RELATIONSHIP BETWEEN ANTHROPOMETRIC PARAMETERS, PHYSIOLOGICAL RESPONSES, ROUTES AND COMPETITION RESULTS IN FORMULA WINDSURFING

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ABSTRACT

Formula windsurfing is faster than the Olympic version, due to a number of unique differences. This study was designed to identify the importance of anthropometric and cardiac factors on the final result of the European Formula Windsurf Championships (2007). We selected 45 competitors (30 amateurs and 15 professionals) of 30±9.77 years of age, a height of 182.6±0.06 cm, a weight of 81.67±7.35 kg and a BMI of 24.7±2.1 kg. They were divided into three groups (PG: 15; TG: 45 and GPSG: 12). We followed the recommendations of Carter and Marfell-Jones for the anthropometric measurements. The route, speed, distance and heart rate were recorded using an FRWD W600 GPS (Global Positioning System) unit. The anthropometric measurements indicate a professional profile with 2.3±0.4 endomorphy 5±0.8 mesomorphy and 2.4±0.6 ectomorphy. Arm span and fat mass show a significant ($p \leq 0.02$) and very significant ($p \leq 0.005$) correlation with the final classification. The average speed was 11.84±2.38 $km \cdot h^{-1}$, the heart rate varied from 128 to 180 $b \cdot min^{-1}$ and the average was 127.62±13.73 $b \cdot min^{-1}$. The distances covered (12784.77±5522.19 m) and the times used for the races (2049.3±989.68 s) were very variable. This will assist not only in initial selection for the sport, but also in the design of training programmes which further develop that morphology, where possible, in the pursuit of improved performance.

Key words: somatotype, anthropometric, windsurf, heart rate, GPS

INTRODUCTION

Windsurfing dates back to 1935, when Tom Blake, one of California's leading surfers, inserted a device into his 14-foot concave board. Seventy-eight years have passed since those beginnings of a new sporting discipline. Nowadays windsurfing is an Olympic sport and has been part of the list of sailing sports since the 1984 Los Angeles Olympics. It is now in an enviable position, with numerous participating countries, converting it into an attractive sport that is in direct contact with the environment.

Windsurfing has shown itself to be a highly demanding discipline. While sailing, the heart rate increases with wind speed from 60 to 200 beats per minute [18]. De Vito et al. [8] showed that when sailing with a wind speed of 4–5 $m \cdot s^{-1}$, average value for oxygen consumption was 43±4 $ml \cdot min^{-1} \cdot kg^{-1}$ (73% of HR_{max}) and the average heart rate (HR) was 169±12 $b \cdot m^{-1}$ (92% of HR_{max}). The physiological demands appear to be influenced by the strength of the wind. During Olympic races with light winds (3–5 $m \cdot s^{-1}$), it has been shown that average heart rate during competition is 167 $b \cdot m^{-1}$, while average lactate concentration is 8.5 $mmol \cdot l^{-1}$ [1, 6]. However, in the same conditions with stronger winds (12–15 $m \cdot s^{-1}$), average heart rate is 154 $b \cdot m^{-1}$, with a lactate concentration of 2.9 $mmol \cdot l^{-1}$. These figures suggest that, in light wind conditions, there are less physiological and metabolic demands. This may be due to the permanent pumping action needed to increase the speed of the boat when the wind is not strong enough. Other authors, such as Vogiatzis et al. [20], showed that the pumping action needed to sail with a wind speed of between 4 and 15 $m \cdot s^{-1}$ leads to a significant increase in the physiological and metabolic demands on the sportsperson (from 19.2 to 48.4 $ml \cdot min^{-1} \cdot kg^{-1}$ and from 110 to 165 $b \cdot m^{-1}$, respectively). It has also been shown that improved performance in the laboratory is highly correlated with the increased amount of time spent at high speeds on the board [7].

At present, among the various international federations promoting windsurfing, the IWA (The International Windsurfing Association) is the organisation that unifies the sport. The association was founded in the UK in January 2001 and its aims include organising such competitions as the Formula Windsurfing European Championships. This class of windsurfing is regarded as the fastest in the world, largely due to the difference in the size of the sail when compared with Olympic windsurfing (12.5 and 9.5 metres respectively).

