Kinematics and thermal sex-related responses during an official beach handball game in Costa Rica: a pilot study

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Summary

Beach handball is a sport characterized by being a complex, dynamic, fluid of constant exchange of offensive and defensive plays. The objectives of this study was describe and analyzing the kinematics and thermal responses in male and female beach handball players during an official game in Costa Rica. Sixteen beach handball players participated, eight women and eight men. All participants were grouped by sex in two teams, male team and female team and every team played against the same adversary. Every game had two periods, 10 min each, 5 min rest, were made. GPS devices were used to quantify the kinematics responses, heart rate was obtained through cardiac monitors, internal temperature was measured using CorTemp pills and body weight loss, sweating rate and fluid intake were calculated. The main results shown significant differences between men and women in the total distance (m) ($p< .01$), average speed (km/h) ($p< .01$), maximum speed (km/h) ($p= .022$), total impacts (g) ($p< .01$), body weight change (%) ($p= .038$), sweat rate (ml/min) ($p< .01$), and liquid intake (ml) ($p< .01$). Internal temperature (°C) was different between men and women after warn-up ($p= .044$) and final first period ($p= .007$). Also, it found a significant decreased in the maximum speed (km/h) ($p= 0.10$) and body load (AU) ($p= .026$) in the second period both in men and women. In conclusion, beach handball is a sport that is played a medium-high intensity [HR mean (men= 156.1±17.5 bpm, women= 158.1±19.8 bpm)]. As a practical implication, this study provides information that may be used as a base or support to plan and designing training methodologies according to the specific kinematics and thermal requirements of beach handball players.

Key words:
Sport. Dehydration. Heart rate. Body temperature. Kinematics.

Respuestas cinemáticas y termorreguladoras relacionadas con el sexo durante un partido oficial de balonmano playa en Costa Rica. Un estudio piloto

Resumen

El balonmano de playa es un deporte caracterizado por ser complejo, dinámico y fluido de constante intercambio de acciones defensivas y ofensivas. El objetivo de este estudio fue describir y analizar las respuestas cinemáticas y termorreguladoras en jugadores masculinos y femeninos de balonmano de playa durante un partido oficial en Costa Rica. Dieciséis jugadores participaron, ocho hombres y ocho mujeres. Todos los participantes fueron agrupados según su sexo en dos equipos, masculino y femenino, cada equipo jugó un partido contra otro equipo. Cada partido tuvo dos periodos de 10 min cada uno, con 5 min de descanso. Se utilizaron dispositivos GPS para cuantificar las respuestas cinemáticas, la frecuencia cardiaca fue obtenida mediante monitores cardiacos, se midió la temperatura interna utilizando píldoras TemCorp y se calculó la pérdida de peso corporal, la tasa de sudoración y la ingesta de líquido. Los principales resultados mostraron diferencias significativas entre hombres y mujeres en la distancia total recorrida (m) ($p< 0,01$), velocidad promedio (km/h) ($p< 0,01$), velocidad máxima (km/h) ($p= 0,022$), impactos totales (g) ($p< 0,01$), cambio en el peso corporal (%) ($p= 0,038$), tasa de sudoración (ml/min) ($p< 0,01$), y líquido ingerido (ml) ($p< 0,01$). La temperatura interna (°C) entre hombres y mujeres fue diferente después del calentamiento ($p= 0,044$) y al final del primer tiempo ($p= 0,007$). También, se encontró una disminución significativa en la velocidad máxima (km/h) ($p= 0,10$) y carga corporal (UA) ($p= 0,026$) en el segundo periodo en hombres y mujeres. En conclusión, el balonmano de playa es un deporte que se juega a intensidad media a alta [FC promedio (hombres= 156,1±17,5 lpm, mujeres= 158,1±19,8 lpm)]. Como implicación práctica, este estudio aporta información que puede ser usada como base para diseñar metodologías de entrenamiento acorde con los requerimientos cinemáticos y termorreguladores de los jugadores de balonmano de playa.

Palabras clave:
Deporte. Deshidratación. Frecuencia cardiaca. Temperatura corporal. Cinemática.

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Introduction

Currently, several sports federations have been developing and promoting disciplines that can to be played on the beach. Soccer, volleyball and recently the handball are among the most popular sports around the world, which are practiced on the sand, and in many cases in hot environments.

Beach handball is a sport characterized by being a complex, dynamic, fluid of constant exchange of offensive and defensive plays. It differs from the indoor handball in the conformation of the teams and in the tactical actions[1,2]. Eight players participate per team during a beach handball match, which can participate in offensive-defensive actions, only attack or only defensive, according to the tactical dispositions. Another difference is the score, which depends on the technical and motor complexity of the executions, for example, the players can make acrobatics moves to score, which will be awarded a double value (2 points) to the team.

