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1 **Title Page**

2 **Conditional analysis of elite beach handball according to specific playing position**
3 **through assessment with GPS**

4
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20
21 **Running heading:** Conditional analysis of beach handball according to specific playing
22 position

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24

25

26 **Abstract**

27 Beach handball needs to continue to develop. **For this reason, observational studies that analyze**
28 **competitive demands are necessary.** Therefore, our objective in this work was to carry out
29 performance assessment of the beach handball players regarding specific playing positions
30 during competition, without modifying the specific structure of the game. The study included
31 57 elite beach handball players. The results showed that significant differences were found in
32 most of the variables studied when the specific playing positions were compared. **Our work has**
33 **led us to conclude that the assessment of the conditional demands of beach handball players in**
34 **competition must be done considering the specific playing positions.**

35

36 **Key words**

37 Sand, high competition, playing position, performance, beach handball, match.

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51 **Introduction**

52 Beach handball is a relatively new sport that has achieved great growth and development in a
53 few years. The sport was created on the Island of Ponza (Italy) in 1992 (Pehrer, & Werkmeister,
54 2006) and in just twenty-six years it is already played on five continents, and constantly
55 expanding. A special scoring system in which spectacular goals, penalties and goalkeeper's
56 goals are awarded with two points, a playing field with rectangular areas, very ample
57 substitution areas and the tiebreaker set system, the shoot-out, make it a very attractive sport to
58 the spectator (Zapardiel, 2015).

59 This is a very demanding sport from a physical point of view mainly due to the rules of the
60 game and the game surface. This surface has to be made up of fine sand and must have a depth
61 of 40 cm (International Handball Federation, 2014). Each team is composed of four players
62 performing different functions both in the offensive and defensive game phase. In the offensive
63 phase, the participants are the specialist player (goalkeeper who leaves his goal), the wings and
64 the pivot. During the game, the wing can be replaced after the offensive phase or he can position
65 to defend (fixed wing). In turn, in the defensive phase, teams are usually made up of other
66 players different from the ones taking part in the offensive phase because the regulations not
67 only allow an unlimited number of substitutions but also facilitate them making the substitution
68 area bigger. In this case, the defensive game is organised with the goalkeeper, the defense
69 centre, the defense right and the defense left.

70 Although beach handball is a little-studied sports specialty, the number of investigations has
71 recently increased in different fields (Bago, 2016; Bebetos, 2012; Cruić, Vuleta, Bazzo, &
72 Ohnjec, 2011; Lara, 2011; Morillo-Baro, 2016; Morillo-Baro, 2009; Morillo-Baro, &
73 Hernández-Mendo, 2015; Morillo-Baro, Reigal, & Hernández-Mendo, 2015; Pehrer, &
74 Werkmeister, 2006; Pueo, Jiménez-Olmedo, Penichet-Tomas, Ortega, & Espina, 2017;
75 Zapardiel, 2015; Zapardiel, Asín-Izquierdo, Moya, Lebrero, García, & Lozano, 2017;

76 Zapardiel, Lara, & Rodríguez, 2013). However, none of the investigations mentioned above has
77 had as main objective the conditional analysis of beach handball according to specific positions,
78 although there are big conditional differences depending on the post. San Pedro (2008) made a
79 performance assessment of the specialist player in beach handball but not of the rest of specific
80 positions.

81 **The observation of the general conditional demands of beach handball has established**
82 **important requirements with a series of actions of constant high intensity (Pehrer and**
83 **Werkmeister, 2006).** This series of actions, 6-7 s at high speed, has short recoveries, and almost
84 never homogeneous (Morillo-Baro, 2009), and they keep repeating during both 10-minute
85 halves of the match (International Handball Federation, 2014). Effort intensity during
86 competition ranges from vigorous to very vigorous during 70% of the playing time, taking the
87 heart rate as reference, which shows records that range between 80% and 83% of the maximum
88 heart rate when the ball is in play (Lara, 2011). In another study, where tests carried out on
89 beach sand with elite beach handball players (adapted Course-Navette and maximum speed
90 during 15 m), average values of blood lactate of 13.44 mmol/l were observed and anaerobic
91 glycolysis was determined as the main way of energy production in this sport (Bago, & Sáez,
92 2013).

93 Regarding game time, time-motion in beach handball players during competition has been
94 studied with GPS technology. An average active time during a 10-minute set resulted in 8.8
95 minutes and 9.3 minutes for male and female, respectively (Pueo et al., 2017). Other examples
96 of the time-motion measurement from a conditional assessment are beach tennis (Pérez, Prau,
97 & Santos, 2013), beach football (Castellano, & Casamichana, 2010) or handball (Michalsik, &
98 Aagaard, 2015; Wagner, Finkenzeller, Würth, & Duvillard, 2014).

99 Likewise, the distance covered by team sport players during competition has been studied, this
100 being one of the external load variables most used with GPS technology. Pueo et al. (2017)

101 determined that the distance travelled by high performance beach handball players during 10
102 minutes was 617 m for male and 559 m for female (Pueo et al., 2017). This distance has also
103 been measured in handball (Michalsik, & Aagaard, 2015; Póvoas, Seabra, Ascensão,
104 Magalhães, Soares, & Rebelo, 2012; Wagner, Finkenzeller, Würth, & Duvillard, 2014).