These differences may make different demands on sportspersons participating in the Formula and Olympic windsurfing classes. In this sense, this study is designed to identify the importance of anthropometric factors and physiological responses on the final classification of the 2007 European Formula Windsurfing Championships.

MATERIALS AND METHODS

The European Formula Windsurfing Championships held at Santa Pola (Spain) included the Qualifying Race for participation in the 2007 World Formula Windsurfing Championships. The championships were organised by the Santa Pola Windsurf Club and the Spanish Royal Sailing Association (RFEV). The championships were governed by ISAF (International Sailing Federation) regulations and the Racing Rules of Sailing (RRS).

Subjects

89 Caucasian males from 18 countries took part in the championships with 45 windsurfers being chosen for the study. Their characteristics were as follows: age 30±9.77, height 182.6±0.06 cm, weight 81.67±7.35 kg and body mass index 24.7±2.1 kg. All the subjects were informed of the tests and measurements that were going to be carried out and gave their written consent.

The chosen subjects were divided into three groups:

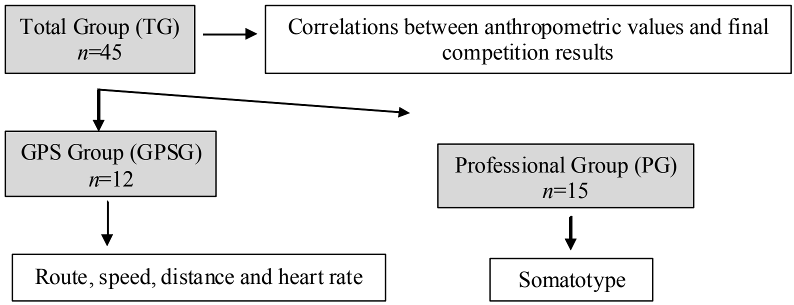


Figure 1. Distribution of the groups for the different aims of the study.

Procedure

A field laboratory was set up in the race area to take the measurements in real competition conditions.

A field laboratory was located in the regatta area in order to allow measurements to be taken as close to competition time as possible. The 45 male participants were categorised as Professionals (n=15) or Amateurs (n=30). All anthropometric measurements were taken in the same tent at an ambient temperature of (22±1°C) by the same investigator, an International Society for the Advancement of Kinanthropometry (ISAK) Level 2 anthropometrist. Measurements followed the protocols of Marfell-Jones et al. [15], and Marfell-Jones [14]. Measurements were taken three times for each subject. The equipment used included a Holtain skinfold calliper (Holtain Ltd. UK), a Holtain bone breadth calliper (Holtain Ltd. U.K), scales, stadiometer and anthropometric tape (SECA LTD., Germany). The physical characteristics were measured in the following order: age, weight, stature, arm span. The following measurements were also taken: sitting height, acromiale height, radiale height, dactylion height, tibiale height, biacromial breadth, biiliocristal breadth, humerus and femur width; pectoral, subscapular, biceps, triceps, suprailiac, supraspinale, front thigh, medial calf and abdominal skinfolds.

Muscle mass was calculated using the Lee equation [13]. Fat mass was calculated using for the Withers equation [21]. Bone mass was calculated using the Döbeln equation, modified by Rocha (as cited in

Carter & Yuhasz [5]). Somatype was calculated using the Heath-Carter equations [4].

In order to record the route (latitude and longitude), speed (km·h^{-1}), distance (m) and heart rate (b·m^{-1}) during the different heats valid for the final classification in said championships; a GPS unit (FRWD W600 Global Positioning System (12-channel GPS receiver; location measurement accuracy < 3 m; distance accuracy > 99%; speed measurement accuracy < 0.2 m·s^{-1}; heart rate measurement accuracy ±1 b·m^{-1}; 30–240 b·m^{-1} heart rate range; dimensions 95×55×15 mm; weight 85 g; temperature range –20 – +50°C)) was fitted to the right arms of 12 subjects (GPSG). The data was recorded every 5 seconds, starting from the beach at the beginning of the race and finishing at the same place at the end. An AVM-40 (Kestrel 4000) anemometer was used to monitor wind speed, which varied from 10 to 14 m·s^{-1}.

