Serbian Journal of Sports Sciences
2007, 1(1-4): 15-20, www.sjss-sportsacademy.edu.yu
UDC 796.325 ISSN 1452-8827

**Original article**
Received: 19 Mart 2007
Accepted: 29 Mart 2007

# BODY FLUID LOSS DURING FOUR CONSECUTIVE BEACH HANDBALL MATCHES IN HIGH HUMIDITY AND ENVIRONMENTAL TEMPERATURES

Dimitrios Karras[1], Costas Chryssanthopoulos, and Vasilios Diafas

*Department of Physical Education and Sport Science, University of Athens, GREECE*

**Abstract** The present study investigated the fluid losses that occur in beach handball (BH) when ambient temperature (T) and humidity (H) are high (T > 28 °C; H > 80%). Seven female handball (HB) players who belonged to different first division Greek HB teams took part in an international BH tournament as members of a BH team. In the tournament the players played 4 consecutive matches within two days. During the warm-up, match, and half-time every player ingested one litre of water. Body fluid losses (BFL) were 0.6-0.8 L whereas when BFL were corrected for fluid intake these values were 1.6-1.8 L respectively. When fluid intake was not taken into account, BFL corresponded to about 1% - 1.4% of body mass (BM). When fluid intake was considered, the BFL corresponded to 2.8% - 3.2% of BM. Beach handballers are advised to practice drinking in training so that they will be able to consume fluid during matches that is about 2% of their BM when humidity and temperatures are high. This practice will assist players to avoid excessive hypohydration and maintain body fluid balance.

***Key words:*** beach handball, fluid intake, fluid loss, females

## INTRODUCTION

Beach handball (BH) is a relatively new but more and more popular game. Each game has two periods of 10 min duration with 5 min interval between. If both teams have scored equal number of goals in one period, the period is extended with the "sudden death" procedure that does not last more than one minute. In order to win a game a team has to have won both periods, otherwise the procedure "one against the goalkeeper" is played by 5 players of each team. The game is played 4 against 4 and each team can have up to 4 players as substitutes. The number of substitutions is unlimited. The dimensions of the court are 27 m length and 12 m width, and each goalkeeper's area is 6 m long. The majority of the BH competitions take place during the summer and in courts situated by the sea. Therefore, the environmental conditions during such games may be characterised by relatively high ambient temperatures (i.e.: > 25 °C) and also by elevated humidity (i. e.: > 65 %). Under such conditions the fluid balance of the athletes is seriously challenged [13].

If athletes do not consume enough fluid to maintain euhydration then a detriment in performance is almost certain. From empirical observations during training sessions we have observed that BH athletes may lose almost one litre of fluid. This body water loss may be close to 2% of body mass for female BH players. Even such small (2%) water deficits have been shown to reduce exercise performance [7]. Furthermore, the exercise induced water deficit will also challenge the cardiovascular system of the athletes and this may be reflected by elevated heart rate (HR) [11].

Despite the fact that numerous studies have been conducted on handball (HB), the vast majority of these investigations were focused on orthopaedic and injury issues. In addition, much research has been carried out on body fluid balance when exercise is performed in warm/humid environment. However, most of this research has been conducted on cycling, running or on team sports such as soccer/football, and rugby [5]. To the best of the authors' knowledge fluid balance during HB and especially BH matches, where athletes may be exposed to higher ambient temperatures than the players in indoor HB games, has not been investigated. Therefore, the main purpose of this study was to observe fluid losses that occurred during BH matches and whether the

provision of one litre of water would be enough to maintain body fluid balance. Furthermore, the HR responses during such matches were also indirectly recorded and evaluated.

## MATERIAL AND METHODS

### SUBJECTS / PLAYERS

Seven female HB players that belonged to different first division Greek HB teams participated in the study. All players had an experience of at least 4 years in BH at the national and international level and as members of a BH team had won twice the Greek National Beach Handball Championship. Their age, body mass (BM), height, body mass index, and estimated maximum heart rate (HRmax = 220-Age) were 26.6 ± 2.4 years, 58.1 ± 2.3 kg, 172 ± 2 cm, 19.5 ± 0.6 $kg \cdot m^{-2}$, and 193 ± 2 $b \cdot min^{-1}$ respectively (mean ± SE).

