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Research article

Quantifying the Activity Profile of Female Beach Volleyball Tournament Match-Play

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Abstract
Effective time-motion analysis can provide information directly applicable to the design of physical conditioning and testing programmes. The aim of the present study was to determine the external output of female beach volleyball players during tournament match-play and to assess the effect of competition level, margin of score differential and alterations of external output within matches. The external output profile of ten adult level (age 27 ± 3 y) and ten under 23 ('U23'; age 19 ± 2 y) female beach volleyball players were determined using GPS technology (10 Hz) during 60 matches (n = 50 first and second sets and 20 third sets files) played during their respective Australian Beach Volleyball Championship tournaments. Comparisons between groups and the influence of contextual factors on the external output within matches were analysed using linear mixed models. Adult beach volleyball players covered a greater relative distance (i.e., $m \cdot min^{-1}$) in speed zone 2 (1.0-1.99 $m \cdot s^{-1}$; 42.0% of total relative distance) and zone 3 (≥2.0 $m \cdot s^{-1}$; 10.9% of total relative distance) compared to U23 players. Relative distance, mean acceleration/deceleration and the relative distance covered in acceleration zone 2 and deceleration zone 2 and 3 was greater in set 1 compared to set 2. Sets that were decided by smaller score margins (<6-point score differential) were comprised of a greater relative distance, peak speed, greater mean acceleration and deceleration output and a greater relative distance in speed zone 1 and 3 compared to sets decided by larger score margins (>5-point score differential). The findings from this study suggest that there are contextual factors that influence the speed and acceleration/deceleration profile of female beach volleyball players such as tournament level, score margin and set-to-set variations that may have implications for the physiological and mechanical requirements of female players preparing for competition.

Key words: Match analysis, gps technology, activity profile, women.

Introduction

Beach volleyball is played both at the domestic and international level worldwide and has been an Olympic sport since Atlanta 1996. Given the international popularity of beach volleyball, there has been an emergence of time-motion analysis research examining the external output profiles and physiological responses of players during beach volleyball competition (Magalhães et al., 2011; Medeiros et al., 2014; Natali et al., 2019; Nunes et al., 2020; Palao et al., 2015; Turpin et al., 2008). Previous research in elite male beach volleyball has reported that players spend ~34% of match time with a heart rate elevated above 80% of peak heart rate (Magalhães et al., 2011), while elite female beach volleyball players perform 219.0 (± 7.4) jumps per match and 5.8 (± 0.2) jumps per point (Turpin et al., 2008) with a mean work-rest ratio of 1:5 (Palao et al., 2015). Importantly, differences in the activity profiles are apparent between playing levels with a reported increase in the duration of each set, total rest time, and number of jumps performed by defenders competing in the U/19 compared to 'adult' matches (Medeiros et al., 2014) and greater external output in international compared to national competition matches (Nunes et al., 2020). It is clear from these studies (Magalhães et al., 2011; Medeiros et al., 2014; Nunes et al., 2020; Palao et al., 2015; Turpin et al., 2008) that beach volleyball is comprised of many explosive efforts and features multiple short bouts of high-intensity movements that are interspersed with brief rest periods. However, further research is required to provide additional detail to these external output profiles. The introduction of new measurement and analysis techniques such as the Global Positioning System (GPS) and associated technology (GPS technology) can be used to quantify the type, duration, and frequency of discrete movements making up the intermittent activity profile in team sports (Aughey, 2011; Cummins et al., 2013). Only one previous study has employed GPS technology to characterize the movement patterns of elite beach volleyball match-play (Nunes et al., 2020). Nunes et al. (2020) suggested that although low-speed activity (i.e., walking and jogging) and low-acceleration and deceleration movements (<2 $m \cdot s^{-2}$) accounted for the majority (~85%) of total distance covered during match-play; the time spent with a heart rate >80% of maximal heart rate was ~55% and there were many instances of high-intensity actions, demonstrating the high internal and external load during beach volleyball match-play. There is no doubt that the study by Nunes et al. (2020) provides important information regarding the movement patterns of elite beach volleyball players. However, the data from this study arose from the longitudinal monitoring of a single pair of beach volleyball players, whereby team tactics and strategy could obscure the true movement patterns inherent across an entire competition. As such, a more comprehensive description of the activity profile of female beach volleyball match-play using GPS technology will provide relevant data on the specific movement profiles of competition and may assist in the development of beach volleyball-specific conditioning programs, testing protocols as well as team recruitment and selection.

