Original Article

Incidence of anthropometric variables on the performance of top Optimist sailors

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ABSTRACT

The aim of this study was to determine the anthropometric profile of top Optimist sailors to examine how anthropometric variables influence their performance, taking the wind conditions into account. The study comprised 180 sailors (158 males and 22 females) aged 11-15 years competing in the Optimist World Sailing Championship held in Las Palmas de Gran Canaria, Spain, from 23 July to 3 August 2003. A descriptive correlational design was used. Assessments were made before and during the championship. The variables studied were body weight, height, arm span, lengths, fat tissue, muscle tissue, somatotype and performance level, in relation to race finishing place. The mean characteristics presented by the Top Group (sailors ranked 1 to 45) were: body weight (48.3 ± 6.4 kg), height (159.9 ± 5.4 cm), arm span (167.4 ± 6.5 cm), trunk length (37.2 ± 3 cm), lower limb length (90.7 ± 3.9 cm), fat tissue (10.5 ± 1.6%), muscle tissue (45.5 ± 2.1%) and somatotype (endomorphy 2.4 ± 0.9; mesomorphy 4 ± 2.5 and ectomorphy 3.3 ± 0.9). A close relation was observed between finishing place and the variables of weight, height, age, arm span, lower limb length, upper arm girth, sum of skinfolds, muscle weight, bone weight and residual weight. Top sailors tend to be meso-ectomorphic, with significant values for muscle mass and linearity and low fat content. **Key words:** DINGHY SAILING, BODY COMPOSITION, WORLD CHAMPIONSHIP, REGATTA

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INTRODUCTION

The international Optimist class is clearly the leading dinghy for beginner sailors around the world. At the 2012 London Olympics, 80% of competing sailors (skippers) had learnt to sail in an Optimist at an early age. Twenty of the 24 medal-winning sailors at the London Olympics were former Optimist sailors and four of them had been World Optimist Champions in the early days of Optimist sailing (International Optimist Dinghy Association, IODA, 2012).

Because the Optimist is the world's most popular sailing class (IODA, 2012), the attention of sports and science specialists is required to study sailors who are seeking sports success at an early age. It is essential to determine the profile of this group, as it will be a reference for all dinghy sailing classes recruiting young sailors who have finished competing in the Optimist class.

The Optimist is an international class, single-handed sailing dinghy (length 2.30 m; beam 1.13 m; sail area 3.5 m^2; minimum weight 35 kg) used for both learning and competing. Optimist sailors often start at the age of eight and the upper age limit is 15.

The anthropometric characteristics of Optimist sailors have been little studied. Oliveira, Polato, Alves, Fraga & Macedo (2011) investigated the weight (45.6 ± 5.5 kg) and height (152.8 ± 5.8 cm) of a group of 50 Brazilian sailors competing in a state championship. Tan & Sunarja (2007) examined sailors' weight loss on a single day to determine their level of dehydration during six hours of competition. Jacinto, Menezes & Schütz (2008) studied the sailing postures of Optimist sailors and the potential incidence of injury during competition. They noted that as sailors are still growing, many morphological changes occurring at these ages can be affected in the long term by postures in the boat. Thus further study of the anthropometric characteristics of top Optimist sailors is required to help detect future talented sailors.

This study determines the anthropometric profile of top Optimist sailors to examine how anthropometric variables influence their performance, taking the wind conditions into account. The competition format was 15 regattas held over six days, where the best sailors raced against each other in a bid to be the most consistent in a range of weather conditions.

MATERIALS AND METHODS

Participants

The sample comprised 180 sailors from 42 international teams (Table 1) - 158 (87.8%) boys and 22 (12.2%) girls -, competing in the Optimist World Sailing Championship held in Las Palmas de Gran Canaria (Spain) from 23 July to 3 August 2003. All subjects were informed of the nature of the study and its intended uses. All parents/guardians of the participants gave signed informed consent, following the ethical principles of the Declaration of Helsinki on research involving human subjects (adopted by the 18th Assembly of the World Medical Association, held in Helsinki in 1964, and amended by the 59th General Assembly, held in Seoul in 2008).

Table 1. International teams and number of sailors by country participating in the study.