### PROCEDURE AND MEASUREMENTS

The team participated in an international European Federation's BH tournament that took place in Sarkoy (Turkey) during the last week of August of the year 2003. The team was actually the winner of this tournament. The players played 4 matches that took place during two consecutive days. On the first day 3 matches were played and the fourth match was played the next day in the morning. The games started at 10:45, 14:00, 16:45 on the first day, and at 12:45 the on the second day, $1^{st}$, $2^{nd}$, $3^{rd}$, and $4^{th}$ match respectively. In the first two games the Greek team played against two Turkish clubs which were beaten by 2-0 and 2-1 respectively. In the third and fourth match the Greek team played against a Bulgarian team. In the third game the Greek team won by 2-0 whereas in the last game the Bulgarian team was the winner by 2-0. All players that formed the other 3 teams of the tournament belonged to the first division indoor HB clubs.

Before the beginning of the warm-up, that lasted five minutes in all games, as well as immediately after the end of each match, the BM of the players was recorded using a weight balance with accuracy ± 0.5 % and graduation 0.1 kg *(Sega 710)*. The balance was placed on a solid and horizontal surface and was calibrated against known weights of 5, 10, and 20 kg before every game. The players were weighed wearing their sporting gear after removing any visible sand and after drying themselves from sweat. Every player's sporting gear was weighed before every warm-up as well as after each match using a balance scale with accuracy ± 2 % and graduation 1 g *(Philips Essence HR 2394)*. This balance scale was also placed on a solid and horizontal surface. The mass of the sporting gear before and after each match was subtracted from the corresponding BM values of each player before and after every game so that the BM before ($BM_b$) and after ($BM_a$) each match were calculated. Body fluid loss (BFL) was calculated by subtracting $BM_a$ from $BM_b$. Also, both the BM after each match and the fluid loss in every game were corrected for fluid intake.

From empirical observations during training we have found that players lose about 1 l in body fluids. Therefore, in order to maintain fluid balance during the tournament every player ingested one litre of water during every match, warm-up, and half-time. The half-time period lasted 5 min. The amount of fluid was consumed at times selected by the players without any guided time plan. However, the players were instructed to ingest all the fluid by the end of each match something that in fact was achieved. Subjects did not urinate during the warm-up, match and half-time and no measurements were made for urine output after the games.

Since no heart rate monitors were allowed during the 4 matches by the officials and in order to indirectly estimate the intensity of exercise and the impact of this physical activity on the cardiovascular system, every player measured her HR at the end of the warm-up period as well as immediately at the end of each game. The HR measurement was achieved using the palpation method on the carotid artery. The HR measurement lasted 15 sec and the recorded pulse value was extrapolated to a 60 sec period. The players were very familiar with this procedure since it was routinely used in almost every training session.

The ambient dry bulb temperature (T) was measured using a thermometer *(Lambrecht 251, USA)* placed in the shade away from the direct sunlight, whereas the relative humidity (H) was measured using an electronic hydrometer *(Lambrecht 250, USA)*. Furthermore, speed wind (SW) was continuously monitored using a speed wind meter *(Belfort 1438, USA)*. From the T and H values the heat index (HI) was calculated according to the following formula that is appropriate for T > 80 $^oF$ and H > 40% and has an error of ± 1.3 $^oF$ [12]:

$$HI = -42.379 + (2.04901523 \times T) + (10.1433127 \times H) - [(0.22475541 \times T \times H)] - [(6.83783 \times 10^{-3}) \times T^2] - [(5.481717 \times 10^{-2}) \times H2] + [(1.22874 \times 10^{-3}) \times T^2 \times H] + [(8.5282 \times 10^{-4}) \times T \times H^2] - [(1.99 \times 10^{-6}) \times T^2 \times H^2] \quad (1)$$

Where: H = relative humidity, T - ambient dry bulb temperature degrees in Fahrenheit (F).