Statistical analysis

Initially, the Statistical Package for Social Sciences (SPSS) v. 14.0 programme was used for a normality test and homogeneity of variance. We then analysed the descriptive statistics and, finally, the Pearson's correlation coefficient was used to estimate the relationship between the anthropometric variables and the competition result.

RESULTS

Table 1 shows the anthropometric data for the professional competitors.

Table1. Descriptive data and somatotype characteristics for professional windsurfers

Professional (*n=15*)		
Dimension	**Mean±SD**	**Range**
Age (year)	25.4±3.9	20–33
Body mass Index (kg)	24.4±0.9	22.6–26.5
Height (cm)	184.6±6.4	172–194
Weight (kg)	83.1±5.3	73.3–92.6
Humerus width (cm)	7.63±0.32	7–8.4
Femur width (cm)	10.32±0.43	9.3–10.9
Upper arm girth (cm)[a]	32.93±1.16	30.2–35.4
Biceps girth (cm)[b]	35.17±1.29	32.5–37.3
Thigh girth (cm)	56.81±3.09	52.1–63
Calf girth (cm)	38.41±2.04	35.4–42
Pectoral skinfold (mm)	5.72±1.02	4–8
Triceps skinfold (mm)	7.67±2.06	5.8–13.4
Subscapular skinfold (mm)	9.69±1.22	8–12.8
Biceps skinfold (mm)	4.04±0.72	3–5.8
Iliac crest skinfold (mm)	12.47±2.53	9–16.8
Supraspinale skinfold (mm)	8.31±2.04	5.4–13
Abdominal skinfold (mm)	11.47±2.42	7.6–16.6
Front thigh skinfold (mm)	11.28±2.73	7.2–17.2
Medial calf skinfold (mm)	7.6±1.67	5.6–11.4
Muscle mass (kg)	35.5±1.8	32.4–38.9
Fat mass (kg)	8.9±1.8	6.4–12.6
Bone mass (kg)	14.1±1.5	11.2–17.3
Arm span (m)	1.9±0.1	1.7–2.1
Endomorphy	2.34±0.45	1.7–3.27
Mesomorphy	5.01±0.87	3.63–6.82
Ectomorphy	2.4±0.63	0.95–3.61

[a] *Midway between acromiom and olecranon, arm relaxed*
[b] *Maximum girth of the tensed upper arm (maximum flexed).*

Figure 2 shows that average muscle mass is 42.7% (35.5±1.8 kg), fat mass 10.7% (8.9±1.8 kg), bone mass 16.9% (14.1±1.5 kg) and residual mass 29.6% (24.6±1.9 kg) of body composition.

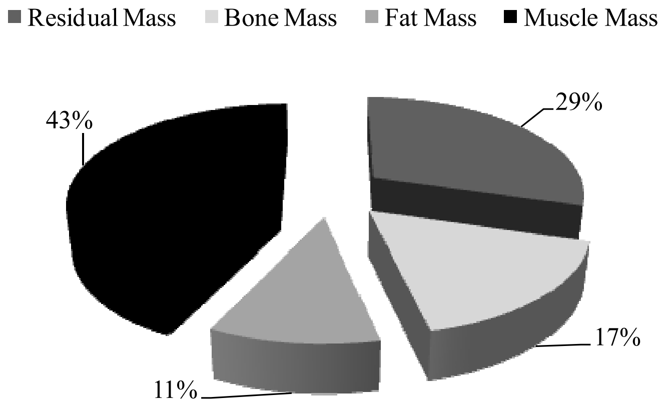


Figure 2. Body composition of professional windsurfers as a percentage.

The anthropometric profile of professional windsurfers competing in the Formula Windsurfing class is 2.3±0.4 endomorphy, 5±0.8 mesomorphy and 2.4±0.6 ectomorphy. The graphic professional somatotype for windsurfers is closer to meso-ectomorphy than to ectomorphy. Figure 3 shows the somatochart displaying the point of inflection of said values.