SAMPLE OF SAILORS							
TEAM	**Sailors**	**TEAM**	**Sailors**	**TEAM**	**Sailors**	**TEAM**	**Sailors**
Germany	5	China	5	Japan	4	Sweden	5
Algeria	1	Korea	5	Malaysia	5	Switzerland	5
Argentina	5	Croatia	5	Mexico	4	Tahiti	5
Australia	4	Denmark	5	Norway	3	Trinidad and Tobago	2
Austria	5	Ecuador	5	Peru	5	Tunisia	4
Barbados	2	Slovenia	5	Poland	5	Turkey	2
Belgium	5	Spain	5	Portugal	5	USA	5
Bermuda	5	Finland	5	South Africa	5	Uruguay	5
Brazil	5	Greece	5	Russia	3	Venezuela	1
Canada	5	Guatemala	3	St. Lucia	2		
Chile	5	Ireland	5	Singapore	5		
Total teams n= 42							
Total sailors n= 180							

The sailors studied were aged from 11 to 15 years (Table 2).

Table 2. Age and gender of sailors.

Age	**Frequency**	**%**
11 years	6	3.3
12 years	24	13.3
13 years	48	26.7
14 years	66	35.6
15 years	38	21.1
Gender	**Frequency**	**%**
Male	158	87.8
Female	22	12.2
Total	180	100

To study the relation between anthropometric variables and competition performance, sailors had to be grouped according to their final ranking in the championship. Two groups were formed, based on statistical analyses. The first group comprised competitors ranked 1 to 45 and was termed Top Group (TG), n=31. The second group comprised sailors ranked 135 to 220 and was termed Fleet Group (FG), n=73. Organising the subjects this way allowed us to study their anthropometric profile in relation to their sports performance and determine the biotype of the world's top Optimist sailors.

Material

The meteorological conditions were identified using a weather buoy from the Canary Islands ACOMAR Network, which is equipped with sensors for weather conditions (wind, atmospheric pressure, PAR or Quantum solar radiation, relative humidity, air temperature) and oceanographic conditions (water temperature, chlorophyll, turbidity, hydrocarbons and current). The buoy includes a GSM communications system (Global System for Mobile Communication) that provides the user with an hourly reading of all the parameters measured and even indicates its position through GPS (Global Positioning System) and shows the state of the battery.

Measuring equipment comprised a Vernier Calliper (Holtain Ltd., Crymych, United Kingdom) with a triangular fixed jaw at the head and a second movable jaw, a measuring range of 63 to 213 cm and a measuring error of ± 0.1 mm, and a Detecto balance (Lafayette Instruments Company, Lafayette, Indiana, USA) with a measuring interval of 0 to 150 kg and accuracy to 200 g. Equipment was regularly calibrated and zero adjustments were made before each measurement. Skinfolds were measured with a Holtain Skinfold Calliper (Holtain Ltd, Dyfed, UK) (Carter & Heath, 1990) with a measuring range of 0 to 48 mm, 0.2 mm dial graduation and 10 g/mm^2 constant pressure. The height of each subject was measured with a Holtain stadiometer (Holtain Ltd, Dyfed, UK), accurate to 1 mm. Girth measurements were taken with a flexible metal measuring tape (Holtain Ltd., Dyfed, UK) with a scale of 0.1 cm.

Procedure

The anthropometric measurements taken for all sailors were: weight, height and dominant side skinfolds (working downwards); upper arm girth and calf girth; and biepicondylar breadth of the humerus and femur and bistyloid breadth. The arm span and the lengths of the foot, lower leg, trunk and thigh were also measured. These measurements were used to determine the values of fat and muscle weight and their percentages, sum of skinfolds and somatotype. The description of anatomical landmarks, body mass, girths, breadths and skinfolds, and the methodology used for data collection, correspond to the work by Lohman, Roche & Martorell (1988). Somatotype was assessed through the methodology described by Heath-Carter (Carter, 1975). The body composition study was based on the proposal presented by De Rose & Guimaraes (1980) using the Matiegka equation (Matiegka, 1921) and fat percentage was determined using the equation developed by Carter (1982, 1984). Body mass index (BMI) was calculated using the Quetelet index (Garrow & Webster, 1985). Bone mass was determined using the Rocha (1975) equation and residual mass was calculated by applying the Würch (1974) equation. Measurements were taken on subjects' dominant side, following the recommendations and methodologies of Durnin & Rahaman (1967); Housh et al. (1990); Martorell, Mendoza, Mueler & Pawson (1988); McArdle, Katch & Katch (1990).

The profile study was based on the mean values of the TG, comprising the 45 top ranking sailors, and was compared with the FG, comprising sailors ranked 135 to 220.

The influence of the weather variables was determined using the measurements registered by a weather buoy to record wind direction and strength during the regattas (Table 3).

