2017, *Retos, 31,* 94-97
 ISSN: Edición impresa: 1579-1726. Edición Web: 1988-2041 (www.retos.org)

Physiological work areas in professional beach volleyball: A case study

Zonas de trabajo en jugadores profesionales de vóley playa: Un estudio de caso

José Manuel Jimenez-Olmedo, Basilio Pueo, Alfonso Penichet-Tomás, Juan José Chinchilla-Mira, José Antonio Perez-Turpin
Universidad de Alicante (España)

Abstract: In this paper, physiological areas of professional beach volleyball players are identified by combining notational analysis tools together with in-sync heart rate capture for specific time periods in competition games. The aim is to identify workload areas depending on the player´s position as well as the changes these areas undergo during real competitions. To this end, a case study is quantitatively analyzed and based on the Spanish National Team during the First International Training Tournament «Sixto Jimenez» played in Tenerife (Spain). Workload ranges differ between blocker player (from 77.71% to 89.13%) and defensive player (from 66.16% to 77.77%), both values are related to their individual HRmax. Furthermore, median HRmax values indicate that blocker player must support an increased workload of 84.78% compared to 71.71% of the defending player. Therefore, the specific position of the defenders established significant differences in their physiological responses.
Keywords: Beach volleyball, performance analysis, Sportcode, heart rate, Polar Team.

Resumen: En este artículo, se identifican las zonas de trabajo fisiológicas de los jugadores profesionales de vóley playa mediante la combinación de herramientas de análisis notacional junto con la captura sincronizada de la frecuencia cardíaca durante períodos de tiempo específicos en partidos de competición. El objetivo es identificar las áreas de trabajo en función de la posición del jugador, así como los cambios que experimentan durante las competiciones reales. Para ello, se analiza un caso de estudio cuantitativamente del equipo español durante el I Torneo Internacional de Entrenamiento Sixto Jiménez, disputado en Tenerife (España). Los rangos de carga de trabajo difieren entre el jugador bloqueador con 77,71% a 89,13% y el jugador defensor con 66,16% a 77,77%, ambos valores relacionados con su FCmáx. Por otra parte, los valores medios de FCmáx indican que el jugador bloqueador debe soportar una mayor carga de trabajo del 84,78% con respecto al 71,71% del jugador defensor. Por lo tanto, la posición específica del jugador defensor estableció diferencias significativas en sus respuestas fisiológicas.
Palabras clave: Vóley playa, análisis del rendimiento, Sportcode, frecuencia cardiaca, Polar Team.

Introduction

The study of physiological areas has been an important part of knowledge that helps to learn about the special characteristics of a wide variety of sports. In this way, it is necessary to distinguish the real physiological work areas to be able to develop correct and specific sport training. For this reason, not only in beach volleyball, but also in other sports, like boxing (Alvarez Berta, Cachón Zagalaz, Brahim, & Mateos Padorno, 2014) badminton (Álvarez, Campos, Portes, Rey, & Martín, 2016) triathlon (Zapico, Benito, Díaz, Ruiz, & Calderón, 2014), and football (soccer) (Casamichana, San Román-Quintana, Castellano, & Calleja-González, 2012; Nikolaidis, Ziv, Arnon, & Lidor, 2015; Pascual Verdú, Orbea Palacios, Carbonell, Alejandro, & Tossi, 2015) , there are studies that establish work areas.

On the one hand, there is evidence that internal load patterns in different sports are related to the quantity of volumes and intensities found during training or actual game situations and that they improve the performance of players (González Fimbres, Griego Amaya, Cuevas Castro, & Hernández Cruz, 2016).

On the other hand, there are a few studies related to the physiological response in beach volleyball players. Due to the interest of researchers working in these areas different studies have been conducted to establish physiological responses (Davies, 2000; Lorenz, Roll, Wiebke, & Jeschke, 2002). A study on the impact analysis and neuromuscular real beach volleyball games in the recovery of players has also been published (Magalhaes, Inacio, Oliveira, Ribeiro, & Ascensao, 2011).