There are few studies that have analysed the intensity of efforts in sports played on the beach. Researches so far published in beach handball have used heart rate (HR) as a parameter to evaluate the physical efforts of the players; it suggests that the practice of beach handball is a vigorous activity[3-6]. In this sense, Lara-Cobos[3] during the 13 matches and Silva *et al.*[4] during a game of female beach handball tournament found that the HR was maintained between 139 and 167 bpm, while other authors[5] reported for male players a mean HR of 164.3 ± 14.5 bpm during three matches.

As to the kinematic responses, recently a comparation was made[6] during four beach handball games the kinematic responses between sexes. They found that men covered more distance than women both in the first and the second period, likewise, men travel more meters at high intensities than women. Total body impacts and body load were higher in women than in men.

Regarding other sports practiced in similar conditions, the mean HR during a beach volleyball match is 149.5 ± 14.1 bpm[5], and in beach soccer matches is 165 ± 20 bpm[7]. The beach soccer players perform high-intensity activities during 3% to 9.5% of the match[7,8].

In addition to the physical efforts performed by the players during a beach handball match, it should also consider the thermal sensation and the effects caused by environmental conditions such as temperature and relative humidity[9,10]. The environmental conditions in combination with the intensity and duration of physical effort can generate excessive levels of sweating, dehydration, loss of body weight and elevation of body temperature in athletes, which may cause alterations in the thermoregulation of the body and in the cardiovascular system of the organism, which increases the possibility of athletes suffering health problems[11-14].

Karras, Chryssanthopoulos, and Diafas[15] evaluated the effect of playing beach handball matches in high humidity and environmental temperatures on the body fluid loss in female players. Zetou, Giatsis, Mountaki, and Komninakidou[16] did not find states of dehydration among elite players and not the elite beach volleyball, and the weight loss reported not exceed 800 grams per player during a tournament in high temperature (>33 °C). During soccer matches in the professional and recreational players, it has been reported an internal body temperature ranged between 37.5 °C and 39.5 °C[17,18].

Based on the scientific evidence so far reported about the beach handball, and the fact that in Costa Rica there are no studies on beach handball, only a few studies worldwide has been performed. To have a deeper understanding about this popularity increasing sport, the objective of this study was to describe and compare the kinematic responses, the change in the body weight, fluid balance and the internal temperature between male and female beach handball players during an official game in Costa Rica.

Material and method

Participants

Sixteen beach handball players participated, eight women and eight men. All players were team members of Costa Rican indoor handball top league club, all participated of an official beach handball tournament organized by the Federación Costarricense de Balonmano. The players were, apparently healthy, well trained (2-3 times/week) and played at least 1 official game/week, with none neuromuscular, cardiovascular or neurological disorders. Participant's characterization is shown in Table 1.

Ethical statement

All subjects were informed of the details of the experimental procedures and the associated risks and discomforts. Each subject gave written informed consent according to the criteria of the Declaration of Helsinki regarding biomedical research involving human subjects[19].

Equipment and procedures

Firstable, all the study methods and informed consent were given to the participants. The characterization of the participants was made taking, weight (Elite Series BC554, Tanita-Ironman®, ± 0.1 kg sensibility), height, age, sport experience. The weight was measured pre- and post- games.

All participants were grouped by sex in two teams, male group (MG) and female group (FG). Each game was conducted under official International Handball Federation rules, the same referees and against the same rival (handball club). Two official games of two periods, 10 min each, 5 min rest, were made. The participants were provided with

Table 1. Participant´s characterization data.

	Men (n= 8)	Women (n= 8)	Total (n= 16)
Age (years)	25.6 ± 9	26 ± 7	25.8 ± 7.8
Weight (kg)	78.1 ± 6.5	70.5 ± 12.7	74.3 ± 10.5
Height (cm)	177.8 ± 4.2	166.8 ± 7.6	173.1 ± 8
Sport experience (years)	9.2 ± 9.8	6 ± 6	7.6 ± 8
Training frequency (days)	3.1 ± 2.3	3.1 ± 1.6	3.1 ± 1.9

an integrated accelerometer and global positioning cell (SP PRO X II, 15 Hz, GPSport, Canberra) to measure the kinematics variables, total distance, body load, impacts, speed average. The impacts above 5g were considered based in Di Salvo *et al*[20] because of their influence in fatigue previously reported. GPS test, re-test reliability is *r*=0.75[21].

