó la hidratación (p = 0,06 vs. p < 0,01), en este caso hubo interacción entre el tratamiento y el tiempo (p < 0,01). La altura de salto después del entrenamiento fue mayor que la inicial (p < 0,01) y también más alta que el grupo *ad libitum* (p = 0,04). En el caso de los chutes, hubo una diferencia significativa en la relación temporal del tratamiento (p = 0,01), lo que indica que la hidratación fue efectiva para reducir el número de errores. Estos datos indican que una deshidratación moderada podría afectar la fuerza muscular de la pierna y reducir la precisión del motor durante un chute simulado del penalti de fútbol.

Introduction

In team sports, competition and training can produce a significant loss of fluids and significant consumption of muscle glycogen, as a result of energy expenditure and the consequent production of metabolic heat. In the majority of team sports in the field, average transpiration rates of 800–1000 ml/h can be observed, but losses that reach 150 or 200% of these indices can also be produced in humid climatic conditions, high temperatures or in certain players.[1–5] The fluid intakes reported in the investigations range from 200 to 1400 ml/h and can reach from 10%[6] to almost 90% in losses due to sweating.[7] In general studies report accumulated deficits during a football match ranging from 1.5 to 2% of body mass; some players could even exceed those levels (i.e., 4–5%), while other players can maintain a better hydration state. Even though the average level of accumulated fluid deficit during a session seems moderate (<2% body mass), the data indicate that players begin training or competition with a certain level of dehydration.[2,8,9] Under these circumstances, it is likely that even a slight to moderate fluid deficit produced during the match may affect performance.

Even though the opportunities to drink liquids are not limited, many team sports players do not consume liquid in the amount necessary to equate sweat losses.[1,3–5,8,9] The options and availability of liquids play an important role. In the case of soccer players, they usually lose 2–2.5 kg of body mass when they are playing in a hot environment (i.e., >30 °C)[1,6] due to the limited opportunity to ingest liquids during a match soccer, only in half-time rest and breaks in the game.[10] In addition, it was determined that soccer players drank less during a session when the liquid was at room temperature than when the liquid temperature was cold.[2] The ambient temperature influences the intake of liquids regardless of the actual needs of drinking. During training in the same group of soccer players in summer and in winter, the balance of liquids was compared and little difference was found in fluid deficits; although the transpiration rates were lower with cold temperatures, the players also decreased their fluid intake.[1]

The progressive dehydration experienced by soccer players could cause deterioration in the execution of the game because dehydration induces fatigue which in turn could hinder motor[11] and cognitive[12] functioning. In addition to affecting muscle work, the negative effect of the fluid deficit on mental state and concentration is added, which is an important factor in determining the result of matches.[5] It has been reported that a large dehydration (3.8% body mass, using diuretics), despite reducing the maximum isometric force, increases the vertical height jump probably because it increases the strength of the leg in proportion to body mass.[13] Taking a leap to nod is a highly demanded task during a football game. A large dehydration could result in a large jump in height, although the effects of moderate dehydration (<3% of body mass, more common in football) on the vertical height jump have not been reported. Dehydration alone (4% loss of body mass) does not affect the strength of the extensor muscle of the knee measured during maximal isometric contraction.[14] This suggests that dehydration may not affect the execution of a penalty kick in football which greatly depends on the strength of the knee extensor. The literature is not conclusive in terms of the effects of fatigue on motor control, although there are studies suggesting that the acuity of the movement is diminished due to muscle fatigue.[15] With decreased central controls, individuals tend to decrease the speed at which they perform a task to maintain the same level of accuracy.[16] It is not clear yet whether exercise in a hot environment that induces dehydration will diminish central control and whether it will affect acuity or speed during a task such as the finishing of a penalty kick in a football game.

This study was aimed at determining whether the hydration status of a professional soccer player affects their physical, technical and tactical condition. Specifically, the effects of hydration status have been examined in physical tasks (vertical jump) and motor (penalty kick), the latter initiated by auditory stimuli in comparison to when they are motivated by a stimulus that involves the recognition of a visual signal and the decision making before the auction. The state of hydration was modified through a situation that produced dehydration (i.e., training) and in which the soccer players were rehydrated with water *ad libitum* or according to nutritional recommendations.