There are a number of contextual factors that may influence the external output profile of athletes competing

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in different sports such as within- and between-match fatigue (Higham et al., 2012; Johnston et al., 2013), the performance or competition level of the athletes (Brewer et al., 2010; Higham et al., 2012; Jennings et al., 2012) and the margin of score differential (Gabbett, 2013; Sullivan et al., 2014). Research demonstrates that smaller score margins are associated with increased external output in Australian football players (Sullivan et al., 2014), while larger winning margins are associated with an increase in relative running distance (i.e., m/min) compared to small and moderate winning margins in Rugby League (Gabbett, 2013). As such, there may also be observable differences in the external output profiles of beach volleyball teams that vary in proficiency, but this remains to be determined. Different levels of competition may also influence the external output profile of match-play, whereby a higher level of competition in rugby sevens (Higham et al., 2012), Australian football (Brewer et al., 2010) and hockey (Jennings et al., 2012) has been associated with higher overall activity profiles than lower levels of competition. The congested match fixture in beach volleyball tournaments may also influence the external output profile in subsequent matches. In other sports, a congested match fixture in a junior rugby league tournament has been shown to contribute to reductions in high-intensity activity and work rates during latter-stage matches (Johnston et al., 2013). Conversely, research in domestic and international rugby sevens tournament match-play has shown no indication of accumulated fatigue over a multi-day tournament (Higham et al., 2012). Despite several investigations in other sports, an analysis of the contextual factors affecting the external output profile of beach volleyball players is warranted.

Effective time–motion analysis can provide an objective yet non-invasive method for quantifying the external output profile of team sports (Aughey, 2011), and provide information directly applicable to the design of physical conditioning and testing programmes (Barris and Button, 2008). Therefore, the aims of this study were to use GPS technology to: 1) quantify the differences in the external output profile of open-age (Adult) and under 23 years (U23) players during tournament match-play, 2) quantify changes in the external output profile within matches to examine the effects of player fatigue, and; 3) examine the influence of the margin of score differential on the external output profile of beach volleyball tournament match-play.

Methods

Subjects

Ten U23 (age 19.3 ± 2.4 y, body mass 71.9 ± 5.2 kg, height 1.76 ± 0.07 m) and ten adult beach volleyball players (age 27.4 ± 2.6 y, body mass 75.9 ± 11.0 kg, height 1.80 ± 0.08 m) were monitored during tournament match-play. All players had a minimum of 7 yr of beach-volleyball training. Pairs were ranked in the top 6 teams out of a possible 24 teams in their respective tournaments. Written informed consent was obtained from players before the investigation and the Griffith University Human Research Ethics Committee approved the study.

Study design

A prospective, observational study design was used to assess the external output profile of U23 and adult female beach volleyball players during competition in order to examine the effect of competition level, margin of score differential and alterations of external output within matches. Adult level and U23 female beach volleyball players wore GPS technology (10 Hz) during 60 matches (50 first and second sets and 20 third set files files) during their respective Australian Beach Volleyball Championship tournaments and we employed linear mixed models to model the external output metrics within each match in order to determine if the set (i.e. set 1, 2 or 3), playing level (i.e. Adult or U23) or score margin (i.e. (Low: <6-point score differential or high: >5-point score differential) were moderating factors on the activity profile of match-play.