To measure the thermal stress participants swallowed a pill to measure intestinal internal temperature (CorTemp 2000, HQInc. and CorTemp Data Recorder V4.3), with an accuracy of ±0.1°C following fabricant. The pill was subministrated an hour before the game[22], and the first measurement was made to each player after the warm-up (15 minutes before start game), the second measurement was made at end the first period and the third measurement was made at end second time. They also wear a heart rate monitor band (Coded T14, Polar, Finland) to measure the heart beats per minute (bpm).

The environmental heat stress was assessed through the Wet-Bulb Globe Temperature (WBGT), obtained with an QUESTemp°36 WBGT (3M, Wisconsin), with a fabricant precision of ± 0.5°C in temperature and ± 5% in relative humidity. It was sat 10 meters from the lateral line of the court. The mean WTGB thermal stress index was 36.1 ± 1.6.

The players got liquid intake *ad libidum*, the total intake (ml) was measured after the game to estimate the sweating rate (SR) of each participant per minute played through the following formula[23].

$$SR = \frac{(\text{weight pre} - \text{weight post}) + \text{total liquid intake (ml)}}{\text{total minutes played}}$$

To know the percentage of body weight lost (%BWL), the following formula was used[23]:

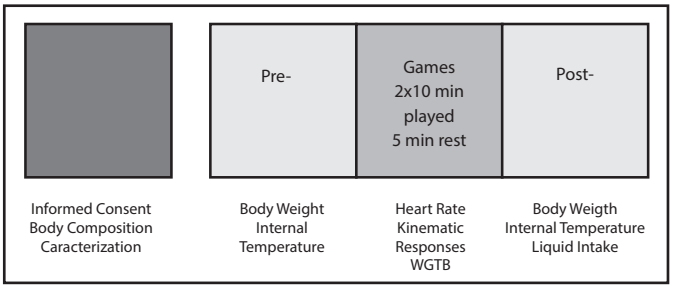
$$\%BWL = \frac{(\text{weight pre} - \text{weight post})}{\text{weight pre}} \times 100$$

The measures were taken immediately before, during and after the official games, for more detail see Figure 1.

Statistical analysis

Descriptive statistics were implemented through the mean (M) and their respective standard deviations (±SD). Results are expressed as means ± standard deviation (SD). The normality of the data of each of the variables was checked by Shapiro-Wilk test and the Levene test for homogeneity of variance; Box's *M* test and Mauchley Sphericity for the homogeneity of the covariance matrices of the dependent variables. Data were analysed using independent group *t*-Student and was subjected a 2 (sex) x 2 (moment) mixed model ANOVA, with an alpha set prior at $p < .05$. The magnitudes of the differences were analysed using the omega squared (ω_p^2) for ANOVA analysis and qualitatively categorized as follow: $\omega_p^2 > .15$ high effect, ω_p^2 around .06 moderate effect and $\omega_p^2 < .01$ as small effect (Cohen, 1977). The magnitudes of the differences were analysed using *d*-Cohen for t-student analysis categorized as follow: $d < .2$ small, *d* around .5 moderate and $d < .8$ large (Cohen, 1977). The data analysis was performed using Statistical Package for the Social Sciences (SPSS, IBM, SPSS Statistics, V 22.0 Chicago, IL, USA).

Figure 1. Schematical design.



Results

Table 2 shows heart rate and kinematics data by period and sex. There was not statistically significant interaction in cinematic variables in sex by period, as follow: total distance [$F_{(1, 14)}$: .039, p= .846, ω_p^2= 0 *(small)*], average speed [$F_{(1, 14)}$: .030, p= .865, ω_p^2= 0 *(small)*], maximum speed [$F_{(1, 14)}$: 2.431, p= .141, ω_p^2= .14 *(small)*], body load [$F_{(1, 14)}$: .005, p= .943, ω_p^2= 0 *(small)*], total impacts [$F_{(1, 14)}$: .252, p= 624, ω_p^2= 0 *(small)*].

The main effects analysis, presented significant differences by group (men *vs* women): total distance [$F_{(1, 14)}$: 12.847, $p < .01$, ω_p^2= .43 *(high)*], average speed [$F_{(1, 14)}$: 12.630, $p < .01$, ω_p^2= .42 *(high)*], total impacts [$F_{(1, 14)}$: 20.496, $p < .01$, ω_p^2= .59 *(high)*], were higher in men than women.

It was also found significant differences between first period and second period: maximum speed [$F_{(1, 14)}$: 8.912, p= .010, ω_p^2= .38 *(high)*], body load [$F_{(1, 14)}$: 6.233, p= .026, ω_p^2= .30 *(high)*] were lower in the second period.