Methods

Participants

Twelve players of semi-professional football, belonging to the affiliate team of Getafe C.F. S.A.D, participated in this study (21.14 ± 1.69 years of age, 177.54 ± 4.43 cm tall, 71.0 ± 4.3 kg body weight). Before participating in the study, the players and the team's technical staff signed a consent form. The injured players and players called on those weekends for the professional team of the same Club were discarded. The study was adjusted to the principles and norms of the Declaration of Helsinki.

Experimental design

An experimental, descriptive, intra-subject research was used,[17] in which the participants acted as their own controls. Therefore, each participant received the experimental treatment (water intake according to recommendations based on the previous measurement of the sweating rate) as well as participated in the control situation (water intake *ad libitum*). Before and after the training sessions, the players made 3 maximum vertical jumps, 4 penalty shots with an auditory signal (i.e., without decision) and 4 penalty kicks initiated by a visual variable (i.e., with decision). The tests were always done at the same time of day (10:00 am) and were separated by 7 days to facilitate recovery. In addition, the tests were conducted 3 days after the previous competition to avoid fatigue of the players. The players were instructed to eat and drink in a similar way the days prior to the experimental sessions, in addition to excluding alcoholic drinks from the diet.

Experimental procedures

This investigation was integrated by a day of familiarization plus two days of experimental tests, which took place in the following way:

Familiarization day: in which the presentation of the study was made to the players, participation consent was requested and feeding guidelines and other considerations that should be present for the day of the experimental tests were given. Anthropometric measures of leg length were taken (from the greater trochanter of the femur to the toe in total plantar flexion) and leg height at 90° (from the greater trochanter of the femur and the floor, with knees bent at 90°), data required by the APP ''My Jump'' to estimate the push distance (difference between leg length and height at 90°). Urine sample bottles were also delivered to be brought on the day of the scheduled session, with the first urine of the day in the morning, since it minimizes possible alterations and maximizes the reliability of the measurement.[18] In this case, the urine color scale[18] was used as reference. In addition to pilot tests of the vertical jump and shots on goalpost evaluations.

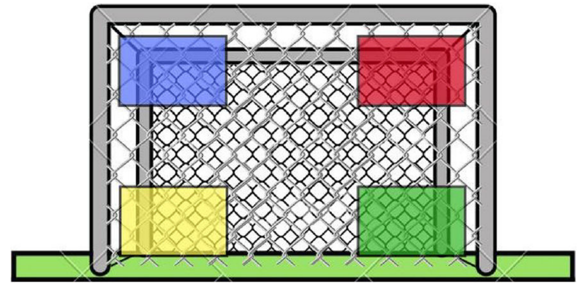

Figure 1 Graphic representation of the soccer precision goalpost used.

First session: Sweating rate with hydration ad libitum. After arriving at the dressing room, prior to the training, the players were asked to deposit the urine bottles in a container. Then the resting heart rate (S Health) and the tympanic temperature were taken. An infrared tympanic thermometer (EasyScan, FTX3 VERT) was used in the left ear canal for three consecutive times and the tympanic temperature reading was averaged. Participants were weighed, in underwear, on an electronic scale (Tanita, BC-601) with an accuracy of ±100 g. After a standard physical warm-up (±30 min.), in a prepared and conditioned area, they performed a soccer execution test that included the vertical jump and the penalty kick. From a standing position with their feet spaced the same distance from their hip width, the participants were instructed to slowly bend their knees until the hip reached a knee flexion mark of 90° and then they jumped as high as they were possible. They were executed 3 vertical jumps[19] always with their hands on their hips to normalize the assistance coming from the upper part of the body. The jumps intermingled in periods of 30 s of rest and standing. The flight time was measured by the IOS operating system APP called ''My Jump''. The players executed 8 penalty kicks to the goalpost, in which a pressure net was used.[19] This network has 4 spaces of precision in the corners equipped with a net bag to collect the balls and has tapes with hooks to fix the net to the poles, that is, could only score a goal if the shots were executed correctly at the corners of the arch according to the indications of each case. The first 4 penalties were initiated by an auditory signal coming from a whistle, that is, without decision, with the indication that the first two went to the upper right corner and the next two to the upper left corner, they were instructed ''to be ready'' and kick the ball to score as soon as they hear the whistle. The execution was registered by video equipment to be analyzed later, with the Kinovea software. After these 4 penalties, under the same conditions, the 4 penalty kicks initiated by a visual signal were registered, with decision, by means of colored cards, which corresponded to the colors marked in each corner of the precision network, Fig. 1. They were instructed to kick the ball to the corresponding corner as soon as they saw the color card. In total, the execution tests lasted approximately 15 min.