These physiological responses have a direct relationship with different factors such as the rules of the game (Giatsis, 2003), the field, the number of players and the environmental conditions (Palao, Valadés, Manzanares, & Ortega, 2014). Of all these conditions mentioned so far, the most studied one has been the playing surface. The sand hinders the movement of players (Smith, 2006), but thanks to this fact, players have developed specific patterns of movement for beach volleyball (Cortell-Tormo, Perez-Turpin, Chinchilla-Mira, Cejuela, & Suarez, 2011; Perez-Turpin, Cortell-Tormo, Suarez-Llorca, Chinchilla-Mira, & Cejuela-Anta, 2009). The playing field forces players to perform more work to minimize the effect of force absorption by sand (Buscà, Alique, Salas, Hileno, & Peña, 2015). This resistance complicates movements such as jumping (Bishop, 2003), since vertical jump height on sand is lower than those made on rigid surfaces (Giatsis, Kollias, Panoutsakopoulos, & Papaiakovou, 2004).

Also, the small number of players increases the number of actions done by each one in contrast to distributing all technical actions necessary to develop the game (Koch & Tilp, 2009b) along different tactical complex (Koch & Tilp, 2009a).

Another factor influencing the physiological response is the role that the player adopts and that sets the pattern of the tactical game (Seweryniak, Mroczek, & Lukasik, 2013). In order to have a wide coverage in the net, blockers show higher values of weight and height than the defenders. For this reason, anthropometric and physical characteristics are crucial to play the role of a blocker or a defender (Palao, Gutiérrez, & Frideres, 2008).

Finally, another condition that influences the physiological response of beach volleyball players is temperature. The high temperatures in which sometimes they must play (Bahr & Reeser, 2012) affect and modify the heart rate of players (Coyle, 2004).

However, there is little knowledge about the physiological response of professional beach volleyball players in real games. In this study, a detailed analysis of heart rate values during a real game on a professional beach volleyball team is conducted as a case study. The main goal is to get insight into the actual physical demands on these players to provide information about the requirements of performance and subject physiological response.

Methodology

Materials and Methods

The case study focuses on a two-man Spanish beach volleyball team (Table 1), playing the most important beach volleyball competition, the FIVB World Tour.

Data collection was performed after players were informed about the aims and objectives of the study, giving their consent according to the guidelines of the Ethics Committee of the University of Alicante.

Table 1
Player's data

	Age	Height (cm)	Weight (kg)
Player 1	29	193.5	87.70
Player 2	24	194.6	92.05

Note: Both players are universal players, non-specific role

Two games of the First International Training Tournament «Sixto Jimenez» were analyzed, carried out in the high performance center T3

Fecha recepción: 13-01-16. Fecha de aceptación: 22-07-16
Jose Manuel Jimenez Olmedo
j.olmedo@gcloud.ua.es

Tenerife in the Canary Islands on the 1st, 2nd and 3rd of April, 2011. The games discussed correspond with quarters and semifinals played in the afternoon. This tournament brought some of the best European teams.

Videotape was made with a semi-professional mini-DV video camera, which was located in the frontal plane to capture the full field at a distance of 5.5 m from the end line on a step. In order to obtain a valid picture for further analysis, the camera is stabilized on a tripod with a lens at 3.5 m off the ground. This position of the camera allows the user to see clearly all the actions carried out during the recording of the game in both sides of the field (Callejon, 2006)

On the one hand, the heart rate values from both players were registered in real time using the monitoring system Polar Team II. On the other hand, video analysis was performed using the software SportCode Pro v. 8.5.2.

Procedure design

Visualization and analysis of video recordings were carried out by two experienced observers (Koch & Tilp, 2009b). To ensure reliability of observation during the study, two intra-operator views were performed. For each of the videos and variables analyzed, error rate was computed based on the following mathematical expression (Hughes, 2004): $Error (\%) = (\Sigma (mod [V1 - V2]) / Vmean) * 100$ where V1 and V2 are the frequencies of the first and second operator observation, respectively, Vmean is the mean value of the two registered observation frequencies and mod is the modulus. The intra-observer analysis reliability gave a margin of error of less than 5% (James, Taylor, & Stanley, 2007) which falls within acceptable margins of error in the visualization and analysis.