The HI is an index that determines the so-called "apparent temperature" which in other words shows how hot the heat-humidity combination makes it feel.

Finally, it should be mentioned that before participation in the tournament all players had followed a two-month preparation/acclimatization period during which they trained for 3 times a week, in the mornings, and at times between 10:00 and 12:00. At these days the T and H averaged 30.2 ± 0.2 $^0$C and 44 ± 1 % respectively (range: T: 27.5-33.9 $^0$C; H: 20-65 %). Also, during that period the team participated in various matches of the National Championship which, in fact, they won.

### Statistical Analysis

The statistical analysis was made using the SPSS statistical package (version 11.0). Body mass, HR, and %HRmax before and after each match were analysed using two-way ANOVA (pre and post game values x 4 matches) for repeated measures. Fluid loss, fluid loss expressed as a percentage of pre-match body mass, and HR increase (HRin) (i.e.: the difference between the HR at the end of each game and the HR at the end of the warm-up) were analysed using one-way ANOVA for repeated measures.

To identify differences between means the simple main effect method was used where adjustment for multiple comparisons was made using the Bonferroni technique. Data are reported as means ± SE. The level of significance was set at $p < 0.05$.

## Results

All environmental data during the four matches are presented in Table 1. Ambient temperature ranged from 81 $^o$F to 84 $^o$F and H from 80% to 90%. The combination of the high T and especially the very high H resulted in higher "apparent temperatures" than the recorded T values as reflected by the HI data (Table 1). These "apparent temperatures", calculated in $^o$F using the aforementioned HI formula, were about 6%, 18% and 13% higher at the 1$^{st}$, 2$^{nd}$ and 3$^{rd}$/4$^{th}$ match respectively than the corresponding T data in $^o$F (Table 1).

The $BM_b$, $BM_a$, and also the body mass after each game corrected for water intake ($BMC_a$) are presented in Table 2. Furthermore, BFL, body fluid loss corrected for water intake (BFLC), body fluid loss expressed as a percentage of body mass before each game (%BFL), and body fluid loss corrected for fluid intake and expressed as a percentage of body mass before each game (%BFLC) are presented in Table 2. As could be expected BM was significantly reduced ($p < 0.01$) after each game when fluid intake was taken into account (i.e.: $BM_b$ vs. $BMC_a$). Surprisingly, however, even though the players consumed one litre of water during each game $BM_a$ was still lower ($p < 0.01$) compared to $BM_b$ in every match. The %BFL varied from 1% - 1.4% when no correction for water intake was made whereas when the fluid consumed during exercise was taken into account (%BFLC) these values ranged between 2.8% and 3.2%. However, no differences in BM were observed between matches.

Finally, HR before ($HR_b$) and HR after ($HR_a$) each match, percentage HRmax before ($\%HRmax_b$) and after ($\%HRmax_a$) every game and HR increase ($HR_{in}$) are also presented in Table 2. As a result of game participation $HR_a$ and $\%HRmax_a$ were higher ($p < 0.01$) compared to the $HR_b$ and $\%HRmax_b$ respectively. At the end of exercise mean HR varied from 160 to 182 b·min$^{-1}$. These values corresponded to 83% and 94% respectively of the theoretical HRmax of the players. However, there was a large variation among players in each match (Table 2) or even for the same player from match to match. The HR variance for the same subject between matches was up to 12 b·min$^{-1}$ in $HR_b$ , and up to 64 b·min$^{-1}$ in $HR_a$. The HR responses between matches were not significantly different.