During the training the players had at their disposal a bottle with water, previously weighed in order to know the volume of liquid content. Also, identified with his name, having the indication that they could only drink from that bottle every time they wanted to hydrate. In this session the water consumption was *ad libitum*, that is, at will. Only the quantity consumed was controlled without giving any kind of recommendation or comments. They only had the indication that if they wanted to swish water or use water to cool their skin they would use other bottles. The soccer rhythm training began, with an average duration of ±134 min. At the same time, environmental parameters such as temperature (33.6 ± 5.3 °C) and relative humidity (20%) were measured at the training field level. In addition to monitoring the intake of liquids and control of the bottles identified, controlling the remaining volume in them and filling them if necessary and pointing the new volume added. At the conclusion of the training, the players were asked to move on to take the body weight again, using the instrument described above. For this measure, the players had to be in their underwear and dry the sweat produced during the training. Tympanic temperature and heart rate were measured again, using the same instruments. Subsequently, the perception of effort (RPE) was recorded using the Borg scale.[19] Finally, and without the players drinking after finishing the training, a new round of soccer execution tests was performed, which included the vertical jump and the penalty kick, as described above.

Second session: Sweating rate with recommended water intake. The protocol to follow during this session was the same as the first session with the only variant of hydration manipulation during training. The players hydrated according to the given hydration recommendations, in order to cover 100% sweat losses, which were calculated taking as a reference the results of the sweating rate of the first session. Because there is considerable variability in sweat rates between individuals, a customized fluid replacement program was used, as previously suggested.[20] In this case the soccer training lasted for ±124 min with an ambient temperature at the field level of 44.9 ± 6.9 °C and 20% relative humidity.

Statistical analysis

The data were analyzed using a two-way ANOVA type analysis (hydration state X time) with repeated measurements. The pathways used for this variance analysis were the pre *vs*. post-training comparison and the comparison of session 1 with hydration *ad libitum vs*. session 2 recommended hydration. In some variables that were measured in a single time by training, the Student's *T*-test was used. Statistical significance was established at a significant level at $p < 0.05$ for all analyzes. The data are presented as mean ± standard deviation.

Results

The urine sample collected before the training indicated that the players arrived at the training session with a similar state of hydration (Table 1). On the day that the players drank water *ad libitum*, the dehydration was significantly greater than on the day on which they followed some hydration guidelines (Table 1). However, the total fluid intake did not have significant differences between sessions ($p = 0.79$). On the other hand, the calculation of the sweating rate of each of the sessions resulted in a significant difference between both, with more sweating being the day of water consumption *ad libitum vs*. the day of water recommendation (Table 1).

In the case of the evaluation of vital signs, was observed that the heart rate increased significantly during both sessions. The values obtained prior to the training sessions were similar, and in both sessions the heart rate values showed significant changes when evaluating post-training values (Table 2). However, the day that the players hydrated following the recommendations given, the heart rate increased significantly when compared to the session where there was hydration *ad libitum*. There was no treatment × time interaction in the heart rate variable ($p = 0.39$).

On the other hand, the tympanic temperature only increased during training in the case of the session in which hydration recommendations were given ($p < 0.01$), while the temperature remained stable in the session with hydration *ad libitum* ($p = 0.07$). There were no differences between the previous measurements of both sessions, unlike the values of tympanic temperature obtained after the training sessions, where the players presented higher temperature after training with hydration recommendations compared to

Table 1 *Evaluation of hydration status* depending on the type of hydration considered.