The participants were monitored during competitive Queensland state adult level tournament matches or U23 National tournament matches. The tournaments were held on the Gold Coast, Queensland during the Summer months and were contested for prize money by teams comprising of semi-professional players and officiated by referees. All matches were played on standard outdoor beach sand courts. Teams played four group stage matches on day one, typically with ~3 h between matches and then, depending on the preliminary match results, up to three finals matches on the second day of competition. There were 20 two-set and 11 three-set U23 tournament matches and 10 two-set and 9 three-set adult tournament matches.

Global Positioning System technology

During the matches participants wore a ‘GPS unit’ containing a receiver (VX Sport VX110 Log, Visuallex Sport International Ltd, Lower Hutt, New Zealand) that collected time and location data using the GPS at a frequency of 10 Hz and a tri-axial accelerometer measuring the rate of change of speed at 100Hz. Previous studies have demonstrated that the VX Sport Log system has small to moderate CVs (8 out of 9 CV% under 5%) and excellent ICCs (>0.96) for and tri-axial accelerometer functionality (Buchheit et al., 2014) for various distance, speed and acceleration metrics, which compare favourably to other prominent manufacturers of GPS units. Each player wore the same GPS unit for each match which was positioned between their scapulae using an elasticised harness worn underneath the playing attire and. Each device was activated, and satellite lock was established for a minimum of 15 min before the commencement of matches. Data were downloaded using the manufacturer’s software (v 2.106.0.0, Visuallex Sport International Ltd, Lower Hutt, New Zealand) and matches were categorised based on the tournament level (U23 or adult). The between set time interval and stoppage time were excluded and a total of 174 match files were included for analysis. The external output profiles were quantified based on the total distance covered (m), relative distance (m·min^{-1}), peak speed (m·s^{-1}), relative distance covered in specific speed zones (m·min^{-1}; zone 1: 0.0 to 0.99 m·s^{-1}, zone 2: 1.0 to 1.99 m·s^{-1} and zone 3: ≥2.0 m·s^{-1}), and an acceleration/deceleration profile. In order to provide an indication of the total acceleration re quirements, we used the raw data to calculate instantaneous acceleration/deceleration (mean acceleration/deceleration; m·s^{-2}) (Delaney et al., 2016), as well as the mean acceleration (mean acceleration; m·s^{-2}) and deceleration only (mean deceleration; m·s^{-2}) by converting the rate of change in speed to 1 Hz measurements (Delaney et al., 2018). In addition, we used the raw data to calculate the distance (m·min^{-1}) covered in predefined acceleration (zone 1: 1.0 to 1.99 m·s^{-1}, zone 2: 2.0 to 2.99 m·s^{-1}, zone 3: 3.0 to 3.99 m·s^{-1} and zone 4: ≥4.0 m·s^{-1}) and deceleration thresholds (zone 1: -1.0 to -1.99 m·s^{-1}, zone 2: -2.0 to -2.99 m·s^{-1}, zone 3: -3.0 to -3.99 m·s^{-1} and zone 4: ≤-4.0 m·s^{-1}). A minimum effort duration criteria of 0.3 s was implemented to prevent brief thoracic movements from registering as locomotive efforts.

Statistical analyses

Descriptive statistics (marginal mean and 95% confidence interval) were used to characterise the external output profile metrics. Linear mixed models were performed using the *lme4* (Bates et al., 2014) and *afex* packages in R Studio Statistical software (version 3.5.3). Linear mixed models were deemed the appropriate statistical method to employ given that our clustered dataset arose from repeated samples from the same subject across numerous time points (Vandenbogaerde and Hopkins, 2010). In order to model the external output metrics within each match, the set (i.e. set 1, 2 or 3), playing level (i.e. Adult or U23) and score margin (i.e. (Low: <6-point score differential or high: >5-point score differential) were treated as fixed effects, while the player and match were treated as random effects. In each external output profile metric, interactions were assessed between set, playing level, and score margin; however, no interactions were present in any analysis and were, therefore, removed from the final model for each metric.