***Table 1***. Ambient dry bulb temperature (T), relative humidity (H), speed wind (SW), and Heat Index (HI) values during the four beach handball matches.

| *Variable* | *1st Match* | *2nd Match* | *3rd Match* | *4th Match* |
|---|---|---|---|---|
| T ($^{o}$F) | 81 | 84 | 84 | 84 |
| T ($^{o}$C) | 27 | 29 | 29 | 29 |
| H (%) | 80 | 90 | 82 | 82 |
| SW ($m.s^{-1}$) | 4.5 | 4.5 | 3.5 | 3.5 |
| HI ($^{o}$F) | 86 | 99 | 95 | 95 |
| HI ($^{o}$C) | 30 | 37 | 35 | 35 |

***Table 2***. Body mass before match ($BM_b$), body mass after match ($BM_a$), body mass after each match corrected for water intake ($BMC_a$), body fluid loss (BFL), body fluid loss corrected for water intake (BFLC), % body fluid loss (%BFL), % body fluid loss corrected for fluid intake (%BFLC), HR before ($HR_b$) and HR after ($HR_a$) each match, % HRmax before (%$HRmax_b$) and after (%$HRmax_a$) every game and HR increase ($HR_{in}$). Numbers in parentheses indicate range of values. Data are means ± SE.

| *Variable* | *1st Match* | *2nd Match* | *3rd Match* | *4th Match* |
|---|---|---|---|---|
| $BM_b$ (kg) | 58.0 ± 2.3 (50.9-63.9) | 57.7 ± 2.4 (50.4-63.9) | 57.5 ± 2.3 (49.9-62.8) | 57.5 ± 2.3 (49.9-64.4) |
| $BM_a$ (kg) | 57.4 ± 2.3* (49.9-63.4) | 57.1 ± 2.3* (49.9-62.4) | 56.8 ± 2.3* (49.4-62.4) | 56.7 ± 2.3* (48.8-62.7) |
| $BMC_a$ (kg) | 56.4 ± 2.3* (48.9-62.4) | 56.1 ± 2.3* (48.9-61.4) | 55.8 ± 2.3* (48.4-61.4) | 55.7 ± 2.3* (47.8-61.7) |
| BFL (l) | 0.6 ± 0.1 (0.2-1.0) | 0.6 ± 0.2 (0.0-1.5) | 0.7 ± 0.1 (0.3-1.1) | 0.8 ± 0.2 (0.3-1.5) |
| BFLC (l) | 1.6 ± 0.1 (1.2-2.0) | 1.6 ± 0.2 (1.0-2.5) | 1.7 ± 0.1 (1.3-2.1) | 1.8 ± 0.2 (1.3-2.5) |
| %BFL (%) | 1.0 ± 0.2 (0.4-2.0) | 1.0 ± 0.3 (0.5-2.4) | 1.3 ± 0.2 (0.4-2.0) | 1.4 ± 0.3 (0.6-2.4) |
| %BFLC (%) | 2.8 ± 0.2 (2.0-4.0) | 2.8 ± 0.2 (2.4-4.0) | 3.0 ± 0.2 (2.1-4.0) | 3.2 ± 0.3 (2.5-4.3) |
| $HR_b$ ($b{\cdot}min^{-1}$) | 95 ± 2 (88-104) | 93 ± 1 (88-96) | 95 ± 2 (92-104) | 94 ± 1 (92-96) |
| $HR_a$ ($b{\cdot}min^{-1}$) | 160 ± 10* (108-180) | 171 ± 6* (140-184) | 182 ± 3* (168-192) | 181 ± 3* (172-192) |
| %$HRmax_b$ (%) | 49 ± 1 (46-54) | 48 ± 1 (46-52) | 49 ± 1 (46-56) | 48 ± 1 (46-52) |
| %$HRmax_a$ (%) | 83 ± 5* (57-93) | 88 ± 3* (73-97) | 94 ± 2* (87-98) | 93 ± 1* (90-97) |
| HRin ($b{\cdot}min^{-1}$) | 65 ± 11 (4-88) | 78 ± 6 (44-92) | 87 ± 4 (72-96) | 87 ± 2 (80-96) |

* Significantly different from before match values ($p < 0.01$).