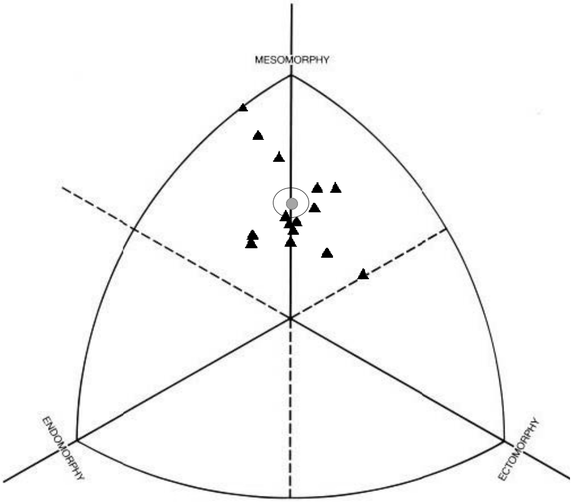
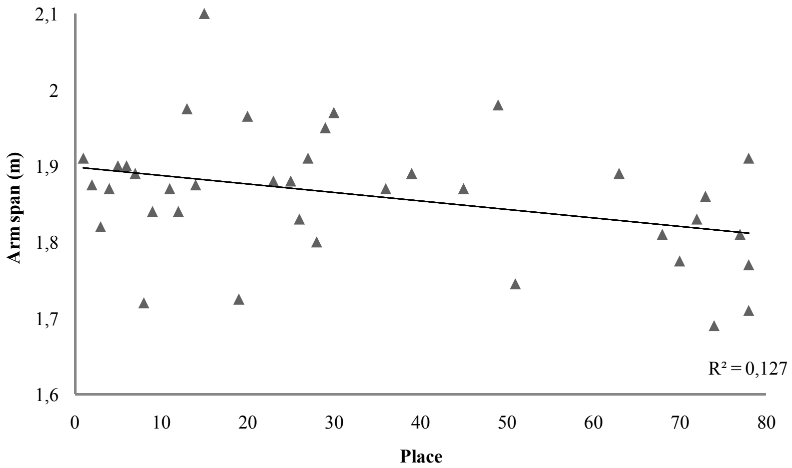
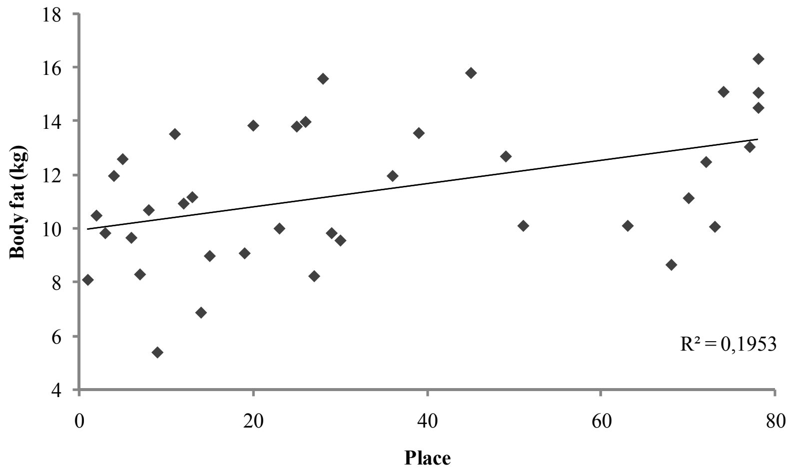


Figure 3. Distribution of somatotypes of windsurfers and mean somatotype of professional windsurfers. The circle around mean (●) represents the somatotype attitudinal distance from the mean value (SAM).

Of all the anthropometric data, only arm span and body fat gave significant correlations with the place obtained in the final classification ($p \leq 0.02$ and $p \leq 0.005$ respectively).





Figures 4 and 5. Relationship between arm span and fat mass and the final classification obtained in the competition.

Table 2 lists the means corresponding to duration, distance, speed, maximum speed, heart rate and maximum heart rate, based on information received from the GPS device during the second heat valid for the final classification of the championships.