Results

Table 1 shows the external output metrics of the U23 and adult level beach volleyball players. The relative distance covered in speed zone 1 was greater in the U23 players (U23: 18.96 ± 0.39 m·min^{-1}; 52.5% of total relative distance, adult: 16.91 ± 0.47 m·min^{-1}; 46.3% of total relative distance $P < 0.001$) compared to the adult level beach volleyball players. Furthermore, the relative distance covered in speed zone 2 (U23: 13.70 ± 0.47 m·min^{-1}; 37.9% of total relative distance, adult: 15.33 ± 0.59 m·min^{-1}; 42.0% of total relative distance, $p < 0.001$) and 3 (U23: 3.39 ± 0.24 m·min^{-1}; 9.4% of total relative distance, adult: 3.99 ± 0.29 m·min^{-1}; 10.9% of total relative distance, $p = 0.003$) was greater in the adult level beach volleyball players, compared to the U23 players. All metrics were relatively stable from match to match for the duration of each tournament in both U23 (CV of external output metrics range: 2.2 - 6.8%) and adult level (CV range: 1.4 - 6.1%) and there was no change in any physical performance metric across the tournament (all $p > 0.05$).

Table 2 shows the external output metrics during each set of the combined U23 and adult level beach volleyball matches. There was a significantly lower total distance covered in the third set (519.60 ± 25.69 m) compared to the first (569.72 ± 16.21 m; $p = 0.001$) and second set (565.62 ± 16.52 m; $P = 0.001$). Furthermore, when total distance was expressed relative to playing time, relative distance was greater in set 1 (37.08 ± 0.73 m·min^{-1}) compared to set 2 (35.54 ± 0.75 m·min^{-1}; $p = 0.001$). The mean acceleration/deceleration was lower in set 2 (0.75 ± 0.02 m·s^{-2}) compared to both set 1 (0.77 ± 0.02 m·s^{-2}; $p < 0.001$) and set 3 (0.77 ± 0.03 m·s^{-2}; $p = 0.034$). In addition, the relative distance covered in acceleration zone 2 and deceleration

Table 1. External output profile metrics of adult female and under 23 year old female beach volleyball players during match-play. Values are expressed as marginal mean (95% CI).

Variable	Adult	U23
Total distance (m)	570.98 (554.28 - 587.69)	552.00 (538.41 - 565.58)
Relative distance (m·min^{-1})	36.54 (35.67 - 37.42)	36.15 (35.43 - 36.86)
Peak speed (m·s^{-1})	3.90 (3.81 - 3.99)	3.89 (3.82 - 3.97)
Mean acceleration/deceleration (m·s^{-2})	0.76 (0.74 - 0.78)	0.76 (0.74 - 0.78)
Mean acceleration (m·s^{-2})	1.18 (1.15 - 1.20)	1.16 (1.14 - 1.18)
Mean deceleration (m·s^{-2})	-1.18 (-1.2 - -1.15)	-1.17 (-1.19 - -1.15)
Relative Distance in Acceleration Zones (m·min^{-1})		
Zone 1	6.19 (6.00 - 6.38)	6.28 (6.11 - 6.44)
Zone 2	7.19 (7.03 - 7.36)	7.28 (7.15 - 7.42)
Zone 3	2.78 (2.67 - 2.90)	2.72 (2.62 - 2.82)
Zone 4	2.16 (2.06 - 2.25)	2.09 (2.01 - 2.16)
Relative Distance in Deceleration Zones (m·min^{-1})		
Zone 1	5.97 (5.83 - 6.12)	6.00 (5.88 - 6.13)
Zone 2	6.19 (6.03 - 6.34)	6.12 (5.99 - 6.24)
Zone 3	2.06 (1.97 - 2.15)	1.99 (1.92 - 2.06)
Zone 4	1.40 (1.33 - 1.47)	1.34 (1.29 - 1.40)
Relative Distance in Speed Zones (m·min^{-1})		
Zone 1	16.91 (16.44 - 17.38)	18.96 (18.57 - 19.35) [a]
Zone 2	15.33 (14.76 - 15.92)	13.7 (13.23 - 14.17) [a]
Zone 3	3.99 (3.70 - 4.29)	3.39 (3.15 - 3.63) [a]

[a] indicates significantly different to an Open set

Table 2. External output profile metrics in first, second, and third sets in beach volleyball tournament match-play. Values are expressed as marginal mean (95% CI).