105 Another aspect measured in beach handball is the distance travelled in speed sections. Pueo et
106 al. (2017) observed that most of the distance covered in this sport oscillates between 0.5 y 13
107 km/h. In the case of beach football, almost half of the movement is done at speeds that ranging
108 between 0.1 and 0.4 km/h, and the rest of the movements between 0.4 and 13 km/h (Castellano,
109 & Casamichana, 2010). **In the same line of observational study of the conditional demands** of
110 beach handball, accelerations and decelerations (Pueo et al., 2017) as well as heart rate (Bago,
111 & Sáez, 2013; Lara, 2011; Pueo et al., 2017) have been measured. On the contrary, no beach
112 handball research assessing the physical condition in a global way has been found. **However, it**
113 **has been found in other sports; in these cases, variables that relate load and time, a method to**
114 **quantify training load such as the training impulse (TRIMPs), a method to quantify the training**
115 **load in relation to heart rate and time with load intensity, or total player load have been used.**

116 In all the studies related to conditional aspects of beach handball previously commented (Lara,
117 2011; Bago, & Saez, 2013; Pueo et al., 2017), beach soccer (Castellano, & Casamichana, 2010)
118 and in many others regarding handball (Corvino, Tessitore, Minganti, & Sibila, 2014; Corvino,
119 Vuleta, & Šibila, 2016; Dello-Iacono, Ardig, Meckel, & Padulo, 2016; Manchado, Tortosa-
120 Martínez, Vila, Ferragut, & Platen, 2013; Porostiaga, Pranados, Ibáñez, González-Badillo, &
121 Izquierdo, 2006; Póvoas, at al., 2012), all players are assessed as a single group and not
122 according to specific playing positions. In some cases, the game structure of the sport was
123 modified in order to carry out the assessment (Pueo et al., 2017). **Therefore, if our aim is to**
124 **make an objective observation of the demands of the beach handball player, it must be done**
125 **regarding specific playing positions and not modifying the structure of the game.** Hence, our

126 objective in this study is to carry out a conditional assessment of the beach handball player
127 according to specific playing positions during competition using GPS technology and without
128 modifying the structure of the game.

129 **Materials and method**

130 *Sample*

131 Twenty five male (mean age: 25.3 ± 4.8 yrs; body weight: 86.9 ± 9.5 kg; body height: $187.5 \pm$
132 7.4 cm) and thirty two female (mean age: 25.3 ± 4.8 yrs; body weight: 60.7 ± 3.8 kg; body
133 height: 168 ± 3.8 cm) elite beach handball players were recruited for this study. All the players
134 were observed during the pre-competition meetings prior to 2017 European Championship.
135 They were also informed about the research protocol and they gave their written informed
136 consent. The Ethics Committee at the University of Alcalá gave institutional approval to this
137 study in accordance with the spirit of the Declaration of Helsinki.

138 **Table 1.** Distribution of sample by sex, height, weight and age (\pm SD)

139 *Material*

140 **To collect data, three receivers GPS (Global Positioning System) & GNSS (Global Navigation**
141 **Satellite System)** OptimEye S5 Catapult Sport, 10Hz GPS, and inertial system were used: 3D
142 Accelerometer 100Hz, 3D Pyroscope 100Hz, 3D magnetometer 10Hz. An automatically
143 synchronized Polar system to monitor physiological data of heart rate was used. This tool is
144 validated by research in a multitude of scientific studies (Johnston, Watsford, Kelly, Pine, &
145 Spurrs, 2014; Luteberget, Holme, & Spencer, 2018; Nicolella, Torres-Ronda, Saylor, &
146 Schelling, 2018).

147 Record sheets were used both for collecting individual data of players in each match and for
148 registering situational variables, as the result and playing times. All registers were collected by
149 just one researcher with over 25 years' experience in beach handball. In addition, all matches

150 were recorded with a SONY HDR-CX240 video camera to perform a subsequent review of the
151 recorded data.

152 ***Study variables***

153 The variables used to assess the internal and external load at mechanical, neuromuscular,
154 cardiorespiratory and metabolic levels were (Edwards, 1993):

- 155 • *Activity time*: time in which the player exceeds the speed of 1 km/ h.
- 156 • *Total distance travelled*: metres travelled by a player.
- 157 • *Velocity and velocity bands*: player speed and time spent in each band previously
158 assigned. Band 1: 1-5.9 km/h; band 2: 6-8.9 km/h; band 3: 9-11.9 km/h; band 4: 12-14.9
159 km/h; band 5: more than 15 km/h.
- 160 • *N accelerations and decelerations*: number of accelerations and decelerations measures
161 by GPS.
- 162 • *IMA ACCEL and IMA DECEL (>2.5 m/s)*: number of accelerations and decelerations
163 higher than 2.5 m/s measured by accelerometer.
- 164 • *Total jump*: number of jumps made at any height measured by GPS.
- 165 • *IMA Jump (>0.4 m)*: number of jumps higher than 40 centimeters measured by
166 accelerometer.
- 167 • *Beats per minute*
- 168 • *TRIMPs*: assessment of workload intensity based on the relationship heart rate-activity
169 time.
- 170 • *Total Player Load (PL)*: assessment of load intensity through mathematical formula
171 based on the data obtained by the accelerometer in all planes (Boyd, Ball, & Aughey,
172 2011).
- 173 • *PL IDUp%*: percentage of accelerations in the coronal plane over the total player load.
- 174 • *PL IDFwd%*: percentage of accelerations in the sagittal plane over the total player load.
- 175 • *PL IDSide%*: percentage of accelerations in the transverse plane over the total player
176 load.

177 ***Protocol***

178 Firstly, the technical staff of the selections was contacted to explain the research project and to
179 request the pertinent permission. Subsequently, the informed consent was sent to the players to
180 be signed.

181 Before the data collection, the players performed the relevant warm-up to play a beach handball
182 match. During the warm-up, the players to whom the device was going to be placed were agreed
183 with the selectors. They must be players who did not change their playing position during the
184 10 minutes of the measurement.

185 Five minutes before each game the chosen players were placed the heart rate bar, the vest and
186 the device. After this and once the initial and individual situational data of the players were
187 obtained, the exact time of start of the matches was noted. All variations in the scoreboard were
188 recorded by time segments of two minutes. All games were recorded to certify the data
189 collected. After finishing each game, the devices were removed. The matches were analysed
190 separately.