Table 2. Variables gathered by the Global Position System device.

n=12	**Duration (s)**	**Distance (m)**	**Speed ($km \cdot h^{-1}$)**	**Speed$_{max}$ ($km \cdot h^{-1}$)**	**HR ($b \cdot m^{-1}$)**	**HR$_{max}$ ($b \cdot m^{-1}$)**
Mean	2049.30	12784.77	11.84	34.32	127.62	180.46
SD	989.68	5522.19	2.38	3.86	13.73	26.92

Figure 6 shows the different routes taken by the competitors to complete the heat.

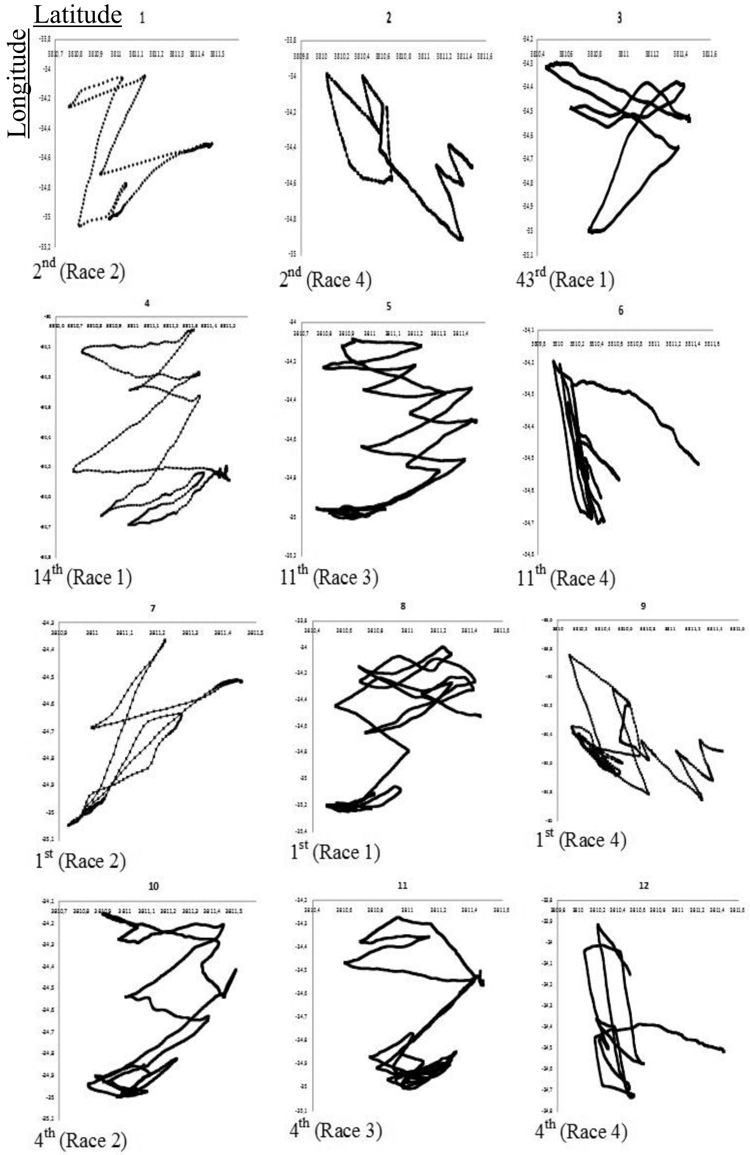


Figure 6. Route taken by each participant for the same heat. (Final classification and race).

DISCUSSION

Literature describing somatotype according to different sport modalities exist [10], even within the same sport, based on changes in technology and regulations experienced over time. Very little research is available, however for windsurfing. Porcella et al. [17] evaluated 79 windsurfers in the World Championships and pre-Olympic races celebrated in 1983 and 1986 in Italy, and found out that the mean somatotype components of the subjects who performed better was 2.57 – 2.68 – 2.97 showing slight domination of ectomorphy. In our study, however, both the professionals and amateurs showed a clear mesomorphy dominance over the other two components. The professionals in our study were also taller, heavier and had bigger arm and calf girths than those in the 1992 study.