## DISCUSSION

The main finding of this study was that $BM_a$ was lower ($p< 0.01$) compared to $BM_b$ in every game (Table 2) despite the fact that one litre of water was ingested by the players during the warm-up, match time and half-time. This fluid loss was 0.6 – 0.8 l which corresponded to about 1.0 - 1.4 % of $BM_b$. This level of hypohydration was similar to that observed in soccer matches and training when ambient temperatures varied from 10 $^{o}$C to 26 $^{o}$C and H from 41% to 78% [3]. However, one should consider that a soccer match lasts at least 90 min whereas in the present study BH players were exposed to the aforementioned environmental and exercise conditions for about 30 min only (match time, warm-up, and half-time). When, however, body fluid loss was corrected for the ingested 1 l of water this fluid loss corresponded to 2.8 – 3.2 % of $BM_a$. The high level of body fluid loss observed in

the study is probably due to the relatively high ambient temperatures but mainly due to the very high humidity levels (80%-90%) that caused sweat to drip from the body, leading to non-functional fluid loss [2].

The water intake clearly reduced the water deficit that would have happened if no fluid had been ingested. Although performance was not evaluated as a separate variable in the study it seems logical to suggest that players were helped by the provision of water. In activities similar to the HB, such as basketball, it has been found that when no fluid is available the shooting ability in the second half of the game is reduced even in thermoneutral (T: 20.8 $^{o}$C; H: 64%) conditions [8].

Another factor that shows the importance of water intake was that the HI in the 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ match varied between 95 $^{o}$F and 99 $^{o}$F (Table 1). For such HI values "extreme caution" is recommended because athletes may suffer from sunstroke, muscle cramps, or even heat exhaustion especially with prolonged physical activity. The availability of water, the relatively short game period, and the aforementioned two-month training-acclimatization period possibly prevented such thermal disorders since no such symptoms were observed by any of the athletes in the present study [9].

The amount of fluid the players ingested during the game (1 litre) corresponded to about 1.7% of their $BM_b$ and was within the amount recommended by the American College of Sports Medicine (450 - 1050 ml for an exercise lasting for 30 - 40 min) [1]. It has been shown that athletes such as runners or game players who "carry their stomach" may experience gastrointestinal discomfort when fluids are ingested during competitions [4]. However, in the present study all the female players tolerated well the volume of water provided and no symptoms of gastrointestinal distress were reported.

The mean HR recorded almost immediately after each game ranged between 160 b·min$^{-1}$ and 182 b·min$^{-1}$ and corresponded to 83%-94% of the estimated HRmax of the players. These values are close to 85% of the HRmax reported by Loftin and co-workers during a 60-min HB match in 47-year-old male players [10]. However, there was a great variability between subjects (108 - 192 b·min$^{-1}$), or even for the same player from game to game (108 - 172 b·min$^{-1}$) in the $HR_a$. This has also been observed by other investigators who measured HR during HB games possibly more accurately than in the present study [6, 14]. This high variability of HR during BH games is probably the result of the endless changes in rhythm inherent in HB [6]. Nevertheless, these changes in the rhythm may be somehow fewer in BH than in the HB played indoors possibly due to smaller court dimensions and the greater difficulty the players have in moving around in BH courts.

The HR measurements in the present study might not be carried out with very high accuracy, due to the fact that no heart rate monitors were allowed by the officials. However, this study, as well as other investigations [6, 10, 14], shows that the cardiovascular system during handball activities is seriously challenged.

## CONCLUSION

In conclusion, during BH matches performed in relatively high environmental temperatures (> 28 $^{0}$C) and high humidity levels (> 80%) excessive body fluid loss takes place. Even though one litre of water is consumed during the warm-up, match, and half-time, female players are hypohydrated to a small degree (1%- 1.4%). It is recommended that BH players should practice drinking during training sessions so that they would be comfortable with consuming fluid during competitions that is close to 2% of their body mass. This practice will help players to maintain body fluid balance after matches and avoid a possible gradual dehydration from game to game. The provision of other fluids such as sports drinks as well as the study of fluid balance in BH activities needs further investigation.