Variable	Set 1	Set 2	Set 3
Total distance (m)	569.72 (553.52 - 585.93)	565.62 (549.11 - 582.14)	519.60 (493.91 - 545.29) [a,b]
Relative distance ($m \cdot min^{-1}$)	37.08 (36.34 - 37.81)	35.54 (34.80 - 36.29) [a]	36.20 (35.08 - 37.32)
Peak speed ($m \cdot s^{-1}$)	3.90 (3.81 - 3.99)	3.92 (3.83 - 4.01)	3.84 (3.71 - 3.98)
Mean acceleration/deceleration ($m \cdot s^{-2}$)	0.77 (0.75 - 0.79)	0.75 (0.73 - 0.77) [a]	0.77 (0.75 - 0.80)
Mean acceleration ($m \cdot s^{-2}$)	1.17 (1.15 - 1.19)	1.17 (1.15 - 1.19)	1.16 (1.14 - 1.19)
Mean deceleration ($m \cdot s^{-2}$)	-1.18 (-1.20 - -1.16)	-1.17 (-1.19 - -1.15)	-1.17 (-1.19 - -1.14)
Relative Distance in Acceleration Zones ($m \cdot min^{-1}$)			
Zone 1	6.31 (6.14 - 6.48)	6.14 (5.97 - 6.31)	6.34 (6.09 - 6.59)
Zone 2	7.41 (7.26 - 7.57)	7.06 (6.90 - 7.23) [a]	7.28 (7.03 - 7.53)
Zone 3	2.79 (2.68 - 2.89)	2.69 (2.58 - 2.80)	2.77 (2.61 - 2.93)
Zone 4	2.11 (2.02 - 2.19)	2.09 (2.00 - 2.17)	2.20 (2.06 - 2.33)
Relative Distance in Deceleration Zones ($m \cdot min^{-1}$)			
Zone 1	6.06 (5.92 - 6.20)	5.90 (5.76 - 6.04)	6.03 (5.82 - 6.25)
Zone 2	6.26 (6.12 - 6.41)	6.01 (5.86 - 6.16) [a]	6.17 (5.94 - 6.40)
Zone 3	2.07 (1.99 - 2.14)	1.96 (1.88 - 2.04) [a]	2.03 (1.91 - 2.15)
Zone 4	1.36 (1.30 - 1.43)	1.35 (1.29 - 1.41)	1.41 (1.31 - 1.51)
Relative Distance in Speed Zones ($m \cdot min^{-1}$)			
Zone 1	17.92 (17.47 - 18.37)	18.07 (17.62 - 18.53)	18.88 (18.18 - 19.58) [a]
Zone 2	15.06 (14.52 - 15.6)	13.92 (13.37 - 14.48)	13.61 (12.74 - 14.47) [a]
Zone 3	3.68 (3.39 - 3.96)	3.49 (3.20 - 3.78)	3.85 (3.39 - 4.30) [b]

[a] indicates significantly different to Set 1, [b] indicates significantly different to Set 2

zone 2 and 3 was lower in set 2 compared to set 1 ($p < 0.05$). There was a greater relative distance covered in speed zone 1 (set 1: 17.92 ± 0.45 $m \cdot s^{-2}$, set 3: 18.88 ± 0.70 $m \cdot s^{-2}$; $p = 0.022$), but lower relative distance covered in speed zone 2 (set 1: 15.06 ± 0.54 $m \cdot s^{-2}$, set 3: 18.88 ± 0.86 $m \cdot s^{-2}$; $p = 0.005$) in set 3 compared to set 1. Finally, there was a greater relative distance covered in speed zone 3 in set 3 (3.85 ± 0.45 $m \cdot min^{-1}$) compared to set 2 (3.49 ± 0.29 $m \cdot s^{-2}$; $p = 0.003$).