Players were monitored with Polar Team Pro II. Each player used this device while playing, and at the same time, the games were recorded to analyze the active time (AT) in relation to heart rate values.

Heart rate values were analyzed in real game by synchronizing the game video with the heart rate video. This allows researchers to obtain real values of heart rate in each moment at a pace of one HR reading per second and player. Active time (AT) and rest time per player in passive time (PT) were also registered (Table 2).

Table 2
Data analysis

	Description
AT	Time since the first contact in serve since the ball touch the sand.
PT	Time since ball touched the sand at the previous point since the player that are doing the service touch the ball at the first push.

Note: AT: Active Time; PT: Passive time

Each period was registered with heart rate values displayed on the screen of polar team application. Therefore, the different heart rate values that depended on the duration of the game were considered (Figure 1). All heart rate frequencies were codified using the software SportCode Pro v 8.5.2.

In order to classify heart rate values in time spans of interest, the following four periods were defined:

- *Set 1*: Actions during the first set
- *Set 2*: Actions during the second set

Also, all techniques for each of the players' actions were counted within these periods,. The following techniques were recorded (Koch & Tilp, 2009b):

- Block.
- Reception.
- Defense.
- Setting.
- Attack.
- Serve.

Therefore, the analysis procedure is summarized as follows:

- Recording and digitization of images.
- Synchronization of video recordings to be merged into one video.
- Definition of code arrays containing the proper elements to be analyzed.
- Coding of images with each of the defined codes.

Figure 1: Synchronized game and data screen of polar team

- Combination of codes to retrieve the exact moment of the registered frequencies.
- Collection of data through protocol observer using Sportcode pro.

Finally, in order to know the working ranges of players, each player's maximum heart rate was needed. For this reason, the team underwent a maximal exercise stress test. The protocol developed on the treadmill began with a steady run at 8 km/h with an increase of 0.25km/h every 15 s with a fixed slope of 1%. During the development of the test, heart rate monitors and a Jaeger gas analyzer model Oxycon Pro were used.

Data analysis

Data were analyzed using SPSS v.22 to perform descriptive statistics. After Kolmogorov-Smirnov normal test, the statistical test applied was a non-parametric test U Mann-Whitney to compare both means between players and between different and established time periods.

Results

The values obtained as a result of the implementation of the methodology and research design are presented. First, a stress test of each of the players was carried out to obtain the maximum heart rate value and to, then, calculate the working areas during the real game (Table 3).

Table 3
Results of the test effort performed by players

Maximum parameters	Time (min)	Final BP (mmHg)	HRmax (ppm)	Resp. rate (bpm	VO_2 (l/min)	VO_2max (ml/kg/min)
Player 1	9.05	175/70	184	59	4.140	47.21
Player 2	11.14	200/60	198	53	5.196	56.48

Note: Final BP = Final blood pressure; HRmax = Maximum heart rate; Resp. rate = Respiratory rate; VO_2= Oxygen consumption; VO_2max = Maximal oxygen uptake

The analysis of the active time in which heart rate values were recorded establishes working ranges for each player. For Player 1 (blocker), a minimum of 90 bpm and a maximum of 180 bpm were recorded, with a working range between 143 bpm and 164 bpm. These

