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ANTHROPOMETRIC AND PERFORMANCE PERSPECTIVES OF FEMALE COMPETITIVE SURFING

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Short Title: Perspectives of Female Surfing

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Abstract

Purpose: To evaluate the anthropometric profiles of female surfers and to identify whether any anthropometrical factors might predict competitive ranking. Secondly to evaluate the activity profile of female competitive surfing with respect to environmental conditions using GPS derived measures. **Methods:** Following institutional ethical approval $n = 31$ female competitive surfers underwent anthropometric assessment (mean age: 20.49, $s = 5.32$ years, stature: 165.2, $s = 4.8$ cm; body mass: 63.0, $s = 6.8$ Kg) a subsample ($n = 22$) wore GPS units during competition at four different locations with varied surfing conditions. **Results:** The mean somatotype values the surfers was found to be (Endo-Meso-Ecto) 4.06 – 4.15 – 2.01. Significant correlations ($p < 0.05$) were found between National ranking and triceps, medial calf skinfolds, sum of six skinfolds, body fat percentage and sum of eight skinfolds. Percentage time sitting, paddling and riding were $62.58\% \pm 10.18\%$, $30.70\% \pm 9.44\%$ and $6.73\% \pm 2.91\%$ respectively. The mean ride time, maximum ride time, total time spent riding and the total distance surfing were significantly correlated with the round of the competition. Furthermore, the number of rides, time spent riding, percentage of total distance surfing and percentage time riding were correlated with heat placement ($p < 0.05$). Time spent sitting was associated with poorer heat placements ($p < 0.01$). **Conclusions:** Body fat levels are associated with national ranking in competitive female surfers. The number of waves ridden in a heat, the length of the rides and activity levels were significantly related to heat placement and competition progression.

Keywords: Body composition; sports; somatotypes; athletic performance/physiology; Muscle, skeletal; body size; body mass index; GPS; wave conditions; competition.

Introduction

Surfing is an intermittent exercise that comprises bouts of high intensity exercise interspersed with periods of low intensity activity and rest. The action of surfing involves the surfer paddling the board out into the area beyond the breaking waves, waiting for a suitable wave when the surfer then paddles into the wave and “pops up” to their feet to ride the face of the wave where they perform an number of manoeuvres before they fall off or the wave dissipates [1]. Only the riding element of the activity is judged during competition but this element only represents 3.8 - 8.12% of the total time surfing with paddling contributing 35 – 54%, waiting 28 – 42% and miscellaneous activities such as “duck diving”, wading, and “wipe-outs” contributing 2.5 – 5% [2-4]. Competition is scored by a panel of judges where points are awarded for technical difficulty and execution of manoeuvres [5].

With increasing professionalism within surfing, scientific study of the area to inform training and development practices has increased with studies focussing on describing the demands of surfing activity [2, 4, 6], the physiological characteristics of high performance surfers [1, 7-11], injury [12, 13], testing for selection purposes [12, 14, 15], scoring in competition [12, 14-16] and the anthropometric profiles of surfers [7, 17]. The majority of this work has been performed using male participants and there have been only a few surfing related studies involving female participants within the nutritional, biomechanical and physiological fields [18-20].

Anthropometric studies of male surfers have found that increased muscularity and lower levels of body fat are associated with improvements in competitive ranking [17]. Lowdon [1] investigated the anthropometric profile of female surfers based on a sample of 14 female surfers competing at collegiate level (from various racial and national backgrounds) and found mean female somatotype scores of 3.9 for endomorphy, 4.1 for mesomorphy and 2.6 for ectomorphy but no significant correlations between somatotype and finishing order were found. Since Lowdon`s work [1] the separate male and female judging criteria have been removed with male and female competitors now competing to the same judging criteria which has a stronger focus on power than the earlier women`s judging criteria. It is possible that these rule changes, have affected the representative physiological characteristics of successful modern female competitive surfers. It has been previously established that there is a relationship between anthropometric measures of muscularity and measures of strength and

power [21]. Strength and power is required to perform many of the scoring manoeuvres in surfing competition but is also required for functional actions such as the “pop-up” where female surfers have been shown to be at a disadvantage compared to their male counterparts [19].