Table 3 shows the external output metrics during matches that were decided by small (<6 point score differential) and large score margins (>5 point score differential). In comparison to matches that were decided by large score margins, players competing in sets decided by small score margins covered a significantly greater total and relative distance, peak speed, greater mean acceleration and deceleration output and covered more distance in speed zone 1 and 3 (all $p < 0.05$).

Table 3. External output profile metrics in sets decided by small (<6 points) and large (>5 points) score margins in adult female and U23 female beach volleyball players. Values are expressed as marginal mean (95% CI).

Variable	Large	Small
Total distance (m)	495.74 (482.59 - 508.89)	675.04 (657.34 - 692.75) [a]
Relative distance ($m \cdot min^{-1}$)	35.64 (34.99 - 36.3)	37.5 (36.67 - 38.33) [a]
Peak speed ($m \cdot s^{-1}$)	3.79 (3.72 - 3.86)	4.09 (4 - 4.19) [a]
Mean acceleration/deceleration ($m \cdot s^{-2}$)	0.74 (0.72 - 0.76)	0.80 (0.78 - 0.82) [a]
Mean acceleration ($m \cdot s^{-2}$)	1.16 (1.14 - 1.18)	1.18 (1.16 - 1.2)
Mean deceleration ($m \cdot s^{-2}$)	-1.16 (-1.18 - -1.15)	-1.2 (-1.22 - -1.17) [a]
Relative Distance in Acceleration Zones ($m \cdot min^{-1}$)		
Zone 1	6.16 (6.02 - 6.31)	6.39 (6.21 - 6.57) [a]
Zone 2	7.14 (7.01 - 7.27)	7.44 (7.26 - 7.61) [a]
Zone 3	2.70 (2.61 - 2.79)	2.83 (2.71 - 2.94)
Zone 4	2.03 (1.96 - 2.10)	2.27 (2.18 - 2.37) [a]
Relative Distance in Deceleration Zones ($m \cdot min^{-1}$)		
Zone 1	5.92 (5.80 - 6.03)	6.12 (5.97 - 6.27) [a]
Zone 2	6.11 (5.99 - 6.23)	6.2 (6.04 - 6.36)
Zone 3	1.98 (1.91 - 2.04)	2.09 (2.01 - 2.18) [a]
Zone 4	1.30 (1.24 - 1.35)	1.49 (1.42 - 1.57) [a]
Relative Distance in Speed Zones ($m \cdot min^{-1}$)		
Zone 1	17.92 (17.55 - 18.29)	18.55 (18.06 - 19.04) [a]
Zone 2	14.27 (13.82 - 14.72)	14.50 (13.89 - 15.10)
Zone 3	3.43 (3.20 - 3.66)	4.00 (3.68 - 4.31) [a]

[a] indicates significantly different compared to large-margin set.

Discussion

Players competing at adult level, covered less relative distance at a lower speed, but more relative distance ≥2.0 $m \cdot s^{-1}$ compared to U23 players. During matches, there was some evidence of either pacing or fatigue whereby players had a lower relative distance and mean acceleration/deceleration in set 2 compared to set 1, but greater distance ≥2.0

$m \cdot s^{-1}$ in set 3. Sets that are decided by small score margins (<5 points) are comprised of a greater relative distance and peak speed, greater mean acceleration and deceleration output and more relative distance in speed zone 1 and 3 compared to sets decided by larger score margins. The findings from this study suggest that there are contextual factors that influence the activity profile of female beach volleyball players such as tournament level, score margin and set-to-set variation that have implications for the physiological and performance requirements of female players preparing for competition.