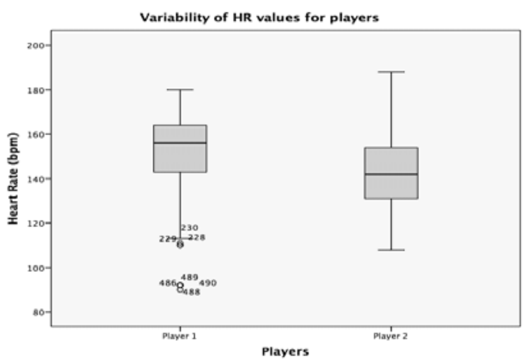

Figure 1: Variability of HR values per player

values reveal a workload between 77.71% and 89.13% of his maximum heart rate (HRmax), while the median of the pulse rate is at 156 ± 21 bpm, which is 84.78% of his HRmax. Similarly, Player 2 (defender) showed a minimum heart rate of 108 bpm and a maximum of 188 bpm, with a working range between 131 bpm and 154 bpm. In this case, workload remains between 66.16% and 77.77% of his maximum heart rate. For this player, the median of the pulse rate is set to 142 ± 23 bpm, 71.71% of his HRmax, as it can be seen in Figure 1.

On the one hand, workload ranges are different between players due to a greater or lesser level of individual intervention as the number and type of actions is different for a blocker and a defender.

On the other hand, the analysis of variation in heart rate as a function of set time reveals a variation which, again, is different for each of the players, as depicted in Table 4. Player 1 (blocker) has a HRmax median value of 152.33±17.52 bpm (82.60% HRmax) for Set 1 and a slightly higher value of 153.23±14.64 bpm (83.15% HR max) for *Set 2*. Furthermore, comparison of heart rate records between each group did not showed significant differences (p=0.648), indicating that there was not a significant variability of the heart rate for each period.

Regarding Player 2 defender, a HRmax median value of 154.28±14.99 bpm (77.91% HR max) for *Set 1* and a slight decrease in *Set 2* to 139.73±14.51 bpm (72.39% HRmax). Again, comparing heart rate records between groups showed significant differences (p=0.001). Therefore, these data show that participation and work load delivered by Player 1 have been more intense as a result of a greater emphasis on the attack of the opposing team.

To explain the physiological response, it is important to describe the numbers of actions for each period (Table 5).

Table 4
HR Values

Player 1		Min (bpm)	Max (bpm)	Q1 (bpm)	Median (bpm)	Q3 (bpm)	IQR
	Set 1	90	180	142	155	166	24
	Set 2	110	174	150	157	163	13
Player 2		*Min*	*Max*	*Q1*	*Median*	*Q3*	*IQR*
	Set 1	113	176	132	148	156	24
	Set 2*	108	188	131	139	150	19

Note: Min = Minimum; Max = Maximum; Q1 = 25th percentile; Q3 = 75th percentile; IQR = interquartile range. *= p value significative comparing set 1 with set 2.

Table 5
Frequency of actions

Player 1		Serve	Reception	Setting	Attack	Block	Defense
	Set 1	20	23	18	35	28	29
	Set 2	18	20	13	24	25	15
Player 2		Serve	Reception	Setting	Attack	Block	Defense
	Set 1	26	13	28	20	23	35
	Set 2	22	13	24	15	12	26

Note: All values shown are in action times

The total actions carried out by Player 1 (blocker) was 268, divided in 153 play actions in set 1 and 115 in set 2. Specially, on the one hand, the more repetitive action was the attack (n=59) and block (n =53), followed in decreasing order by defense (n =44), reception (n=43), serve (n =38) and setting (n =31). On the other hand, Player 2 (defender) performed 257 actions, split in 145 actions in set 1 and 112 in set 2. The more common actions were defense (n =61) followed to settings (n =52). The rest of frequencies registered was in decreased order: services (n=48), attack (n =35), block (n=35) and finally reception (n =26). In addition, no significant differences were established in the number of actions for each player (p=0.093)

Discussion

The establishment of the working areas during actual game helps to determine the actual performance of players in real game situations (González Fimbres et al., 2016), in contrast to laboratory tests, that differ from the actual game situations in which the sport is played. Different aspects like field dimensions, quality of sand, weather conditions and number of players (Tili & Giatsis, 2011) determine the physical demands of players. Therefore, these determining factors should be considered in beach volleyball as well, as they cause a physiological response that influences heart rate.