191 Data were transferred every day to the Open Field tool of Catapult Sport for analysis.

192 *Statistical analysis*

193 Statistical analysis was carried out using SPSS software (version 22). A descriptive analysis of
194 the variables studied was carried out, using the Kolgomorov-Smirnov test to check normality.
195 Subsequently, the inferential analysis was carried out. The variables that followed normality
196 and that showed significance in the Levene test were studied with the Welch test; those that did
197 not show significance were studied with the ANOVA test. The variables that did not follow
198 normality were studied with the Kruskal-Wallis test. The Tukey test was used for the post hoc
199 tests of ANOVA; the test of Pames-Howell was used for the post hoc of Welch test; and the
200 Mann-Whitney U-test was used for the post hoc of Kruskal-Wallis test. **A two-way ANOVA**
201 **(factor sex and position) was performed to compare differences in position between male and**
202 **female players and their interaction between these factors.**

203 **Results**

204 The effects of sex and position on all variables are shown in Table 2. Significant position and
205 interaction effects in distance, number accelerations, number decelerations, number of jumps,
206 IMA jumps and total player load were found. The differences of these variables regarding the
207 position can be attributed to the interaction of sexes.

208 **Table 2.** Effects of sex and position on all variables

209 Table 3 shows the activity time according to the specific playing position during a 10-minute
210 set (match set). In the general analysis regarding specific positions of women, statistically
211 significant differences were found ($p < .001$). In the detailed analysis, significant differences
212 were found between the fixed wing and the wing ($p < .001$), the defender ($p = .004$) and the
213 pivot ($p = .001$). In the general analysis between the specific positions of men, statistically
214 significant differences were found ($p = .001$). In the detailed analysis, statistically significant
215 differences were found between the pivot and the specialist ($p = .028$), the wing ($p = .013$), and
216 the fixed wing ($p = .005$), and between the fixed wing with the defender ($p = .003$).

217 On the other hand, in table 3, the distance travelled it is also showed according to the specific
218 playing position during a 10-minute set. In the general analysis between the specific positions
219 of women, statistically significant differences were found ($p = .002$). In the detailed analysis,
220 statistically significant differences were found between the fixed wing and wing ($p = .001$) and
221 the defender ($p = .001$). No significant differences were found between the specialist nor with
222 the wing ($p = .414$) nor with the pivot ($p = .368$), nor with the defender with the pivot ($p =$
223 $.788$). In the general analysis between the specific positions of men, statistically significant
224 differences were found ($p = .000$). In the detailed analysis, statistically significant differences
225 were found between the wing and the fixed wing ($p = .016$) and with the specialist ($p = .010$),
226 between the defender and the fixed wing ($p = .004$) and the pivot ($p = .010$). No significant
227 differences were found between the pivot and the wing ($p = .114$).

228 **Finally, in table 3, the distance travelled it is showed** in each previously assigned speed section.
229 This has been compared by specific positions. In the general analysis of women, statistically
230 significant differences were observed in all the speed sections, except for the speed section
231 greater than 15 km / h ($p < .01$). In the detailed analysis, significant differences occur between
232 the fixed wing and the rest of the specific posts ($p < .01$). In the general analysis of men,
233 statistically significant differences were observed in the speed section between 1 and 6 km / h
234 ($p < .05$). In the detailed analysis, significant differences can be seen between the specialist, the
235 wing and the fixed wing ($p < .01$).

236 In the general analysis of the maximum speed of women, statistically significant differences
237 were observed ($p = .003$). In the detailed analysis, significant differences were found between
238 the wing and the specialist ($p = .009$) and the fixed wing ($p = .007$). In the general analysis of
239 the maximum speed of men, statistically significant differences were observed ($p < .001$). In the
240 detailed analysis, there are differences between the specialist and the wing ($p = .014$) and the
241 pivot ($p < .001$); between the wing and the fixed wing ($p = .003$); and between the fixed wing
242 and the pivot ($p = .003$).

243 **Table 3.** Activity time (\pm SD), distance travelled (\pm SD), distance covered in speed sections and maximum speed
244 (\pm SD) in a 10-minute set regarding specific position

245 Table 4 shows the total number of accelerations and decelerations performed in a 10- minute
246 set depending on the specific position and measurements with GPS system and IMA system
247 (inertial system).

248 The general analysis of GPS measurements of women showed statistically significant
249 differences ($p < .001$) in accelerations and decelerations. In the detailed analysis of the number
250 of accelerations, there were differences between the fixed wing and the specialist ($p < .001$), the
251 wing ($p < .001$), the defender ($p = .026$) and the pivot ($p = .018$). In the detailed analysis of the
252 number of decelerations, the differences existed between the fixed wing and the specialist (p
253 $< .001$), the wing ($p = .001$), the defender ($p = .001$) and the pivot ($p < .005$). In men, the general

254 analysis showed statistically significant differences ($p < .001$) in the three variables. In the
255 detailed analysis of the number of accelerations, the differences existed between the specialist
256 and the wing ($p = .008$) and the pivot ($p = .006$); and between the fixed wing and the wing ($p =$
257 $.002$), the pivot ($p = .002$) and the defender ($p = .033$). In the decelerations, the differences
258 existed between the specialist and the fixed wing ($p = .004$), the defender ($p = .022$) and the
259 pivot ($p = .002$); and between the fixed wing and the wing ($p = .001$), the defender ($p = .003$)
260 and the pivot ($p < .001$). In the jumps, differences were only found between the fixed wing and
261 the pivot ($p = .001$).