Time – motion analysis has been used to evaluate the performance profile of surfers in a number of studies [2-4, 22]. However, all of these studies have relied on male participants and the performance profile is known to vary according to the nature and ability of the surfers [2] and whether they are surfing in competition [3, 4] or surfing recreationally [2, 6]. The areas in which surfing takes place for example a beach break or point break have been shown to affect the profile of surfing activity [3] as has the nature of the wave conditions (height and period) during recreational surfing [2]. No study has evaluated the activity profile of female surfers in competition or evaluated the effect of wave / environmental conditions during competition.

The aim of this study was twofold; firstly to evaluate the anthropometric profiles of female surfers and to identify whether any anthropometrical factors might predict competitive ranking. Secondly to evaluate the activity profile of female competitive surfing with respect to environmental conditions using Global Positioning Systems (GPS) derived measures. We hypothesised that body compositional variables will correlate with competitive ranking and that the activity profile of competitive female surfers will vary in respect to the environmental conditions.

Material and methods

Measurements were taken during United Kingdom Professional Surfing Association (UKPSA) events which took place at Fistral Beach, Cornwall, England; Watergate Bay, Cornwall, England; Thurso East, Scotland and Brimms Ness, Scotland during the 2015 season. Anthropometric measures of stature, body mass, skinfolds, girths and bone breadths were taken to evaluate body composition characteristics. These characteristics were then correlated with end of year rankings. GPS units (Catapult S5, Catapult Sports, Australia) were worn during competition and speed thresholds were calculated from the GPS data to identify the speed and distance characteristics of individual rides. The ride data was then

correlated with heat placing, stage of competition (rounds) and the prevailing surf conditions (wave height, wave period and wind relative wind orientation).

Subjects

Following institutional ethical approval and signed Informed consent, 31 female surfers participated in this study (mean age: 20.49, SD = 5.32 years, stature: 165.2, SD = 4.8 cm; body mass: 63.0, SD = 6.8 Kg). These surfers were likely to train rigorously and also compete regularly in high level surfing competitions.

Procedures

Anthropometric measures were performed at the contest venues and included stature (Seca 225, Birmingham UK), body mass which was measured to the nearest 0.01Kg using a digital scale (SECA 770, Birmingham UK), skinfolds (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh and medial calf) were measured using calibrated Harpenden callipers (John Bull, British Indicators, West Sussex, UK), girths (arm flexed and tensed, waist, gluteal and calf) were measured using an anthropometric tape (Lufkin W606PM, Cooper Hand Tools, Tyne & Wear, UK). Bone breadths (humerus and femur) were measured using a Holtain anthropometer (Holtain Ltd, Dyfed, UK). The measures were taken by one technician who was accredited (level 1) by the International Society for the Advancement of Kinanthropometry (ISAK) The Technical Error of Measurements (TEM) for the technician were <0.95mm, <0.45cm, <0.03cm for all skinfolds, girths and breadths respectively. All measures were taken in accordance with the guidelines of the International Society for the Advancement of Kinanthropometry [23] on the right hand side of the body regardless of handedness or stance. Measurements were taken twice and variation between measures was less than 1% for body mass, stature, girths and breadths with variability of less than 5% for skinfolds.

Somatotype were calculated using the Heath Carter somatotype method [24]. Sum of eight skinfolds and sum of six skinfolds (excluding bicep and illiac crest) were calculated according

to Norton & Olds [25]. Body fat percentage values were calculated using the equation of Yuhasz [26].

A sub sample of participants (n= 22) volunteered to wear a 10Hz GPS unit during surfing competition to allow the tracking of positional data. The device was placed inside two knotted nitrile gloves in order to waterproof the unit and then located inside the wetsuit between the shoulder blades in-line with the spine. Speed thresholds were calculated from the GPS data to identify the speed and distance characteristics of individual rides [27]. The perceived wave height was recorded as the estimated wave face height by the researchers [28]. Wave period values were recorded retrospectively using historical internet based forecast data for the respective location (www.magicseaweed.com). All GPS data was downloaded to a PC and analysed using Logan Plus 4.0 (Catapult Innovations, Australia) software. Exclusion criteria for the GPS data included loss of satellite coverage during the session, loss of data through battery failure, unit deactivation or software errors. The number of satellites ranged from 11 to 15 (mean = 13 ± 1) with a mean horizontal dilution of precision of 0.96 ± 0.29). A low horizontal dilution of precision (within range of 0–50) indicates an optimal geometrical positioning of orbiting satellites for accurate monitoring of position [29, 30].