The results of the present study show that within the confinements of our specific sample population (U23 and adult) and small sample size specific to two tournaments, adult female players cover on average 571 m each set at various speeds, while U23 players cover 552 m. The majority of previous studies that have attempted to quantify the activity profile of players during beach volleyball match-play used notational analysis based on qualitative data (Magalhães et al., 2011; Medeiros et al., 2014; Palao et al., 2015; Turpin et al., 2008). It is clear from these studies (Magalhães et al., 2011; Medeiros et al., 2014; Palao et al., 2015; Turpin et al., 2008) and those of the present study, that beach volleyball is comprised of many explosive efforts and multiple short bouts of high-intensity movements. As such, the acceleration and deceleration capacity of beach volleyball players is important because these actions are thought to influence the aspects of match-play that determine the outcome of a match (Palao et al., 2015). One previous study has employed GPS technology to characterize the external output of elite female beach volleyball match-play (Nunes et al., 2020). Nunes et al. (2020) studied a top-level female pair during international and national competitions and reported that low-speed activity (i.e., walking and jogging) and low-acceleration and deceleration (<2 $m \cdot s^{-2}$) accounted for the majority (~85%) of total distance, similar to the present study. Despite this, the time spent with a heart rate >80% of maximal heart rate was ~55% of match time indicating that the high-intensity movements of beach volleyball match-play do incur a high internal load.

In relation to other sports, results from the present study show that the mean acceleration and deceleration metrics were comparable to that of professional rugby league players in National Rugby League matches (mean acceleration 1.16 $m \cdot s^{-2}$, mean deceleration -1.14 $m \cdot s^{-2}$, mean acceleration/deceleration: 0.72 $m \cdot s^{-2}$). Research in other sports with small court dimensions (30 x 20 m) such as small-sided soccer games (Hodgson et al., 2014) have reported substantial acceleration demands, whereby players covered distances of 9.4, 3.6 and 1.4 $m \cdot min^{-1}$ in low (1.0 - 2.0 $m \cdot s^2$), medium (2.0 - 3.0 $m \cdot s^2$) and high (>3.0 $m \cdot s^2$) acceleration zones, respectively, which is comparable to the present study. Given that these movements are performed on sand in beach volleyball, it could be suggested that performing frequent accelerations are also associated with a greater metabolic cost compared to performing these actions on solid ground (Brito et al., 2012; Gaudino et al., 2013). For example, while the reduction in total distance covered on sand may be partially compensated for by covering greater distances on solid ground, blood lactate, perceived exertion, mean heart rate and time spent with a heart rate >90% peak heart rate are higher when playing small-sided recreational soccer games on sand compared to asphalt (Brito et al., 2012). Furthermore, other research shows that ground contact time, energy cost, metabolic power and deceleration is greater when sprinting on sand compared to natural grass and artificial turf (Gaudino et al., 2013). As such, the metabolic consequences resulting from performing high-intensity movements on sand in beach volleyball competition have implications for the physical preparation of beach volleyball players.

We observed differences in the relative distance covered within different speed thresholds between different levels of competition, whereby players competing at adult level, covered less distance at a lower speed, but more distance ≥2.0 $m \cdot s^{-1}$ compared to U23 players. One previous study (Nunes et al., 2020) has assessed the influence of competition level on the external output of beach volleyball players by comparing the output of an elite female pair in national and international standard competitions. Nunes et al. (2020) reported that total distance and peak velocity, as well as the relative distance covered in various speed and acceleration zones were greater in international compared to national standard matches. In other sports, competition level also seems to influence the external output profile of players during matches, where there were meaningful differences in the mean game external output metrics of female National elite level compared to adult domestic rugby sevens' players (Clarke et al., 2017). Furthermore, Jennings et al. (Jennings et al., 2012) demonstrated that international field hockey players perform more high-speed running (>4.17 $m \cdot s^{-1}$) and had a greater total distance than their national-level counterparts. It should be noted that the level of competition may have been more comparable in the present study (i.e., U23 National and adult open state level), compared to previous research (Clarke et al., 2017; Jennings et al., 2012; Nunes et al., 2020) that has compared the external output profile of female athletes from different levels of competition. Indeed, the larger magnitude of difference between the playing standard of adult domestic and international players studied in these investigations (Clarke et al., 2017; Jennings et al., 2012; Nunes et al., 2020) may have exacerbated the differences observed between playing levels in these studies.