262 In the analysis with IMA, women did not show statistically significant differences in any of the
263 variables. In men, the general analysis showed significant differences in the decelerations ($p =$
264 $.022$), in the accelerations to the left ($p = .008$) and to the right ($p = .009$), and in the jumps (p
265 $= .001$). In the detailed analysis of the decelerations, significant differences were found between
266 the fixed wing and the specialist ($p = .032$) and the wing ($p = .035$); however, in the
267 accelerations to the right and left, differences were only found between the specialist and the
268 pivot ($p = .001$). In the jumps, the significant differences existed between the fixed wing and
269 the specialist ($p = .007$), the wing ($p = .009$), and the pivot ($p = .025$).

270 **Table 4.** Total number of accelerations, decelerations and jumps (\pm SD) depending on the specific position
271 measured by GPS and IMA

272 Regarding internal load variables, Table 5 shows heart rate data depending on the specific
273 playing position. In the general analysis between the specific positions of women, statistically
274 significant differences were found in the minimum pulsations ($p = .000$), in the maximum ($p =$
275 $.016$) and in the average ($p = .004$). In the detailed analysis of the minimum heart rate,
276 statistically significant differences were found between the specialist and the fixed wing (p
277 $< .001$), the defender ($p = .012$), and the pivot ($p < .001$); between the wing and the fixed wing
278 ($p < .001$) and the pivot ($p = .017$), and between the fixed wing and the defender ($p = .005$). In
279 the detailed analysis of the average heart rate, statistically significant differences were only

280 found between the wing and the fixed wing ($p = .009$). In the detailed analysis of the average
281 heart maximum, differences were only found between the fixed wing ($p = .005$) and the
282 specialist, and the wing ($p = .007$).

283 In the general analysis by heart rate zones ($> 80\%$) of women according to the specific positions,
284 significant differences were only found in the 80-90% area, observing significant differences
285 between the fixed wing and the specialist ($p < .001$), the wing ($p < .001$), the defender ($p < .001$)
286 and the pivot ($p = .002$).

287 In the general analysis between the specific positions of men, only statistically significant
288 differences were found in the minimum pulsations ($p = .014$). Neither in the maximum
289 pulsations ($p = .091$) nor in the mean of the pulsations ($p = .092$) were significant differences
290 found. In the detailed analysis of the minimum pulsations, only statistically significant
291 differences were found for the wing with the fixed wing ($p = .015$) and with the pivot ($p = .023$).

292 In the general analysis by heart rate zones according to the specific positions of men, no
293 significant differences were found.

294 **Table 5.** Beats per minute (\pm SD) according to gender based on specific position

295 Finally, to assess the competitive load in beach handball, Table 6 shows the TRIMPs and the
296 different data of Player Load in a 10-minute set depending on the specific position. In women,
297 in the general analysis, significant differences were found in all the variables except in the
298 Player Load 1DSide%. In the detailed analysis of the TRIMPs we found significant differences
299 of the fixed wing with the specialist ($p = .006$) and with the wing ($p = .020$). In the detailed
300 analysis of the Total Player Load we found significant differences of the fixed wing with the
301 rest of the specific posts ($p < .001$). In the detailed analysis of the Player Load 1DUp% we only
302 found significant differences between the wing and the pivot ($p = .001$). On the other hand, in
303 a detailed analysis of the Player Load 1DFwd% we found significant differences between the
304 pivot and the wing ($p = .002$) and with the defender ($p = .035$).

305 In men, in the general analysis, significant differences were found in the Total Player Load (p
306 $<.001$), in the Player Load 1DUp% ($p <.001$), in the Player Load 1DFwd% ($p = .001$) and in
307 the Player Load 1DSide% ($p <.001$). In the detailed analysis of Total Player Load we found
308 significant differences between the specialist with the wing ($p <.001$), with the defender ($p =$
309 $.001$) and with the pivot ($p <.001$); and between the fixed wing with the wing ($p <.001$), with
310 the defender ($p = .001$) and with the pivot ($p <.001$). In the detailed analysis of Player Load
311 1DUp% we found significant differences between wing and the rest of the specific positions (p
312 $<.001$). In the detailed analysis of the Player Load 1DFwd%, we found differences between the
313 pivot and the wing ($p = .024$) and the fixed wing ($p =.026$). Finally, in the detailed analysis of
314 the Player Load 1DSide% we found significant differences of the specialist with the wing (p
315 $<.001$) and with the pivot ($p = .002$); and of the wing with the fixed wing ($p = .008$), with the
316 defender ($p = .020$) and with the pivot ($p = .001$).

317 **Table 6.** TRIMPs y Player Load (\pm SD) por sexo en función del puesto específico

318 **Discussion**

319 During the short history of beach handball, only research articles related to conditional demands
320 have been published, taking as a reference the means of the whole group. In no case have the
321 specific playing positions been taken into account. Our contribution to scientific knowledge has
322 been the conditional assessment of elite beach handball players according to specific positions.
323 With this article, we provide a series of data that should be the reference of the study of the
324 physical condition in the beach handball player. In most of the variables studied there have been
325 significant differences in both men and women. Therefore, the physical condition of the beach
326 handball player should be programmed in the most individualized way possible.

327 Currently, there is only one study that has assessed the conditional demands of beach handball
328 players with the GPS system (Pueo et al., 2017). In this article, the means of all the specific
329 positions were taken as a reference and although it will be the reference article of this
330 discussion, we will do it by comparing the means that we also found in our study.