Variable	Session	Value	*p*-Value
Urine color test	Ad libitum	5.0 ± 1.7 points	.27
	Hid. recommended	5.8 ± 1.1 points	
% of body weight loss	Ad libitum	1.3 ± .8%	.01
	Hid. recommended	5.0 ± .6%	
Total consumption of liquid	Ad libitum	1029.6 ± 554.7 cc	.79
	Hid. recommended	985.2 ± 221.9 cc	
Sweating rate	Ad libitum	730.3 ± 275.6 cc/h	.02
	Hid. recommended	516.9 ± 112.2 cc/h	

Table 2 *Evaluation of vital signs* depending on the type of hydration and session considered.

Variable	Session	Pretraining	Posttraining	*p*-Value
Heart rate	Ad libitum	62.3 ± 10.2 bpm	90.8 ± 10.2 bpm	<.01
	Hid. recommended	68.0 ± 16.0 bpm	101.3 ± 8.5 bpm	<.01
Tympanic temperature	Ad libitum	35.6 ± .3 °C	35.3 ± .6 °C	.07
	Hid. recommended	35.4 ± .4 °C	36.1 ± 02 °C	<.01

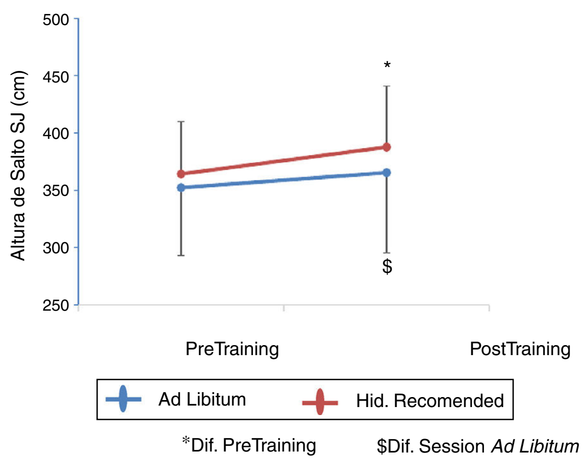

Figure 2 Changes in the height of the SJ jump depending on the type of hydration considered.

the session with hydration *ad libitum* ($p < 0.01$). In this case there was interaction between treatment and time ($p < 0.01$) (Table 2).

Jumping height was similar before training in both sessions ($p = 0.15$). When the players drank *ad libitum*, the jump height did not change after training ($p = 0.15$). However, when the players followed the hydration guidelines, the post-training jump height was higher than that of the start ($p < 0.01$) and also higher than that of the *ad libitum* water consumption situation ($p = 0.04$). There was no interaction in the treatment × time relationship in the jump height variable type SJ ($p = 0.42$, Fig. 2).

Table 3 shows the accuracy of goalpost shooting. As indicated by the data, there were no changes in the experimental tests with auditory signal neither in the comparison between pre *vs.* post-training nor in the comparison between hydration *ad libitum* and recommended hydration. On the other hand, in the case of shots on goalost with a visual signal, there were no changes in the experimental tests in the pre *vs.* post-training comparison, nor in the comparison between both pre-training sessions and both post-training sessions. However, there was a significant difference in the treatment/time ratio in hits from shots to goalpost with visual signal ($p = 0.01$). It should be noted that the scale of perception of effort (Borg, 1975) did not present differences between both training sessions (15.4 ± 1.4 points *vs.* 15.5 ± 0.7 points; $p = 0.79$).

Discussion

The main findings of this study report that the dehydration achieved and the rate of sweating was greater when the players drank water *ad libitum* compared to the recommended rehydration. However, an increase in the post-training jump height was observed and a decrease in the number of errors in the shots on goal when the players followed the hydration guidelines.