Table 3. Sample of mean wind direction and intensity during racing at the World Optimist Championship. Data recorded by the Canary Islands ACOMAR network weather buoy

Table of winds during the World Optimist Championship (23 July - 3 August 2003)				
Day	**Regatta**	**Mean Wind Direction (º)**	**Wind Intensity**	**Mean Strength**
26-July	1 & 2	20º NNE-30º NNE	3-4 Bft.	10 knots
27-July	3, 4 & 5	350º NNO-20º N	4-4 Bft.	14 knots
28-July	6 & 7	360º N	4 Bft.	13 knots
31-July	8, 9 & 10	330º NNO-340º NNO	4-5 Bft.	16 knots
1-August	11, 12 & 13	320º NNO-330º NNO	4-5 Bft.	15 knots
2-August	14 & 15	340º NNO-350º NNO	4 Bft.	12 knots
Total of the means during the championship			4 Bft.	13 knots
NOTE: Bft. (Beaufort)				

Statistical Analysis

Data were statistically treated using the SPSS computer package for Mac (IBM SPSS Statistics 20). The mean, standard deviation and quartiles of the sample were calculated for all variables analysed. Non-parametric tests were used, such as Spearman's correlation coefficient (Glass & Stanley, 1974), to examine the relation between performance and the anthropometric variables analysed. All of this was compared using a bloxplot and a Voronoi diagram as a way to divide the sample into two clearly defined groups.

RESULTS

The results of the study showed differences between the two groups organised from sailors ranked 1 to 45 (TG; n=31) and 135 to 220 (FG; n=73) (Figures 1 and 2).

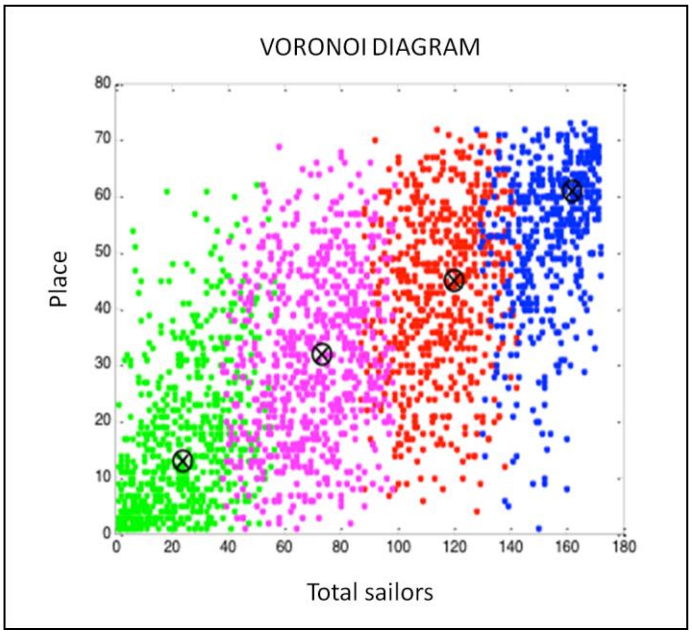


Figure 1. Voronoi diagram of sailors' championship finishing places.

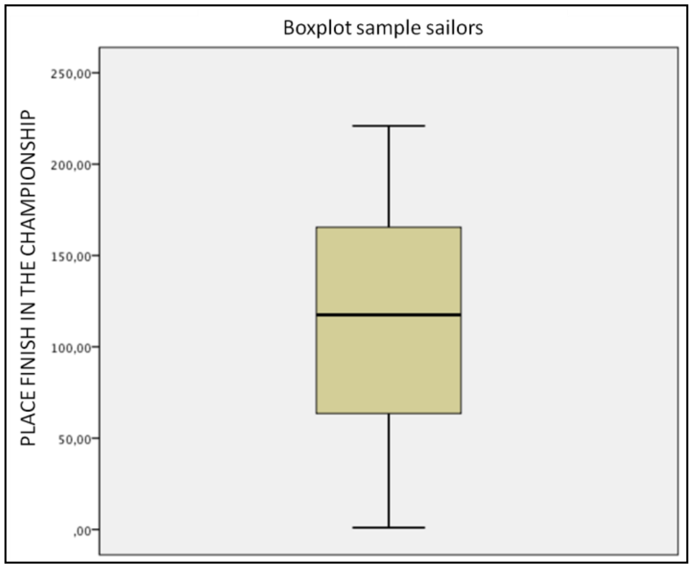


Figure 2. Boxplot of the total sample of sailors.

Table 4 shows the data for age, weight and height by the results obtained in the championship.

Table 4. Differences in age, weight and height between Top Group and Fleet Group.

Variables	Top Group (place < 45)	Fleet Group (place>135)
Age (years)	14 ± 0.77	13.2 ± 1.1
Weight (kg)	48.8 ± 6.37	44.2 ± 7.1
Height (cm)	160 ± 5.4	155.6 ± 8

Note: Data of Age, Weight and Height are mean ± standard deviation.