331 Beach handball is a very particular sport in relation to activity time due to the continuous
332 substitutions of players that occur during a match. Pueo et al. (2017) found activity times of 8.8
333 minutes in men and of 9.3 in women in a ten-minute set. A great difference can be observed
334 with the data from our study where the highest average activity time was found in men with 6.1
335 minutes. The player who enjoys more activity time during a beach handball match is the one
336 who is not substituted, the fixed wing; in our study this player showed an activity time of 7.7
337 minutes, far from the average observed in the study by Pueo et al. (2017). The reason for this
338 difference is determined by the fact that players were not substituted during the match in Pueo
339 et al (2017). In other sports, we can observe the difference in this variable depending on the
340 play structure. In handball, the average active time in a 10-minute set is 8.9 minutes for men
341 and 8.4 for women (Michalsik, & Aagaard, 2015). In beach tennis, the average real playing
342 time over a 10-minute period is 2.1 minutes (Pérez, Prau, & Santos, 2013). **What is really**
343 **remarkable about our study is that there are significant differences between several of the**
344 **specific playing positions; this has never been studied in beach handball before. In this sense,**
345 **we believe that if we want to make an objective assessment in this sport, valuations must always**
346 **be made regarding specific positions.**

347 The distance travelled by team players during competition is one of the most widely used
348 external load variables with GPS technology. The sources consulted make a description of the
349 distances travelled and compare them with different sports, with sports played on different court
350 surfaces, with different assessment criteria and with assessment criteria that do not fit into the
351 game structure of the sport. Our proposal aimed at strictly respecting the game structure of
352 beach handball and, hence, the simple comparison of distances would not provide meaningful
353 data to the scientific field. Therefore, we carried out the comparison based on the activity time.
354 Under this premise, we can conclude that the studies by Pueo et al. (2017), Michalsik and
355 Aagaard (2015) and ours are very similar regarding the distance traveled by men in 1 minute of

356 activity time, 70, 73 and 73 m·min⁻¹ respectively. In our study, women made 78 m·min⁻¹, 79 in
357 Michalsik and Aagaard (2015) and 60 in Pueo et al. (2017). It should be noted that in the study
358 by Michalsik and Aagaard (2015) the valued sport is handball that is practiced on a hard surface.
359 On the same surface, beach soccer increases the distance travelled in 1 minute of activity time,
360 97.7 m·min⁻¹ (Castellano, & Casamichana, 2010). The explanation for this difference can be
361 found in the dynamics of the beach soccer game in which long movement patterns without a
362 ball are made in a larger field.

363 Another valued aspect in beach handball is the distance travelled in speed sections. Pueo et al.
364 (2017) observed that both men and women spent most of their active playing time between
365 walking and jogging. The same situation occurs in our study. Men are 56.8% of active time at
366 speeds between 1 and 6 km / h, and women 62.8% of active time. In beach soccer, there is the
367 highest activity time between these speeds, 70.1% in Castellano and Casamichana (2010), and
368 85.8% in Scarfone, Antonio, Carlo, Laura and Antonio (2015). Both in Pueo et al. (2017) and
369 in our study, beach handball players (men and women) are approximately 30% of the activity
370 time running. In beach soccer this time is reduced to 22% in Castellano and Casamichana (2010)
371 and 11.8% in Scarfone et al. (2015). In our study, men are running fast about 3% of their activity
372 time, as in Pueo et al. (2017), Castellano and Casamichana (2010) and Scarfone et al. (2015).
373 In the case of women, 2% both in Pueo et al. (2017) and in our study. As mentioned in previous
374 paragraphs, what is really remarkable is that in our study there are significant differences
375 between several of the specific playing positions. In both men and women, the fixed wing is
376 the player who is at speeds between 6 and 12 km/h most of the activity time. This data is
377 something that must be taken into account for individualized physical preparation. In our study,
378 the maximum speed was reached by the fixed wings in both men and women. The wings were
379 the ones with the lowest maximum speed, finding significant differences with the fixed wings
380 and the specialists. Women reached a maximum speed of 6.0 m/s and men of 7.1 m/s, a higher

381 speed than the data collected by Castellano and Casamichana (2010) in beach soccer players,
382 6.0 m/s.

383 The intensity of an activity can also be measured through the number of accelerations that occur
384 in this activity. In order to be able to compare with other sports that do not have the same
385 temporal structure as beach handball, we will adjust the number of accelerations to those
386 produced in one minute. Pueo et al. (2017) found that in a beach handball match there was an
387 average of 2.6 acc/min in men and 2.2 acc/min in women. In our study we found 18.4 acc/min
388 in men and 16.0 acc/min in women. When the accelerations were carried out above $2 \text{ m} / \text{s}^2$,
389 the study by Pueo et al. (2017) showed 0.05 acc / min in women and 0.1 acc / min in men. In
390 our study, we found a higher number of accelerations, 0.24 acc / min in women and 0.44 acc /
391 min in men. The coincidence between both studies is found when we observe that in the two
392 studies accelerations above $2 \text{ m} / \text{s}^2$ are twice as high in men as in women. In the study by
393 Pueo et al. (2017) the substitutions of players that are made in a beach handball match are not
394 made; for this reason, the observed differences can be justified since in the substitutions of
395 players there are accelerations and decelerations. We have not found any study of sports
396 accelerations that use the beach sand playing surface. In handball, Barbero, Pranda-Vera,
397 Calleja-González and Del Coso (2014) found 5.4 acc / min in men. In this study, the specific
398 playing positions were compared. In this sense, Barbero et al. (2014) did not find significant
399 differences in relation to the accelerations of the athletes. In our study of beach handball, we
400 did find significant differences between the different positions. This is justified by the different
401 playing structures of both sports.