The GPS files were subsequently analysed using Matlab (Version R2105b); using the 10Hz sampling the velocities derived from the changes in Longitude and Latitude allows the distance covered (m) to be calculated by multiplication of the speed ($\text{m} \cdot \text{s}^{-1}$) by the time in seconds. A ride was identified when the speed of the surfer was greater than the minimum ride speed threshold of $2.5 \text{ m} \cdot \text{s}^{-1}$ for a minimum of 4 seconds. Data that were above the minimum wave speed threshold but lasted less than 4 seconds were discounted as waves and reported as paddling; where the wave speed dropped below the minimum riding threshold for a period of less than 4 seconds (during a turn or stall) the analysis removed the section of data below this threshold and interpolated the data to allow the two (or more) discreet bouts to be counted as one. The data for each ride was then used to give values for maximum speed, minimum speed, standard deviation of the wave speeds, distance and duration of the rides. GPS can occasionally produce spurious data through loss of signal or through the surfer performing free falls or aerial manoeuvres. A maximum wave speed threshold was

incorporated using theoretical maximum speed threshold for a surfer, where Max Speed Threshold $\approx 6.04 \sqrt{H_b}$

Here, H_b is the breaker height as calculated by $1.29 \times$ the significant wave height [31]. Occasionally, the GPS signal can be lost or unreliable during surfing activity leading to erroneous data points which can be isolated based on unrealistic surfer velocities. Any data points that were found to be in excess of 1.2 times of the max speed threshold were removed and interpolated using the data points immediately preceding and following the spurious point. The times when the surfers are travelling at less than $0.5 \text{ m} \cdot \text{s}^{-1}$ were identified as “waiting” (there may be some movement due to local wave, wind or tidally induced flows). Surfers were identified as “paddling” when their speeds were in excess of the “waiting” threshold but below the minimum ride speed threshold. The totals of “riding”, “waiting” and “paddling” were summed. Percentages were given for time spent in each of these activities and the distance covered per hour both surfing and paddling were calculated.

Statistical analyses

Means and standard deviations were calculated for each of the anthropometric variables. As the ranking data (dependant variable) is of neither interval or ratio level, Spearman`s rank correlation coefficients (r_s) were calculated to establish the relationship between the different anthropometric variables and the ranking of the professional surfers. Analysis of the wave data allowed calculation of maximum, minimum, mean and standard deviation values for ride distances, speeds, and time. Total number of rides, total distance covered, total distances ridden, total and percentage time riding, total time and percentage time waiting, total time and percentage time paddling, total time and percentage time in miscellaneous were also calculated. Spearman`s rank correlations (ρ) were used to determine the relationship for heat position and also the stage of the competition as determined by the round of competition with ride parameters and performance parameters. Pearson`s correlations (r) were performed between the wave parameters wave height, wave period and wind direction with the, ride parameters, and performance parameters.

All statistical analyses were performed using IBM SPSS Statistics version 22, with statistical significance set at $p < 0.05$.

Results

The descriptive statistics for the anthropometric variables of the surfers are presented in Table 1, which also includes the correlations (Spearman's rank) for the calculated anthropometric indices and the ranking. Significant correlations ($p < 0.05$) were found between National ranking and triceps skinfold, medial calf skinfold, sum of six skinfolds, body fat percentage and sum of eight skinfolds. The somatotype values of the surfers can be seen in Figure 1. The mean somatotype value was found to be 4.06 – 4.15 – 2.01 for endomorphy, mesomorphy and ectomorphy respectively.