Regarding the HR, no differences were found in heart rate between the sexes [$F_{(1, 14)}$: .046, p= .833, ω_p^2= .043 *(small)*], either between periods [$F_{(1, 14)}$: .192, p= .668, ω_p^2= .043 *(small)*].

Table 2. Heart Rate and kinematics data by period and sex.

	Men (n= 8)			Women (n= 8)		
	1st period	2nd period	Total	1st period	2nd period	Total
Heart rate (bpm)	155.9 ± 18.1	155.9 ± 19.8	156.1 ± 17.5	156.5 ± 23.1	159.3 ± 17	158.1 ± 19.8
Total distance (m)a	503.2 ± 138	435.5 ± 128.1	938.7 ± 211.8	332.2 ± 134.7	281.2 ± 87.7	613.4 ± 145
Average speed (km/h)[a]	3 ± .81	2.6 ± .8	2.8 ± .6	2 ± .8	1.7 ± .5	1.8 ± .4
Maximum speed (km/h)[a,b]	17.1 ± 1.8	14.7 ± 1.7	15.9 ± 2.1	14.0 ± 2.5	13.2 ± 2.0	13.6 ± 2.2
Body load (AU)[b]	9.4 ± 4	7.3 ± 3.7	16.7 ± 7.4	6.8 ± 3.2	4.6 ± 2.7	11.3 ± 4
Total impacts (g)[a]	696.6 ± 198.7	554.6 ± 188.4	1251.3 ± 302.8	397.9 ± 135.8	320.5 ± 168.5	718.4 ± 138.4

[a]Significant differences between sex p<.050.
[b]Significant differences between periods p<.050.

Table 3. Fluid intake, fluid balance and internal temperature variables by sex.

	Men (n=8)	Women (n=8)	ES *(rating)*
Weight change (%)	.1 ± .8[a]	.9 ± .8[a]	-.57 *(moderate)*
Sweat rate (ml/min)	72.2 ± 20[a]	41.3 ± 17.5[a]	.82 *(large)*
Liquid intake (ml)	1443.8 ± 399.5[a]	825 ± 349.5[a]	.82 *(large)*
Internal Temperature after warm-up (ºC)	38.1 ± .9[a]	39.0 ± .7[a]	.55 *(moderate)*
Internal Temperature final first period (ºC)	37.6 ± 1.6[a]	39.6 ± .8[a]	.80 *(large)*
Internal temperature final game (ºC)	37.9 ± 1.7	38.3 ± 1.6	.20 *(small)*

[a]Significant differences between sexes $p<.050$.

Table 3 shows fluid intake, fluid balance and internal temperature data by sex. There were found statistical differences between sex values of: the women presented a weight change % [$t_{(14)}$= -2.288, p= .038, d= -.57 *(moderate)*], internal temperature after warm-up [$t_{(14)}$= -2.217, p= .044, d= .55 *(moderate)*], and final first period [$t_{(14)}$= -3.173, p= .007, d= .80 *(large)*] higher than men. While men had a sweat rate per minute played [$t_{(14)}$= 3.296, p< .01, d= .82 *(large)*], and liquid intake [$t_{(14)}$= 3.297, p< .01, d= .82 *(large)*]; higher than women. No differences were found in internal temperature final game between sexes [$t_{(14)}$= -.956, p= .355, d= .20 *(small)*].

Discussion

The objective of this study was to describe and compare the kinematic responses, the change in the body weight, fluid balance and the internal temperature in male and female during an official beach handball game in Costa Rica.

Despite we have found few studies about beach handball, we discuss our results comparing it with handball indoor or with the scientific evidence so far reported about the beach handball and also other sport played on the sand in heat environment such as beach soccer and beach volleyball.

Kinematics responses

The total distance traveled per player in this study was 613.4 ± 145 m (38.8 ± 11.7 m/min) in average per game, which is lower than the reported by Pueo *et al.*[6] in elite beach handball. Men covered more distance (m) than women; it coincides with what is reported in the literature[6].

When comparing the distance traveled during beach handball match with indoor handball matches, differences are found. Female players U19 performed above 6300 m (105 m/min) per game, analyzed by video[25], whereas Michalsik and Aagaard[26] reported average distance traveled for men of 3627 ± 568 m and for women of 4002 ± 551 m. This could be due to the differences in the dynamics of play that are shown between both sport modalities (indoor vs beach) and in the surface where are practiced, in this sense the sand limits more the movements in comparing with the firm surface. Moreover, the results found in this study not agree with the total distance traveled in other sport played on sand like as beach soccer, who reports an average 1135 ± 26.8 m (97.7 ± 15.1 m/min) per game[7].