In both sessions the players came to training with a similar state of hydration. On the other hand, the calculation of the sweating rate of each of the sessions gave a significant difference between both, with more sweating being the day of water consumption *ad libitum*. In the case of the evaluation of vital signs, was observed that the heart rate increased significantly during both sessions, especially in the one that hydrated following the recommendations given. Tympanic temperature had significant differences only in the case of the session in which hydration recommendations were given, in this case if there was interaction between treatment and time. It is known that the rate of sweating can vary depending on environmental factors such as temperature, relative humidity and wind speed, or other factors such as exercise intensity, physical condition, acclimatization to heat or the use of sportswear that they favor the exhalation of sweat through the skin.[9] So it is important to note that during this investigation the environmental temperature at the level of the field of play was higher in the second session, that is, the day where hydration recommendations were given, however, the humidity was higher on the day of water intake *ad libitum*. On the other hand,[21] in their investigation, after 90 min of continuous exercise (with a temperature of 23 °C and 23% of relative humidity) without hydration, the men

Table 3 Percentage of shot on target depending on the type of hydration and session considered.

Shots on target	Session	Pretraining	Posttraining	*p*-Value
Auditive signal	Ad libitum	25 ± 26.1%	29.2 ± 23.4%	.69
	Hid. recommended	33.3 ± 24.6%	22.9 ± 16.7%	.21
Visual signal	Ad libitum	52.1 ± 22.5%	43.8 ± 15.5%	.10
	Hid. recommended	37.5 ± 19.9%	50 ± 23.8%	.49

reported a loss of body mass slightly higher than that of the women, while maintaining a personalized hydration protocol, said change was not manifested and the physiological responses were similar in both sexes. In addition, they found that in that case the degree of dehydration did not alter the physical performance, but the physiological parameters (temperature, heart rate and blood pressure) regardless of sex.[21]

Loss of more than 2% of body weight after exercise may affect athletic performance due to decreased body fluid.[20,22,23] To generate a loss of 2% of weight due to dehydration, brings hyperthermia as a consequence, which increases the work of the cardiovascular system, generating an increase in the perception of effort, reduction of blood flow and alteration in the metabolism in the skeletal muscles during the exercise.[24–26] On the contrary,[16] indicate that the intake of water, by itself, attenuates the decrease in neuromuscular force produced by exercise of moderate intensity in a hot environment; more if 6% carbohydrates are added to this liquid, the effect is even greater on the neuromuscular force.

The fact of avoiding the dehydration of the players improved the height jump and reduced the error rate of the penitentiaries with visual signal. When the players followed the hydration guidelines, the post-training jump height was higher than the start and also higher than the *ad libitum* water consumption situation. Regarding the accuracy of the shot at goalpost, there were no changes in the experimental tests with auditory signal, but in the case of shots on goalpost with visual signal there were no changes in the experimental tests with relation pre-training *vs.* post-training, however, if there was a significant difference in the treatment $\times$ time relationship. It should be noted that the scale of perception of effort[19] did not present differences between the two training sessions. These data together could indicate that a moderate dehydration could affect the muscular strength of the leg and reduce the motor precision during a simulated soccer penalty kick. It should be noted that the greater the level of dehydration, the greater the physiological tension and the decrease in performance in aerobic exercise.[23]

The execution of a soccer skill (dribbling) deteriorates when adult soccer players become dehydrated when exercising in a thermoneutral environment[27] while the perceived strength increases in comparison to the rehydration test. As in the results obtained in this study, the aforementioned investigations also refer to the increase in the error rate. The accuracy of the penalty kick was reduced by fatigue induced by dehydration, especially when introducing the decision-making variable. This result could be interpreted, taking into account that the visual signal produced longer response times as opposed to the auditory signal, which seems to have given time for the accuracy to be restored despite the hydration condition. The delay in this response could be explained by the speed-precision exchange principle.[28] If the fatigue induced by dehydration decreases the control of the motor units, whether speed or precision, the task performed will be affected. By introducing two cognitive components in the penalty as initiators for the response of the shot and taking into account that both signals, auditory signal through the propagation of sound and light propagation for the visual signal through color cards, were much more fast that the response time observed could suggest that the nature of the signal was not a factor that affected the motor response time for the shot. Severe dehydration increased the height of the vertical jump by 7% probably due to a greater reduction in body mass (3.8% loss of body weight) than in strength of the leg (increase in strength in proportion to resistance of the weight).[29] Although the players who participated in this study lost body mass, that is, they were dehydrated in the first session where the water intake was *ad libitum*, but without reaching the same percentage of body weight loss in Viitasalo[29] (1.3 ± 0.8 *vs.* 3.8%), alteration was also observed in the height variable of the vertical jump. For its part in the investigation of Armstrong et al.[30] no significant differences were observed between the different hydration conditions in vertical jump height, taking into account that the body mass decreased 2.4 ± 0.4% and 4.8 ± 0.4%, respectively, during their intervention in hypohydrates in approximately 2.5% of body mass, and hypohydrates in approximately 5% of body mass.[30]