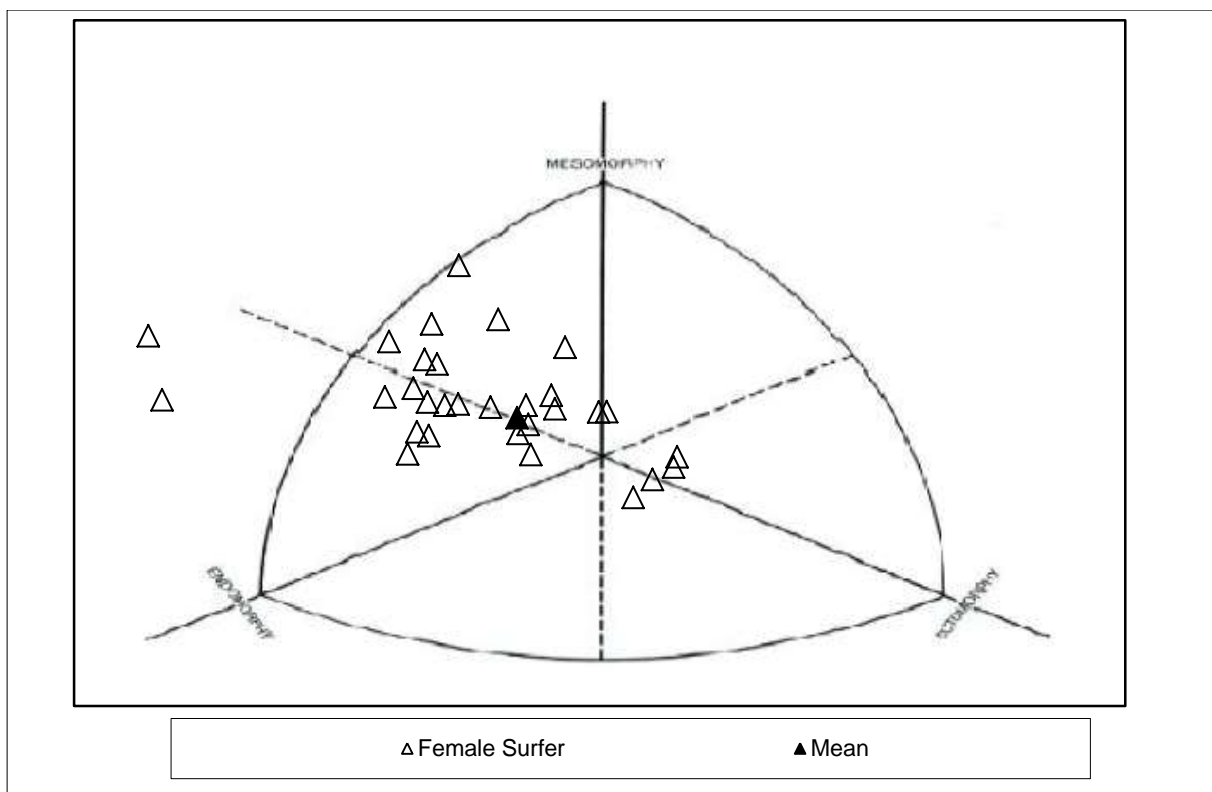


Figure 1. Somatotype distribution of the surfers ($n = 31$), mean somatotype (endomorphy, mesomorphy, ectomorphy) = 4.06 – 4.15 – 2.01.

Table 1. Anthropometric variables (mean \pm s) of female competitive surfers and correlation with national ranking.

Measure	Mean \pm SD	Spearman's Correlation (ρ)
Body mass (kg)	63.0 \pm 6.8	0.090
Stature (cm)	165.2 \pm 4.8	-0.067
Triceps skinfold (mm)	14.9 \pm 4.8	0.371*
Subscapular skinfold (mm)	12.4 \pm 6.2	0.214
Biceps skinfold (mm)	6.8 \pm 2.6	0.337
Iliac Crest skinfold (mm)	15.9 \pm 5.4	0.034
Supraspinale skinfold (mm)	12.1 \pm 4.5	0.292
Abdominal skinfold (mm)	19.4 \pm 6.4	0.226
Front Thigh skinfold (mm)	21.6 \pm 7.8	0.289
Medial Calf skinfold (mm)	13.9 \pm 3.7	0.370*
Relaxed arm girth (cm)	27.3 \pm 2.5	-0.031
Flexed arm girth (cm)	29.5 \pm 2.5	0.100
Waist girth (cm)	71.9 \pm 5.2	0.196
Gluteal girth (cm)	95.7 \pm 7.1	-0.045
Calf girth (cm)	33.8 \pm 2.3	0.066
Humerus breadth (cm)	6.4 \pm 0.9	-0.063
Femur breadth (cm)	8.7 \pm 0.8	0.179
Endomorphy	4.06 \pm 1.28	0.318
Mesomorphy	4.02 \pm 1.00	0.084
Ectomorphy	2.01 \pm 0.97	-0.055
Waist to hip ratio	0.75 \pm 0.07	0.161
Sum of 6 skinfolds (mm)	94.4 \pm 25.6	0.416*
body fat percentage	18.19 \pm 3.97	0.416*
Sum of 8 skinfolds (mm)	117.2 \pm 29.9	0.418*