## PRACTICAL APPLICATION

When temperature (T) and humidity (H) are high (T > 27 $^{o}$C; H > 80 %) beach handball players are advised to consume fluids that correspond to about 1.5-2% of their body mass. This should first be practised in training. Furthermore, acclimatization to warm (> 28 $^{o}$C) environments prior to competing in warm/humid conditions seems to help avoiding thermal disorders during competition.

### ACKNOWLEDGEMENTS

*The authors gratefully acknowledge Dr. Ziakopoulos , Director of the Division of the Hellenique National Service of Meteorology, Ministry of Defense,for providing the necessary equipment for the measurements of the various environmental parameters reported in the study.*

## REFERENCES


1. American College of Sports Medicine (1996). Position Stand: Exercise and fluid replacement. *Med Sci Sports Exerc.,* 28(1): i-vii.
2. American College of Sports Medicine, American Dietetic Association and Dietitians of Canada (2000). Joint Position Statement: Nutrition and Athletic Performance. *Med Sci Sports Exerc*., 32(12): 2130-2145.
3. Broad E. M., Burke L. M., Cox G. R., Heeley P., & Riley M. (1996). Body weight changes and voluntary fluid intakes during training and competition sessions in team sports. *Int J Sport Nutr*., (6): 307-320.
4. Brouns F., Saris W. H. M., & Rehrer N. J. (1987). Abdominal complaints and gastrointestinal function during long-lasting exercise. *Int J Sports Med*., 8: 175-189.
5. Burke L. M., & Hawley J. A. (1997). Fluid balance in team sports. Guidelines for optimal practices. *Sports Med*., 24(1): 38-54.
6. Delamarche P., Gratas A., Beillot J., Dassonville J., Rochcongar P., & Lessard Y. (1987). Extent of lactic anaerobic metabolism in handballers. *Int J Sports Med*., 8(1): 55-59.
7. Graig F. N., & Cummings E. G. (1966). Dehydration and muscular work. *J Appl Physiol*., 21(2): 670-674.
8. Hoffman J. R., Stavsky H., & Falk B. (1995). The effect of water restriction on anaerobic power and vertical jumping height in basketball players. *Int J Sports Med*., 16(4): 214-218.
9. Jeukendrup A. & Gleeson M. (2004). *Sports Nutrition. An introduction to energy production and performance* (pp. 175 – 176). Champaign, IL., USA: Human Kinetics.
10. Loftin M., Anderson P., Lytton L., Pittman P., & Warren B. (1996). Heart rate response during handball singles match-play and selected physical fitness components of experienced male handball players. *J Sports Med Phys Fitness.*, 36(2): 95-99.
11. Montain S. J. & Coyle E. F. (1992). Influence of graded dehydration on hyperthermia and cardiovascular drift during exercise. *J Appl Physiol*., 73(4): 1340-1350.
12. National Weather Service (2001). "Heat index". *National Weather Service Birmingham*, Alabama, USA; www.srh.noaa.gov/bmx/
13. Sawka M. N., & Pandolf K. B. (1990). Effects of body water loss on physiological function and exercise performance. In: Gisolfi C. V., & Lamb D. R. (Eds.). *Fluid homeostasis during exercise. Perspectives in Exercise Science and Sports Medicine,* Benchmark Press Inc., 3: 1-38.
14. Soares J. M. C. (1988). Telemetrical study of handball goal-keeper's heart rate during official and non-official competitions in the attack and defense phases. *J Sports Med*., 28: 220-223.



*Address for correspondence:*

Dr. Dimitrios Karras
Department of Physical Education and Sport Science,
University of Athens,
41 Ethnikis Antistasis Street,
Dafni, 172 37 Athens, GREECE
Phone: (Athens) 210-7276124
Fax.: (Athens) 210-7276124
***E-mail***: dkarras@phed.uoa.gr