The maximum speed reached by the players in this study (14.7 ± 2.1 km/h) was shown below the value reported other sport as beach soccer during a match[7]. Men showed an average and maximum speed (km/h) higher than women. This may be related to the fact that men performed quickest movements and travel more distance running at high-intensity and in sprints[6]. The above, also might explain that men had more total body impacts than women.

It was also observed that the values of kinematics variables both men and women decreased in the second period. The maximum speed and body load was significantly, whereas the values of total distance, speed average and total impact not significantly. This decrease can be due onsets of muscle fatigue which causes alterations in the contractile responses, causing a decrease in the speed and efficiency of movements, reverberating in the physical performance during the game. Also, the extreme environment's conditions could affect. It have been notable that affect the physical performance of the athletes[9,10]. The WTGB in both games (36 ºC) was above the recommend values (<30 ºC) for sports practice[9,10].

No differences were found between sex and pre-post in kinematic responses and HR. Heart rate presented by the players during the matches coincides with that reported in studies of beach handball in female players[3,4,6], and in male players[5,6]. Compared with other sports such as soccer[7,8] and beach volleyball[5], heart rate also shows similar results. The above, demonstrate that handball matches were played at vigorous intensity as well have been reported in the literature[3-6]. Also, the results reinforce that beach handball is an activity that demands the use of aerobic and anaerobic energy systems.

Thermal responses

In this study, the percentage of body weight loss did not overcome 1% of the body weight of the players after the games. The body weight loss in men was 0.078 kg, while in women was 0.66 kg. These results are similar to the values reported of beach volleyball players[14]. However, this does not coincide with that reported by other authors, who found that beach handball players lost 2.8% body weight in average in beach handball matches of 30 minutes in high heat and humidity environments[16]. Likewise, these results are different from the reported in football players, in which it was observed that the body weight decreases 2.58 ± 0.88 kg after a match of 90 minutes[11].

This difference in the lost body weight could be due to the greater intake of liquid shown by men. For the case of the men, the liquid intake

was similar to that reported in male beach volleyball players[16] but the liquid ingested by women was below the reported[16]. Nevertheless in male soccer players the liquid intake reported during matches[11] is higher than the reported in this study, which can be due to the duration of the activities; a football match lasts 90 minutes, while a beach handball match only 20 minutes. This difference may increase or decrease the need to ingest fluid, mainly because the quantity of liquid intake during sports activities with times less than one hour is shown insufficient in accordance with the recommendations[27].

Also, we can view that men had a higher liquid intake and sweating rate than women. These results agree with the literature, which has indicated that the higher fluid intake increased sweating during physical exercise because the liquid is used in the sweating and evaporation process as the main physiological mechanism to regulate body temperature[11,12]. Therefore these results evidenced that an adequate hydration can prevent health problems for athletes relations with dehydration[27].

In this study sweating rate per minute was 72.3 ml for men and 41.3 ml for women, both values are shown over the sweet rate reported in futsal players (12.3 ml/min played) after the games[24]. In this sense, a possible justification will be the environmental conditions of temperature and relative humidity to which the players were exposed to their respective analyzed events.

As for the internal body temperature, although we could not obtain the basal temperature of the athletes or before the game, after the first time, the temperature was 38.6 ºC and remained similar at the end the second time 38.3 ºC, it which is similar to the internal temperature of soccer players during 90-minute matches[17,18]. In the measurement after warn up and the final first time, women had an internal temperature higher than men. This values found in our study are observed as normal for well-trained players, who activate their thermoregulatory responses (sweating and evaporations) faster and more efficiently to prevent the body from suffering heat problems.

However, one of the limitations of this study was not having taken the effective time each player in the match, as well as the considerations of the demands according to the game positions. For future research, it is recommended to complement kinematic analyses and thermal responses with tactical analyses, because they can help to understand players' responses in competitions. Besides that, we suggest that for future research the effect of kinematics, physiological and thermal responses on performance in beach handball match should be analyzed.

In conclusion, beach handball is a sport that is played a medium-high intensity, whose behaviors and demands differ from other sports due to its characteristics of game, which conditions the players to make short but explosive movements, therefore the distances traveled are short due the rules allow players not to actively participate throughout the game.

Also, our results suggest that the physical effort performed by the players are different between sexes, which cause the thermoregulatory mechanisms of each player responds to the physical efforts and because to the environmental conditions.

As a practical implication, this study provides information that may be used as a base or support to plan and designing training methodologies according to the specific kinematics and thermal requirements of beach handball.

Conflict of interest

The authors do not declare a conflict of interest.

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