402 Regarding the maximum heart rate, the results are lower than other studies of beach handball
403 (Pueo et al., 2017; Lara, 2011), as in other sports such as beach soccer where higher maximum
404 heart rate figures are found (Castellano, & Casamichana, 2010; Scarfone, et al., 2015). This
405 could be due to the fact that in our study the players made the frequent breaks that occur in the

406 official beach handball matches, something that differs from the rest of the studies because
407 either it was not considered in the studies of beach handball or the structure of game is different
408 in other sports. However, the average heart rate data are higher, although very similar to those
409 provided by other scientific studies in competition (Castellano, & Casamichana, 2010,
410 Scarfone, et al., 2015). Regarding the activity time in sections of heart rate percentage, we
411 obtained very similar times to those obtained in handball by Pueo et al. (2017), both in the 80-
412 90% zone, and in the zone >90%); and inverse to those obtained in beach soccer (Castellano,
413 & Casamichana, 2010) with a large percentage of time in zone >90%.

414 The continuous substitutions taking place in official beach handball matches give the
415 assessments made using GPS devices very special features. In spite of this, in the data collection
416 of this study we wanted to reflect all the substitutions that occurred during an official match.
417 Our decision was made based on reflecting everything that takes place in this type of matches
418 as accurately as possible. To provide a more complete assessment of the internal load that
419 occurs in a beach handball match, the variables TRIMPs and Player Load were also collected
420 and analyzed.

421 In most of the variables studied in our work, significant differences were found between the
422 different specific positions of beach handball, so we believe that it is necessary to make this
423 type of assessment following this line, if we want it to be objective. It has already been done in
424 other sports (Barbero et al., 2014; Dellal, Wong, Moalla, & Chamari, 2010; Di Salvo, Baron,
425 Tschan, Montero, Bachl, & Pigozzi, 2007; Miñano, 2015; Zubillaga, Porospe, Hernandez, &
426 Blanco, 2009) and the significance is marked by the structure of the sport and the type of
427 variable studied.

428 **Conclusions**

429 Given the quality of the sample, we can ensure that the data obtained correctly represent the
430 conditional **information** and competition profile of professional beach handball players. There

431 are significant differences in the conditional data of competition in beach handball players
432 according to sex; in addition, significant differences can be observed depending on the playing
433 position, both in men and women. Given the novelty of this research study, new studies of a
434 similar profile are necessary to determine the conditional structure and physiological response
435 of the beach handball player in competition, giving solidity to the data provided in this scientific
436 study.

437 *Practical applications*

438 This study has shown differences in the conditional assessment of the specific positions of elite
439 beach handball players. This makes us understand that not all beach handball players have the
440 same conditional needs to compete. Therefore, the conditional training of elite beach handball
441 players should be focused on the development of physical abilities individually. This could lead
442 to better performance of the athlete's energy system.

443 *Lines for investigation*

444 After observing the results obtained in this research project and verifying that scarce research
445 of this type can be found in beach handball, it would be interesting to carry out more research
446 in this aspect with the objective of establishing a foundation and being able to confirm a
447 conditional profile of the professional beach handball player.

448 From that point, it will be interesting to assess the variation of the athlete's results in terms of
449 different contextual and situational elements, such as model of game, rival, competition, result,
450 etc. also being able to observe the data at different moments of the competition, as well as to
451 determine all this in the different levels of performance of the beach handball player.

452

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455 *Declaration of interest statement*

456 The authors declare that they have no conflicts of interest.

457

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Table 1. Distribution of sample by sex, height, weight and age (\pm SD)

	Height (cm)	Weight (kg)	Age (years)
Female (n=32)	168.00 (3.86)	60.78 (3.87)	25,38 (4.82)
Male (n=25)	187.52 (7.48)	86.96 (9.53)	25.40 (3.26)

Table 2. Effects of sex and position on all variables

	Sex		Position		Interaction	
	F	p	F	p	F	p
Activity Time	14.2	.001	13.0	.000	3.8	.110
Distance	11.8	.001	19.8	.000	9.8	.000
N Accelerations	6.5	.014	14.1	.000	4.5	.003
N Decelerations	5.6	.022	14.1	.000	5.0	.002
IMA ACCEL(>2.5m/s)	2.0	.161	2.3	.072	.3	.828
IMA DECEL(>2.5m/s)	5.2	.026	4.9	.002	1.4	.219
N Jumps	20.5	.000	.8	.513	3.8	.009
IMA Jumps (>0.4m)	22.9	.000	10.9	.000	8.3	.000
Average Beats Per Minute	1.3	.256	5.1	.002	2.0	.107
TRIMPs	2.5	.115	9.1	.000	1.5	.202
Total Player Load	4.0	.045	27.9	.000	6.6	.000

N. accelerations: number of accelerations measured by PPS, N. decelerations: number of decelerations measured by PPS, IMA ACCEL(>2.5m/s): number of accelerations > 2.5 m/s measured by IMA, IMA DECEL(>2.5m/s): number of decelerations > 2.5 m/s measured by IMA, N Jumps: number of jumps measured by PPS, IMA Jumps (>0.4m): number of jumps >0.4m measured by IMA, TRIMPs: assessment of workload intensity based on the relationship heart rate-activity time, Total Player Load: assessment of load intensity through mathematical formula based on the data obtained by the accelerometer in all planes

Table 3. Activity time (\pm SD), distance travelled (\pm SD), distance covered in speed sections and maximum speed (\pm SD) in a 10-minute set regarding specific position