*significantly correlated with national ranking $p < 0.05$

Table 2 presents the GPS derived indices and correlation with competition progress and heat placing. The overall average percentage time sitting, paddling and riding were $62.58\% \pm 10.18\%$, $30.70\% \pm 9.44\%$ and $6.73\% \pm 2.91\%$ respectively. The mean ride time, maximum ride time, the standard deviation of the ride times, standard deviation of ride distances and total time spent riding significantly correlated with the round of the competition ($p < 0.05$). In addition, the standard deviation of the maximum ride speeds and the total distance surfing were also significantly correlated ($p < 0.01$) with the round of competition. Furthermore the number of rides, time spent riding, percentage of total distance surfing and percentage time riding were significantly correlated with heat placement ($p < 0.05$). The total number of rides was also significantly related to heat placement ($p < 0.01$), with the percentage time spent sitting being associated with poorer heat placements ($p < 0.01$).

Table 3 presents the GPS derived indices and correlation with wave and wind conditions. Significant relationships were found between the speed and distance characteristics ($p < 0.01$) of the rides and the wave height, as well as wave period. The total time spent riding and the percentage of total distance spent surfing were also significantly correlated to wave height ($p < 0.05$). Wind conditions and as such wave quality was not significantly related to any of the GPS derived ride parameters.

Table 2. GPS derived indices and correlation with competition progress and heat placing.

Variable	Mean ± SD	Spearman's Rank Correlation with round (ρ)	Spearman's Rank Correlation with Heat position (ρ)
Number of Rides (1)	7 ± 3	0.115	-0.418**
Mean max ride speed (m.s.⁻¹)	6.55 ± 0.97	0.0208	0.51
Standard deviation of max ride speeds	1.30 ± 0.70	0.515**	0.002
Mean ride time (s)	18.1 ± 12.64	0.351*	0.095
Max ride time (s)	32.07 ± 22.85	0.361*	-0.055
Min ride time (s)	6.69 ± 3.15	0.217	-0.151
Standard deviation of ride times (s)	12.21 ± 16.00	0.330*	0.149
Mean ride distance (m)	78.12 ± 80.02	0.288	-0.152
Maximum ride distance (m)	155.93 ± 196.14	0.324	-0.246
Minimum ride distance (m)	24.17 ± 15.07	-0.007	-0.032
Standard deviation of ride distances (m)	56.47 ± 99.80	0.323*	-0.207
Total time spent riding (s)	114.52 ± 73.73	0.337*	-0.349*
Distance surfing (%)	488.01 ± 434.84	0.310	-0.371*
Total Distance (m)	1267.43 ± 579.49	0.413**	-0.438
Distance Surfing (m)	35.60 ± 13.44	0.041	-0.129
Time sitting (%)	62.58 ± 10.18	-0.021	0.614**
Time paddling (%)	30.70 ± 9.44	-0.038	-0.592
Time riding (%)	6.73 ± 2.91	0.136	-0.407*

Table 3. GPS derived indices and correlation with wave and wind conditions

Variable	Pearson's Correlation with Wave Height (m)	Pearson's Correlation with Wave Period (s)	Pearson's Correlation with Wind Direction (1)
Number of Rides (1)	-0.140	-0.267	0.259
Mean max ride speed (m.s.-1)	0.627**	0.648**	-0.113
Standard deviation of max ride speeds	0.616**	0.557**	0.196
Mean ride time (s)	0.772**	0.729**	-0.178
Max ride time (s)	0.628**	0.656**	-0.169
Min ride time (s)	0.475**	0.481**	-0.335
Standard deviation of ride times (s)	0.494**	0.493**	-0.071
Mean ride distance (m)	0.611**	0.576**	-0.121
Maximum ride distance (m)	0.574**	0.508**	-0.011
Minimum ride distance (m)	0.219	0.141	-0.017
Standard deviation of ride distances (m)	0.551**	0.463**	0.058
Total time spent riding (s)	0.348*	0.278	0.006
Distance surfing (%)	0.338*	0.268	0.017
Total Distance (m)	0.252	0.208	-0.009
Distance Surfing (m)	0.294	0.221	-0.018
Time sitting (%)	0.120	0.291	-0.198
Time paddling (%)	-0.171	-0.288	0.156
Time riding (%)	0.173	0.003	0.186

Discussion

Anthropometric Measures

The key findings of this study provide reference values for competitive female surfers, no previous study has provided detailed anthropometric values in respect of skinfolds, girths and bone breadths for professional female surfers. The values presented in this study provide a reference for future studies with similar samples of participants and identify that measures of adiposity are associated with poorer rankings in national competition.