In agreement with previous research in other team sport athletes, beach volleyball players demonstrated alterations in the external output profile during subsequent periods of match-play (Aughey, 2010; Rampinini et al., 2009; Rienzi et al., 1999). Interestingly, relative distance and relative distance covered in acceleration zone 2 and deceleration zone 2 and 3 was greater in set 1 compared to set 2. In addition, there was a greater relative distance covered in speed zone 1 and 3, but lower relative distance covered in speed zone 2 in set 3 compared to set 1 and 2. Whether these alterations in the activity profile are due to fatigue, pacing or situational differences is difficult to determine. Indeed, whether decrements in work-rate observed during subsequent periods of match-play in European and Australian Football players is due to these contextual factors is an ongoing debate (Aughey, 2010; Bradley and Noakes, 2013). It should be mentioned that using time-motion data to determine if pacing or fatigue occurs during beach volleyball is challenging given the complexities of the intermittent nature of match-play. Nonetheless, the ability of players to sustain high intensity activity over the duration of a match suggests that fatigue may be an important consideration to maintain performance during beach volleyball match-play. Further investigations are required to confirm the temporal and transient fatigue patterns during beach volleyball match-play.

There were substantial increases in most of the external output metrics during sets that were decided by small (<6-point score differential) and large score margins (>5-point score differential). These results are similar to previous research in Australian Football (Sullivan et al., 2014), whereby players accumulated more high-speed running distance (>14.5 $km \cdot h^{-1}$) and greater total distance and body load relative to playing time during quarters decided by smaller score margins (<9 points) compared to larger score margins (>19 points). Although not measured in the present study, it is likely that more successful beach volleyball teams have greater proficiency in technical performance components compared to less-successful teams (Palao and Ortega, 2015). As such, when more proficient teams compete against each other, the rallies are likely to be longer and the continuity of each rally duration would increase the number of high-intensity actions undertaken by the players (i.e., contacts, jumps, accelerations). Given that there is likely to be less variation in the quality of opposition in higher levels of beach volleyball competition, the increase in physical performance required for higher levels of competition and during sets decided by small score margins has implications for the selection and physical preparation of beach volleyball players.

Conclusion

Although most external output metrics were similar between adult level and U23 state level matches, players competing at adult level, covered less relative distance at a lower speed, but more relative distance $\geq 2.0\ m \cdot s^{-1}$ compared to U23 players. We also showed that sets that were decided by small score margins (<5 points) were associated with an increase in external output compared to sets decided by larger score margins. Within matches, there was some evidence of altered external output during the second set, which may have been due to either pacing, fatigue or other contextual factors. Within the confinements of our specific sample population (U23 and adult female beach volleyball players) and small sample size specific to two tournaments, it could be suggested that senior level beach volleyball players and players competing against more highly skilled opponents are likely to require superior aerobic and anaerobic physiological capabilities in order to tolerate the greater external output profile. Furthermore, in order to maximise the physical preparation of players, training should comprise of many explosive efforts and multiple short bouts of high-intensity movements.

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Key points

- Sets that are decided by small score margins (<5 points) are comprised of a greater relative distance and peak speed, greater mean acceleration and deceleration output and more relative distance in speed zone 1 and 3 compared to sets decided by larger score margins.
- Within beach volleyball matches, there is some evidence of altered external output during the second set, whereby relative distance (i.e., $m \cdot min^{-1}$), mean acceleration/deceleration and the relative distance covered in acceleration zones was greater in set 1 compared to set 2 which may have been due to either pacing, fatigue or other contextual factors.
- In order to maximise the physical preparation of players, training should comprise of many explosive efforts and multiple short bouts of high-intensity movements.

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