	SP	S (n=8)	W (n=6)	FW (n=7)	P (n=4)	D (n=7)	\bar{X} (n=32)
F	AT (min)	5.3 (2,1)	2.9 (1.1)	7.7 (1.3)	3.0 (1.7)	4.2 (1.0)	4.8 (2.3)
	Distance (m)	317.8(100.3)	292.7 (29.2)	630.1 (66.8)	286.7 (7.1)	282.1 (102.7)	369.7 (158.4)
	Distance (m) 1-6 km/h	168.8 (55.5)	139.0 (59.7)	370.0 (23.5)	256.7 (9.3)	177.5 (71.2)	220.1 (99.8)
	Distance (m) 6-9 km/h	67.4 (25.6)	62.9 (16.4)	136.4 (34.1)	14.6 (17.2)	56.3 (21.9)	72.6 (44.4)
	Distance (m) 9-12 km/h	31.1 (17.3)	23.9 (4.9)	71.0 (39.0)	1.8 (3.6)	17.0 (9.9)	31.7 (30.1)
	Distance (m) 12-15 km/h	13.1 (11.5)	23.5 (16.3)	13.2 (10.4)	.0 (.0)	1.0 (1.5)	10.8 (12.8)
	Distance (m) +15 km/h	1.6 (1.7)	2.3 (2.5)	1.6 (2.6)	.0 (.0)	1.3 (1.5)	1.2 (1.9)
	Maximum speed (m/s)	5.7 (1.0)	3.9 (0.5)	6.6 (1.0)	4.6 (0.1)	4.6 (1.0)	5.1 (0.1)
M	SP	S (n=6)	W (n=4)	FW (n=5)	P (n=4)	D (n=6)	\bar{X} (n=25)
	AT (min)	6.7 (0.4)	7.1 (1.8)	7.6 (0.9)	4.3 (0.4)	4.8 (0.4)	6.1 (1.5)
	Distance (m)	607.6(103.2)	310.8 (19.5)	597.3 (86.3)	284.1 (6.7)	354.8 (25.5)	445.6 (156.3)
	Distance (m) 1-6 km/h	412.6 (121.9)	141.7 (67.8)	354.1 (85.9)	256.3 (30.1)	237.7 (65.5)	290.6 (122.2)
	Distance (m) 6-9 km/h	88.7 (59.2)	49.2 (\pm 9.9)	104.0 (50.8)	16.4 (19.7)	58.0 (40.6)	66.5 (49.6)
	Distance (m) 9-12 km/h	55.8 (54.0)	21.4 (8.1)	74.0 (43.9)	4.9 (9.8)	58.0 (40.6)	38.0 (40.6)
	Distance (m) 12-15 km/h	9.0 (12.6)	15.0 (14.0)	21.2 (13.1)	1.5 (2.7)	.0 (.0)	9.1 (12.3)
	Distance (m) +15 km/h	.0 (.0)	2.3 (2.6)	2.5 (5.1)	.0 (.0)	.0 (.0)	.8 (2.5)
Maximum speed (m/s)	6.5 (0.3)	3.6 (0,7)	7.1 (0.6)	4.7 (0.2)	5.7 (0.7)	5.7 (1.2)	

F: female, M: male, PP: playing position, AT: activity time, S: specialist, W: wing, FW: fixed wing, P: pivot, D: defender, \bar{X} : sample average

Table 4. Total number of accelerations, decelerations and jumps (\pm SD) depending on the specific position measured by GPS and IMA

	PP	S (n=8)	W (n=6)	FW (n=7)	P (n=4)	D (n=7)	\bar{X} (n=32)
F	N Accelerations	151.6 (41.8)	146.0 (67.9)	233.1 (20.7)	144.0 (23.5)	160.7 (41.4)	169.4 (52.5)
	N Decelerations	132.0 (38.5)	128.0 (57.3)	230.4 (21.6)	133.7 (14.4)	137.7 (46.4)	154.2 (55.3)
	IMA ACCEL(>2.5m/s)	2.1 (2.7)	3.5 (2.5)	3.1 (4.9)	3.2 (1.5)	.7 (1.2)	2.4 (2.9)
	IMA DECEL(>2.5m/s)	1.2 (1.5)	2.6 (1.8)	2.8 (2.8)	2.7 (1.8)	2.1 (2.1)	2.2 (2.0)
	IMA COD L (>2.5m/s)	1.8 (2.1)	2.6 (1.8)	4.4 (5.7)	2.5 (1.2)	2.2 (2.6)	2.7 (3.2)
	IMA COD R (>2.5m/s)	1.7 (1.9)	2.6 (1.8)	5.1 (5.1)	3.5 (.9)	2.2 (3.3)	3.0 (3.2)
	N Jumps	1.3 (1.7)	3.6 (2.9)	3.1 (3.2)	3.5 (.5)	1.8 (2.3)	2.5 (2.4)
	IMA Jumps (>0.4m)	.0 (.0)	.0 (.0)	.4 (.7)	1.0 (.0)	.2 (.7)	.2 (.5)
	PP	S (n=6)	W (n=4)	FW (n=5)	P (n=4)	D (n=6)	\bar{X} (n=25)
M	N Accelerations	235.5 (41.1)	146.0 (71.5)	254.0 (12.9)	144.0 (32.5)	184.6 (15.8)	198.0 (55.3)
	N Decelerations	223.8 (44.4)	132.5 (60.0)	244.4 (21.1)	126.0 (18.4)	157.1 (12.6)	181.6 (57.4)
	IMA ACCEL(>2.5m/s)	5.1 (2.4)	3.7 (2.0)	5.2 (2.5)	3.7 (1.1)	3.8 (1.7)	4.4 (2.0)
	IMA DECEL(>2.5m/s)	2.0 (1.0)	2.5 (1.7)	11.2 (4.2)	2.7 (0.5)	3.6 (2.3)	4.4 (4.1)
	IMA COD L (>2.5m/s)	6.6 (2.1)	2.2 (2.0)	6.6 (3.7)	2.2 (.5)	4.1 (1.4)	4.6 (2.8)
	IMA COD R (>2.5m/s)	6.1 (1.1)	2.5 (1.7)	6.6 (2.6)	3.7 (.9)	5.0 (0.8)	5.0 (2.0)
	N Jumps	7.1 (2.2)	3.2 (3.2)	7.0 (.7)	3.7 (.5)	6.3 (1.9)	5.7 (2.4)
	IMA Jumps (>0.4m)	.3 (.5)	.0 (.0)	4.0 (1.2)	1.0 (.0)	2.1 (2.3)	1.5 (1.8)