All this makes us think that the treatment carried out during these sessions could be enough to cause changes in the replacement of fluids of the players and as a consequence in voluntary dehydration during the competition and therefore in their sports performance. However, we must be aware that these positive results do not imply a change in the habits of these players and that, by not applying the proposed strategies, players may return to their usual hydration patterns. Therefore, we understand that field supervision and fluid supply activities during these sessions should be part of the usual practice during training and competition of a professional team and insist on the need to control as many variables as possible affect athletic performance. We must be rigorous both during training and in competition with regard to the replacement of liquids to avoid the possible negative effects of dehydration.[31]

Due to the climatic conditions and planning of the sessions, based on the football season, the research had the limitation of occurring on days with different environmental temperature characteristics, although it was possible to compensate efficiently the sweat losses, it would be interesting to know what the behavior would have been like if the weather conditions would have been similar. In addition, there was a small sample, since being a affiliate team players can be promoted to the professional team, if necessary, and participate in different trainings, which was considered within the exclusion parameters. Finally, during the dates planned for the execution of the tests, two players of the staff were injured, therefore, they could not participate in the regular training.

Conclusions

In conclusion, avoiding dehydration through a personalized recommendation guideline and based on the previous measurement of the sweating rhythm improved the jumping height and reduced the error rate of the penalti kick with visual signal, when compared with a rehydration *ad libitum*. The accuracy of the penalty kick was reduced by fatigue induced by the state of dehydration, especially with the decision-making variable. These data could indicate that a moderate dehydration could affect the muscular strength of the leg and reduce the motor precision during a simulated soccer penalty kick. In addition, the data suggest that using rehydration according to the thirst stimulus may not be the best strategy to avoid reductions in the physical and technical performance of soccer players.

Conflict of interest

The research was solely funded by the corresponding authors' institution. The results are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