According to Mendez-Villanueva [32] the average height of the 2003 WCT top 17 professional female surfers was $162.0 \pm 4.9\text{cm}$ and Lowdon [7] and Felder [18] found values of $165.7 \pm 4.9\text{cm}$ and $166.2 \pm 6.7\text{cm}$ for 14 and 10 elite female surfers respectively. Giving a range of $157.1 - 172.9\text{cm}$ based upon the means and standard deviations of these studies; the values of stature ($165.2 \pm 4.6\text{cm}$) for the surfers in the current study fall well within this range. Lowdon [7] and Felder et al [18] reported body mass values of $59.3 \pm 6.7\text{kg}$ and $57.9 \pm 8.3\text{kg}$, respectively. Although the surfers in this study would fall within the range of body mass values presented by these studies the mean value of the current sample is considerably higher ($63.0 \pm 6.8\text{ Kg}$) than those of previous studies.

The somatotype values of the surfers in the current study suggest similar levels of endomorphy, mesomorphy and ectomorphy to those presented by Lowdon [7]. However the mean body fat values of 19.5% for 14 elite female surfers [9] and $22.0 \pm 4.0\%$ for 10 elite female surfers reported by Felder et al [18] are slightly higher than those presented in the current study ($18.19 \pm 3.97\%$). These findings along with the might suggest a trend towards lower body fat levels and increased muscle mass in female professional surfers than reported in the early studies; potentially due to the demands of competing to the modern judging criteria where the focus has moved from awarding scores for “grace and flow” to exhibiting power [33, 34]. Furthermore increased professionalism and pressure from sponsors to maintain an “attractive / marketable” appearance may also influence the body composition of female surfers [5, 35].

Whilst it is accepted that surfing performance can be highly variable in nature [36] and thus it is difficult to predict an individual's success from one event to another. Correlating anthropometric variables with the end of year ranking provides the opportunity to identify relationships between surfer characteristics and their performance over a number of events. In the case of the British Championship the rankings are based upon the results of up to eight events. Previous studies of the anthropometric profile of competitive surfers [7, 17] have not found significant correlations between anthropometric measures and competition placings or national ranking. However, Barlow et al [17] found significant relationships between rankings based upon rating of ability [37] and end of year rankings across junior competitive, intermediate and professional British surfers with endomorphy, mesomorphy, sum of six skinfolds and body fat percentage. Thus, suggesting that higher levels of muscularity and lower levels of adiposity were associated with placement along a scale of ability from intermediate to professional. The current study supports the notion that adiposity is negatively associated with success in national ranking for female surfers with the measurements of triceps skinfold, medial calf skinfold, sum of six skinfold, body fat percentage and sum of eight skinfold being significantly ($p < 0.05$) correlated with national ranking. The score for mesomorphy was not significantly related to ranking in the current study; however based on the assumption that fat free mass can be calculated as total mass minus body fat percentage / 100 * total body mass it can be assumed that fat free mass is significantly associated with national ranking.

Performance Analysis

The performance measures obtained identify that the female surfers spent $62.58 \pm 10.18\%$ of the time sitting, $30.7 \pm 9.44\%$ of the time waiting and $6.37 \pm 2.91\%$ of the total time actually riding. When comparing these values to those of male surfers during competition it is apparent that the female surfers spend a greater proportion of their time waiting / sitting than the reported values for males which range from 28%-42% of total time [3, 4]. The female surfers also appear to spend less time paddling compared to male surfers who are reported to spend between 35%-54% of their total time paddling [4, 6]. The time spent riding was comparable to the 3.8%-8% range presented in the literature for male participants during competition by Mendez-Villanueva et al [4] and Farley et al [3]. Overall this suggests that the female surfers are not as active in their approach to catching waves and positioning as their

male counterparts. However the participants in the current study had similar wave counts during their 20 minute heats (7 ± 3 waves) to the surfers observed during competition by Farley et al. [3] (7 ± 2 waves). It is likely that the reduced time spent paddling will account for the some of the difference in total distance during the heat that was observed in this study ($1267.43 \pm 579.49\text{m}$) in comparison to that of the Farley et al. [3] study ($1.605 \pm 313\text{m}$). Given the similar wave counts and difference in the activity profile between male [3] and female surfers we could suggest that female surfers do not actively compete for waves in the same way as their male counterparts.