PP: playing position, F: female, M: male, S: specialist, W: wing, FW: fixed wing, P: pivot, D: defender, \bar{X} : sample average, N: accelerations: number of accelerations measured by PPS, N: decelerations: number of decelerations measured by PPS, IMA ACCEL(>2.5m/s): number of accelerations > 2.5 m/s measured by IMA, IMA DECEL(>2.5m/s): number of decelerations > 2.5 m/s measured by IMA, IMA COD L (>2.5m/s): number of accelerations to the left >2.5 m/s measured by IMA, IMA COD R (>2.5m/s): number of accelerations to the right >2.5 m/s measured by IMA, N Jumps: number of jumps measured by PPS, IMA Jumps (>0.4m): number of jumps >0.4m measured by IMA

Table 5. Beats per minute (\pm SD) according to gender based on specific position

	PP	S (n=8)	W (n=6)	FW (n=7)	P (n=4)	D (n=7)	\bar{X} (n=32)
F	Minimum (bpm)	96.3 (9.4)	108.7 (15.1)	147.4 (14.7)	137.5 (6.4)	120.2 (16.1)	120.2 (22.9)
	Maximun (bpm)	164.1(15.2)	147.8 (17.2)	174.9 (7.6)	160.1 (10.8)	168.8 (15.1)	163.9 (15.5)
	Average (bpm)	134.3 (14.5)	133.1 (18.7)	163.6 (10.9)	151.3 (12.7)	144.1 (17.4)	144.7 (18.1)
	80-90% (min)	1.7 (1.2)	2.1 (2.0)	7.4 (1.8)	3.2 (0.3)	3.2 (1.5)	3.6 (2.6)
	>90% (min)	.26 (.31)	.01 (.03)	.62 (.81)	.02 (.05)	.74 (.10)	.37 (.66)
	PP	S (n=6)	W (n=4)	FW (n=5)	P (n=4)	D (n=6)	\bar{X} (n=25)
M	Minimum (bpm)	129.4 (11.8)	114.3 (5.1)	137.1 (11.3)	136.9 (5.7)	125.9 (10.2)	128.9 (11.7)
	Maximun (bpm)	169.1 (7.3)	154.3 (10.1)	171.8 (11.3)	160.3 (1.5)	162.9 (12.7)	164.4 (10.8)
	Average (bpm)	153.6 (10.4)	139.2 (9.3)	155.4 (10.9)	151.1 (5.5)	146.8 (7.9)	149.6 (9.9)
	80-90% (min)	4.8 (2.5)	2.2 (2.4)	5.5 (3.8)	3.1 (0.9)	2.1 (2.0)	3.6 (2.7)
	>90% (min)	.14 (.22)	.15 (.31)	.12 (.17)	.00 (.00)	.10 (.26)	.11 (.21)

PP: playing position, F: female, M: male, S: specialist, W: wing, FW: fixed wing, P: pivot, D: defender; \bar{X} : sample, average, BPM: beats per minute

Table 6. TRIMPs y Player Load (\pm SD) por sexo en función del puesto específico

	PP	S (n=8)	W (n=6)	FW (n=7)	P (n=4)	D (n=7)	\bar{X} (n=32)
F	TRIMPs	23.5 (8.0)	18.8 (10.1)	38.7 (4.6)	33.8 (2.1)	28.9 (9.7)	28.4 (10.2)
	Total PL	36.3 (10.3)	33.6 (6.4)	71.6 (10.9)	30.5 (3.3)	40.7 (15.3)	43.8 (18.2)
	PL 1DU _p %	41.2 (3.2)	38.9 (.4)	42.9 (3.3)	43.3 (.9)	38.6 (2.0)	40.8 (3.0)
	PL 1DF _{wd} %	27.5 (2.2)	28.0 (.5)	27.0 (2.5)	25.5 (.5)	29.7 (2.8)	27.7 (2.3)
	PL 1DS _{ide} %	31.1 (1.8)	32.7 (.6)	30.0 (1.2)	31.1 (.3)	31.5 (2.2)	31.2 (1.7)
	PP	S (n=6)	W (n=4)	FW (n=5)	P (n=4)	D (n=6)	\bar{X} (n=25)
M	TRIMPs	36.2 (6.3)	18.9 (11.8)	38.6 (9.6)	34.0 (2.2)	33.0 (4.9)	32.8 (9.4)
	Total PL	66.0 (13.0)	32.3 (6.6)	67.2 (6.1)	30.3 (1.9)	43.5 (6.2)	49.7 (17.5)
	PL 1DU _p %	44.1 (1.0)	38.7 (.8)	42.9 (1.0)	43.3 (.4)	43.0 (.7)	42.6 (1.9)
	PL 1DF _{wd} %	27.3 (1.7)	27.9 (.7)	27.9 (1.0)	25.5 (.5)	26.8 (1.9)	27.1 (1.5)
	PL 1DS _{ide} %	28.5 (.7)	33.1 (.3)	29.1 (1.2)	30.9 (.1)	30.1 (1.4)	30.1 (1.8)

PP: playing position, F: female, M: male, S: specialist, W: wing, FW: fixed wing, P: pivot, D: defender, \bar{X} : sample, average, TRIMPs: assessment of workload intensity based on the relationship heart rate-activity time, Total PL: assessment of load intensity through mathematical formula based on the data obtained by the accelerometer in all planes, PL 1DU_p %: percentage of accelerations in the coronal plane over the total player load, PL 1DF_{wd} %: percentage of accelerations in the sagittal plane over the total player load, PL 1DS_{ide} %: percentage of accelerations in the transverse plane over the total player load.