References

1. Broad EM, Burke LM, Cox GR, Heeley P, Riley M. Body weight changes and voluntary fluid intakes during training and competition sessions in team sports. Int J Sport Nutr. 1996;6:307–20.
2. Godek SF, Godek JJ, Bartolozzi AR. Hydration status in college football players during consecutive days of twice a day preseason practices. Am J Sports Med. 2005;33:843–51.
3. Shirreff SM, Aragon-Vargas LF, Chamorro M, Maughan RM, Serratosa L, Zachwieja JJ. The sweating response of elite professional soccer players to training in the heat. Int J Sports Med. 2005;26:90–5.
4. Stofan JR, Jachwieja JJ, Horswill CA, Murray R. Sweat and sodium losses during practice in professional football players. Med Sci Sports Exerc. 2003;34:S113.
5. Stofan JR, Jachwieja JJ, Horswill CA, Murray R, Eichner ER, Anderson S. Sweat and sodium losses in NCAA football players: a precursor to heat cramps. Int J Sport Nutr Excerc Metab. 2005;15:641–52.
6. Mustafa KY, Mahmound NE. Evaporative water loss in African soccer players. J Sports Med Phys Fitness. 1979;19:181–3.
7. Kirkendall DT. Effects of nutrition on performance in soccer. Med Sci Sports Exerc. 1993;25:1370–4.
8. Godek SF, Bartolozzi AR, Godek JJ. Sweat rate and fluid turnover in American football players compared with runners in a hot and humid environment. Br J Sports Med. 2005;39:205–11.
9. Maughan RJ, Merson SJ, Broad NP, Shirreffs SM. Fluid and electrolyte balance in elite male football (soccer) players training in a cool environment. J Sports Sci. 2005;23:73–9.
10. FIFA. Laws of the gameZurich: Federation International de Football; 1995.
11. Montain SJ, Smith SA, Mattot RP, Zientara GP, Jolesz FA, Sawka MN. Hypohydration effects on skeletal muscle performance and metabolism: a 31P-MRS study. J Appl Physiol. 1998;84:1889–94.
12. Cian C, Barraud PA, Melin B, Raphel C. Effects of fluid ingestion on cognitive function after heat stress or exercise-induced dehydration. Int J Psychophysiol. 2001;42:243–51.
13. Greiwe JS, Staffey KS, Melrose DR, Narve MD, Knowlton RG. Effects of dehydration on isometric muscular strength and endurance. Med Sci Sports Exerc. 1998;30:284–8.
14. Bosco C, Luhtanen P, Komi PV. A simple method for measurement of mechanical power in jumping. Eur J Appl Physiol Occup Physiol. 1985;50:273–82.
15. Pedersen J, Lönn J, Hellström F, Djupsjöbacka M, Johansson H. Localized muscle fatigue decreases the acuity of the movement sense in the human shoulder. Med Sci Sports Exerc. 1999;31:1047–52.
16. Fritzsche RG, Switzer TW, Hodgkinson BJ, Lee SH, Martin JC, Coyle EF. Water and carbohydrate ingestion during prolonged exercise increase maximal neuromuscular power. J Appl Physiol. 2000;88:730–7.
17. Montero I, León OG. A guide for naming research studies in Psychology. I J Clin Health Psychol. 2007;7:847–62.
18. Armstrong LE, Maresh CM, Castellani JW, Bergeron MF, Kenefick RW, LaGasse KE, et al. Urinary indices of hydration status. Int J Sport Nutr. 1994;4:265–79.
19. Borg G. Simple rating methods for estimation of perceived exertion. Phys Work Effort. 1975:39–46.
20. Sawka M, Burke L, Eichner E, Maughan R, Montain S, Stachenfeld N. American college of sport medicine position stand exercise and fluid replacement. Med Sci Sports Exerc. 2007;39:377–90.
21. Ramos-Jiménez A, Hernández-Torres R, Wall-Medrano A, Torres-Durán P, Juárez-Oropeza M, Viloria M, et al. Respuestas fisiológicas asociadas al género e hidratación durante el spinning. Nutr Hosp. 2014;29:644–51.
22. Maughan R, Whiting P, Davidson R. Estimation of plasma volume changes during marathon running. Br J Sports Med. 1985;19:138–41.
23. Sawka M, Noakes T. Does dehydration impair exercise performance? Med Sci Sports Exerc. 2007;39:1209–17.
24. Bigard X, Sánchez H, Claveyrolas G, Martin S, Thimonier B, Arnauld M. Effects of dehydration and rehydration on EMG changes during fatiguing contractions. Med Sci Sports Exerc. 2001;33:1694–700.
25. Casa D, Armstrong L, Hillman S, Montain S, Reiff R, Rich B, et al. National athletes trainers' association position stand: fluid replacement for athletes. J Athl Train. 2000;35:212–24.
26. González-Alonso J, Calbet J, Nielsen B. Muscle blood flow is reduced with dehydration during prolonged exercise in humans. J Physiol. 1998;15:895–905.
27. McGregor SJ, Nicholas CW, Lakomy H, Williams C. The influence of intermittent high-intensity shuttle running and fluid ingestion on the performance of a soccer skill. J Sports Sci. 1999;17:895–903.
28. Fitts PM. The information capacity of the human motor system in controlling the amplitude of movement. J Exp Psychol. 1954;47:381–91.
29. Viitasalo JT, Kyröläinen H, Bosco C, Alen M. Effects of rapid weight reduction on force production and vertical jumping height. Int J Sports Med. 1987;8:281–5.
30. Armstrong LE, Kraemer WJ, Volek JS, Maresh CM, Judelson DA, Farrell MJ, et al. Effect of hydration state on strength power and resistance exercise performance. Med Sci Sports Exerc. 2007;39:1817–24.
31. Barbero JC, Castagna C, Granda J. Deshidratación y reposición hídrica en jugadores de fútbol sala: efectos de un programa de intervención sobre la pérdida de líquidos durante la competición. Eur J Hum Movement. 2010;17:93–106.