Considering the relationship between the GPS derived indices and round progression we can see that as the competition progresses and moves towards potentially higher standards weaker competitors are eliminated from the competition. We can see that the duration of rides increases as the competition progresses which allows greater opportunity to perform scoring manoeuvres and also increases the total distance covered by the surfer in the heat. When investigating the GPS derived indices with respect to heat position we can see that the number of rides being caught, the total time spent riding, distance surfing and total percentage time riding are significantly ($p < 0.05$) related to better heat positions. Furthermore the percentage time sitting / waiting is strongly ($p < 0.01$) related to poorer heat positions. These findings suggest that female surfers should aim to achieve a good wave count during their competition and avoid time waiting or sitting rather than being overly selective in terms of their wave choice which could lead to low wave counts. Although competitor's score is based on the two highest scoring waves it is likely that having a high wave count increases the opportunity to achieve a high scoring wave or potentially pressures the surfer's opponent into making tactical errors.

The current study found that increases in both wave period and wave size were significantly related to the ride parameters in terms of the physical length of each ride, the duration of each ride and the speeds achieved during each ride. This in turn resulted in greater total distances being covered during the session. The proportions of time spent in each activity were not related to the wave conditions suggesting that surfers during competitive heats are influenced by the competitive situation rather than the nature of the size of the waves as was found during recreational surfing [2]. The wind direction was not related to the measures

investigated in this study; further studies should consider the manoeuvres used in different wind conditions and how this influences scoring potential.

Conclusions

This study concludes that body fat levels are associated with national ranking in competitive female surfers. However the activity profile of competitive female surfers does not vary in respect to the environmental conditions but rather varies in relation to the nature of the level of competition. Modern female competitive surfers are heavier and carry lower levels of body fat (thus higher levels of lean mass) than similar female surfers who competed under previous judging criteria possibly suggesting a greater requirement for optimised power to weight ratio under the current competitive format. Female competitive surfers should aim to maintain a relatively high lean mass to body fat % and should aim to maintain a body fat % towards the lower end of the 18.19 ± 3.97 region. Coaches should work with female surfers to ensure that body composition is managed with respect to performance and that muscularity is maintained.

The number of waves ridden in a heat, the length of the rides and activity levels were significantly related to heat placement and competition progress which suggests female surfers should aim to maintain competitive pressure through actively seeking scoring waves over their opponents. Female surfers should aim to maximise their wave count and activity levels during competition in order to achieve success.

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References

1. Lowdon, B.J., *Fitness Requirments for Surfing*. Sports Coach, 1983. **6**: p. 35-38.
2. Barlow, M.J., et al., *The effect of wave conditions and surfer ability on performance and the physiological response of recreational surfers*. The Journal of Strength & Conditioning Research, 2014. **28**(10): p. 2946-2953.
3. Farley, O., N. harris, and A. Kilding, *Physiological demands of competitive surfing*. Journal of strength And Conditioning Research, 2012. **26**(7): p. 1887-96.

4. Mendez-Villanueva, A., D. Bishop, and P. Hamer, *Activity profile of world-class professional surfers during competition: a case study*. J Strength Cond Res, 2006. **20**(3): p. 477-82.
5. League, W.S., *WSL RULE BOOK 2016*. 2016, Santa Monica, CA.
6. Meir, R.A., B.J. Lowdon, and A.J. Davie, *Heart rates and estimated energy expenditure during recreational surfing*. Australian Journal of Science and Medicine in Sport, 1991. **23**(3): p. 70-74.
7. Lowdon, B.J., *The Somatotype of International Surfboard Riders*. Australian Journal of Sports Medicine, 1980. **12**: p. 34-39.
8. Lowdon, B.J., *Specificity of Aerobic fitness testing of surfers*. The Australian Journal of science and medicine in sport, 1989. **21**(4): p. 7-10.
9. Lowdon, B.J. and N. Pateman, *Physiological parameters of international surfers*. Australian Journal of Sports Medicine, 1980. **12**: p. 30-33.
10. Mendez-Villanueva, A., et al., *Upper body aerobic fitness comparison between two groups of competitive surfboard riders*. J Sci Med Sport, 2005. **8**(1): p. 43-51.
11. Barlow, M.J., et al., *Associations of Power at $\dot{V}O_{2peak}$ and Anaerobic Threshold with Rank in British High Performance Junior Surfers*. Human Movement, 2015. **16**(1): p. 28-32.
12. Lundgren, L.E., et al., *Development and Evaluation of a Simple, Multi-factorial Model Based on Landing Performance to Indicate Injury Risk Among Surfing Athletes*. International journal of sports physiology and performance, 2015.
13. Lundgren, L., et al., *High ankle sprain: the new elite surfing injury?: case report*. International SportMed Journal, 2014. **15**(4): p. 321-327.
14. Farley, O., et al., *Comparison of the 400 metre time endurance surf paddle between elite competitive surfers, competitive surfers and recreational surfers*. 2013.
15. Tran, T.T., et al., *Comparison of physical capacities between nonselected and selected elite male competitive surfers for the national junior team*. Int J Sports Physiol Perform, 2015. **10**(2): p. 178-182.
16. Mendez-Villanueva, A., I. Mujika, and D. Bishop, *Variability of competitive performance assessment of elite surfboard riders*. Journal of strength and conditioning research., 2010. **24**(1): p. 135-139.
17. Barlow, M.J., et al., *Anthropometric variables and their relationship to performance and ability in male surfers*. European journal of sport science, 2014. **14**(sup1): p. S171-S177.