There are a few studies that deal with the physiological variables carried in male beach volleyball players. The study of the heart rate monitoring during three-set games in Portuguese players can be pointed out (Magalhaes et al., 2011). Despite not distinguishing between playing positions, results showed an average heart rate of 75% of HRmax, similar to those obtained in the present study with a workload between 77.71%-89.13% (HRmax) for Player 1 (blocker) and 66.16%-77.77% (HRmax) for Player 2 (defender). In the study of Magalhaes, no significant differences between analyzed sets were obtained, both for heart rate values and blood lactate values taken during games. However, this study recorded heart rate values with statistically significant differences for each set time only in Player 2 (defender).

This physiological response is related to different aspects of the beach volleyball game. In fact, the number of actions taken by a player or another is conditioned to the strategy of game used by the opposing team (Jimenez Olmedo, Penichet Tomas, Saiz Colomina, Martinez Carbonell, & Jove Tossi, 2012). Players must undertake a greater number of game actions because each player must support the offensive load. Specifically, in the sample studied, Player 1 was the player who served and received the longest games (n=43) when compared to his partner (n=26). This meant that a greater load was applied to this player who had to perform more actions to develop the attack.

In addition, although there are different tactical elements in beach volleyball (Koch & Tilp, 2009b), not all of them have the same physical demands for the player. It is important to know that actions like blockades and attacks lead to an accumulation of fatigue which causes a jump lost up to 25% (Edwards, Steele, & McGhee, 2010). For this reason, the loss of 14% jump in sand with respect to land (Giatsis et al., 2004), would help to explain the higher heart rate values in players who perform more attacks and blockades than those doing defenses and settings. Besides, a study on actions taken in beach volleyball players (Palao, López-Martínez, Valadés, & Ortega, 2015) states that blocker players take on average more jumps than defending players and even than players who exchange blocker and defender roles.

However, not only the number of shares or the player who performs determines the physiological response, but also the playing surface hinders the displacement (Smith, 2006) and the execution of movement patterns which are primarily offensive hued frontal displacements (Perez-Turpin, Cortell-Tormo, Suarez-Llorca, et al., 2009) giving priority to the construction of the attacks and block actions.

On the other hand, another element to consider is the high temperatures that can be reached in a real beach volleyball game (Bahr & Reeser, 2012), which determine the cardiac response. In these environmental conditions, the cardiac response also plays a role since the loss of 1% of body weight due to dehydration drives an increase of 5-8 beats per minute (Coyle, 2004). This factor must be taken into account since the loss of fluids during a beach volleyball game is between 1039-1996 ml/h, which involves a dehydration level of between 0.8% and 1.14% (Zetou, Giatsis, Mountaki & Komninakidou, 2008).

Furthermore, in order to understand the physiological response of players, the influence of the number of actions, both defensive and offensive, must be considered. This would explain the higher median value of HRmax recorded by Player 1 (blocker) against Player 2 (defender). Player 1 (blocker) performed more block and attack actions and more global actions than his teammate.

Finally, working time slots play a role in the cardiac response, as players have large time periods between points to undertake appropriate recovery. In this regard, previous studies established the temporal patterns of beach volleyball, but a more recent study establishes a ratio of 1:4.57 work time (Perez-Turpin, Cortell-Tormo, Chinchilla-Mira, Cejuela-Anta & Suarez-Llorca, 2009) stating that players would have ample periods to ensure a proper recovery between points.

Conclusions

In this paper, optimal working areas and recovery of players for set time periods have been established through the combination of analysis methodology and registration of associated heart rate.

The specific work of each player, as a result of their playing position, has established differences in their physiological responses. For example, the blocker (Player 1) has showed a median HRmax value of 84.78% compared to 71.71% of the defending player (Player 2). Not only median values differed, but also their optimum working areas showed a difference. For the blocker, that area is established between 77.71% to 89.13% of HR max, while the defender is working on a less demanding area of between 66.66 to 77.77%.

Both players share the number of played actions, but Player 1 blocker) carried out more demanding actions of attacks and blocks than Player 2 (defender) who performed more defensive actions and settings.

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