It is not immediately obvious why these significant changes have occurred. Since 2006, there have been significant changes in the characteristics of board, with the development of a larger, more rigid table needing greater muscularity to sail it successfully (The Mistral One Design used until the 2004 Athens Olympic games was superceded by the Neilpryde RS:X for the Beijing Olympics). However, these changes alone cannot explain the differences in height and muscularity observed since 1992 as they are far are too recent. Professional windsurfers (and indeed all elite athletes) take far longer than a year to significantly change their group morphological profile.

What is more likely is that the changes seen in professional windsurfers parallel increases in height and muscularity in many strength sports over the past fifteen years, and it is clear that strength is a significant factor in windsurfing success.

Dyson et al. [9], discovered significant differences ($p<0.001$) between upper muscular group and lower muscular group use when they carried out a research over levels of muscular activity in Trapezius, Carpi flexors, Biceps brachii, gluteals and tibials, finding greater muscular participation of the upper muscular group, particularly isometrically. Campillo et al. [2], observed that much of the pain and injury seen in this sport was concentrated in the forearms and that this pain could be related to arm span, subjects with greater arm span being less likely to suffer pain. In our study we found the professional group presented a larger mean arm span than the amateur group (5.3%; $p<0.05$), but we did not conduct any comparison of pain experienced by the two groups so cannot comment on that aspect.

However, in our study we did not find significant correlations between the amount of muscle mass and the results of the competition, the same being true of body mass index and height. Nevertheless, we did observe significant correlations between the final classification and a larger arm span, something that should be taken into account when finding new talent. The same can be said for lesser fat mass. It also appears to be true that arm span could also be related to certain injuries suffered by windsurfers. Campillo et al. [2] observed that most pain caused by this kind of sport is felt in the forearm and that said pain could be related to arm span, as subjects with greater arm span usually have less problems and, on the other hand, said problems can be minimised by using a thinner boom.

With regard to the heart rate values, our results are similar to other studies of the Olympic class (145 and 173 $b \cdot m^{-1}$) [9]. It should be pointed out that the range of the Formula class is slightly greater (128 and 180 $b \cdot m^{-1}$). In the same way, Allen and Loke [1] saw that, with a wind speed of 3–5 $m \cdot s^{-1}$, mean heart rate during competition was 167 $b \cdot m^{-1}$ and with strong winds (12–15 $m \cdot s^{-1}$) mean HR was 154 $b \cdot m^{-1}$ in the Olympic class. Perhaps the reason Formula class has lower heart rate values is due to the structural differences of the materials used for each discipline. Vogiatzis et al. [20] state that the most important factor for energy demand during windsurfing is the pumping action and perhaps Formula windsurfing demands less pumping because the larger sail allows more advantage to be taken of gusts of wind. In addition, Castagna et al. [6] considered that Olympic windsurfing was a physical task linked with a high aerobic level demand, as is Formula windsurfing, although with slightly lower values.

The information provided by GPS devices can be of considerable help in acquiring a better understanding of the competitive reality of sports covering long distances. For example, they have been used for cross-country skiing [12], orienteering races [11] and mountain biking [3, 16].

With our results, based on GPS information, we observed great variability in the distances covered 12784.77±5522.19 m, and consequently in the time taken to complete the races 2049.3±989.68 s. This may be due to the different ways of approaching the races, as can be seen in Figure 5. These are related with the direction of the wind and the influence it has on the criteria of the judging committee when setting the course. In addition, the competitors have their own ways of taking advantage of the strength of the wind and trying to optimise this leads to significant differences when dealing with the course set. With regards to speed (11.84±2.38 km·h^{-1}) and maximum speed (34.32±3.86 km·h^{-1}), we observed that they were presented in a quite homogenous fashion.

CONCLUSIONS

It is of considerable value to identify the current anthropometric profile of elite windsurfers, as this knowledge enables sport scientists and coaches to better match morphology with the performance required for success. This will assist not only in initial selection for the sport, but also in the design of training programmes which further develop that morphology, where possible, in the pursuit of improved performance.

It is probable that the need for environments with strong winds to hold Formula windsurfing championships and/or the structural difference lead to heart rates being somewhat lower than those observed for other windsurfing classes.

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