18. Felder, J.M., et al., *Nutritional practices of elite female surfers during training and competition*. Int J Sport Nutr, 1998. **8**(1): p. 36-48.
19. Eurich, A.D., et al., *Performance differences between sexes in the pop-up phase of surfing*. J Strength Cond Res, 2010. **24**(10): p. 2821-5.
20. Secomb, J.L., et al., *Comparison of the sprint paddling performance between competitive male and female surfers*. J Aus Strength Cond, 2013. **21**(S2): p. 118-120.
21. Bale, P., *The relationship of physique and body composition to strength in a group of physical education students*. Br J Sports Med, 1980. **14**(4): p. 193-8.
22. Lowdon, B.J., J. Patrick, and K. Ross, *Manoeuvres used and judges scores in an international csurfing contest. Summary report*. 1996, Belconnen, ACT: Australian sports commission.
23. Marfell-Jones, M., T. Olds, and A.D. Stewart, *International standards for anthropometric assessment*. 2006, Potchesfroom: International Society for the Advancement of Kinanthropometry.
24. Withers, R.T., et al., *The relative body fat and anthropometric prediction of body density of South Australian females aged 17-35 years*. Eur J Appl Physiol Occup Physiol, 1987. **56**(2): p. 181-90.
25. Norton, K. and T. Olds, *Anthropometrica*. 2004, Sydney University of New South Wales Press.
26. Yuhasz, M.S., *Physical fitness manual*. 1974, London Onatario: University of Western Ontario.
27. Davidson, M., *A baseline Study of Surfing Conditions in the Boscombe Region and an investigation of Potential Improvements Due to the Installation of an Artificial Surfing Reef*. 2009, University of Plymouth.
28. Caldwell, P.C., *Validity of north shore, Oahu, Hawaiian Islands surf observations*. Journal of Coastal Research, 2005: p. 1127-1138.
29. Jennings, D., et al., *Variability of GPS units for measuring distance in team sport movements*. International journal of sports physiology and performance, 2010.
30. Witte, T. and A. Wilson, *Accuracy of WAAS-enabled GPS for the determination of position and speed over ground*. Journal of biomechanics, 2005. **38**(8): p. 1717-1722.
31. Dally, W.R., *The maximum speed of surfers*. Journal of Coastal Research, 2001(Special issue no.29): p. 33-40.
32. Mendez-Villanueva, A. and D. Bishop, *Physiological aspects of surfboard riding performance*. Sports Med, 2005. **35**(1): p. 55-70.

33. ASP, *87-88 Rule book*. 1987, Huntington Beach: Association of Surfing Professionals.
34. ASP, *2013 ASP Rule Book*. 2013, Association of Surfing Professionals, LLC.: Coolangatta.
35. Knijnik, J.D., P. Horton, and L.O. Cruz, *Rhizomatic bodies, gendered waves: Transitional femininities in Brazilian surf*. *Sport in Society*, 2010. **13**(7-8): p. 1170-1185.
36. Mendez-Villanueva A., I. Mujika, and D. Bishop, *Variabilty of competitive performace assessment of elite surfboard riders*. *Journal of Strength and Conditioning Research*, 2010. **24**(1): p. 135-139.
37. Hutt, J.A., K.P. Black, and S.T. Mead, *Classification of surf breaks in relation to surfing skill*. *Journal of Coastal Research*, 2001: p. 66-81.

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