The skinfold values for the two groups of sailors are shown in Table 5.

Table 5. Mean skinfold values by finishing place

Skinfold (mm)	Top Group (place < 45)	Fleet Group (place >135)
Subscapular	6.8 ± 1.4	7.2 ± 2.6
Triceps	9.5 ± 2.9	10.5 ± 3.6
Suprailiac	6.5 ± 3.2	7.4 ± 3.6
Abdominal	8.7 ± 2.4	9.2 ± 4.1
Anterior thigh	12.8 ± 4.5	14.1 ± 5.2
Lower leg	12.5 ± 4.5	12.6 ± 4.5
Sum of Skinfolds	56.9 ± 17.1	61.1 ± 20.8

Note: Data are mean ± standard deviation.

The values for muscle girths, bone breadths, and lengths for the two groups of sailors are shown in Table 6.

Table 6. Mean values of girths, breadths and lengths by race placing

Variable	Top Group (place < 45)	Fleet Group (place>135)
Arm girth	23.3 ± 3.7	22 ± 2.2
Calf girth	33.2 ± 6.1	31.3 ± 4
Bistyloid breadth	5.2 ± 0.3	5.1 ± 0.4
Biepicondylar humerus breadth	6.5 ± 0.3	6.3 ± 0.4
Biepicondylar femur breadth	9.6 ± 0.5	9.3 ± 0.6
Arm span	167.5 ± 6.5	161.3 ± 8.9
Foot length	25.1 ± 1.3	24.7 ± 1.7
Lower leg length	46.9 ± 2.1	44.9 ± 6
Trunk length	37.3 ± 3	35.7 ± 3
Thigh length	43.8 ± 2.3	42.8 ± 3.7
Lower limb length	90.7 ± 3.9	86.3 ± 14.5
Body area	14.8 ±1.1	13.9 ± 1.4

Note: Data are mean ± standard deviation.

Table 7 shows the mean values and standard deviation of body composition for the two groups (TG and FG).

Table 7. Mean values of body composition

Body composition	Top Group (place<45)	Fleet Group (place>135)
Fat weight	5.2 ± 1.1	5.1 ± 1.7
Muscle weight	22.2 ± 3.5	19.8 ± 3.2
Adipose tissue	10.6 ± 1.6	11 ± 2
Muscle tissue	45.6 ± 2.1	43.8 ± 6.8

Note: Data are mean ± standard deviation

For the sailors' somatotype, the data show values with endomorphic, mesomorphic and ectomorphic components (Table 8).

Table 8. Mean values for sailor somatotypes.

Somatotype	Top Group (place<45)	Fleet Group (place>135)
Somatotype (Endomorphy)	2.5 ± 0.9	3 ± 1.2
Somatotype (Mesomorphy)	4.2 ± 2.5	4 ± 1.2
Somatotype (Ectomorphy)	3.5 ± 0.9	3.7 ± 1

Note: Data are mean ± standard deviation.

The values obtained from the correlational analysis are shown in Table 9.

Table 9. Statistical values. Correlations of the variables with the regatta finishing place.

SPEARMAN'S CORRELATIONS	
ANTHROPOMETRIC VARIABLE	**PLACE**
Age	-.277 (**)
Weight	-.205 (**)
Height	-.223 (**)
Triceps skinfold	.168 (*)
Suprailiac skinfold	.149 (*)
Anterior thigh skinfold	.158 (*)
Humerus breadth (biepicondylar)	-.197 (**)
Arm span	-.284 (**)
Foot length	-.155 (*)
Lower leg length	-.228 (**)
Lower limb length	-.178 (*)
Body area	-.223(**)
Muscle weight	-.212(**)
Bone weight	-.194(**)
Residual weight	-.236 (**)
Somatotype (endomorphy)	.196(**)

*The correlation is significant at $p<0.05$ level (bilateral) between finishing place and variable.
**The correlation is significant at $p<0.01$ level (bilateral) between finishing place and variable.

DISCUSSION

The results obtained in this study showed very different significances (Table 9) that require discussion to determine their incidence in sailors' performance. Each variable associated with performance was therefore analysed using the graphs shown below (Figure 3 to Figure 19).

Figure 3 shows the distribution of the age variable in relation to performance. The general pattern is for a lower ranking at a younger age, suggesting that Optimist results can be related to sailors' learning and maturity. This relation shows a negative significance (-277**). Age is therefore a conditioning factor in performance in that it enables competitors to acquire skills and experience in high level competitions with a large number of competitors.

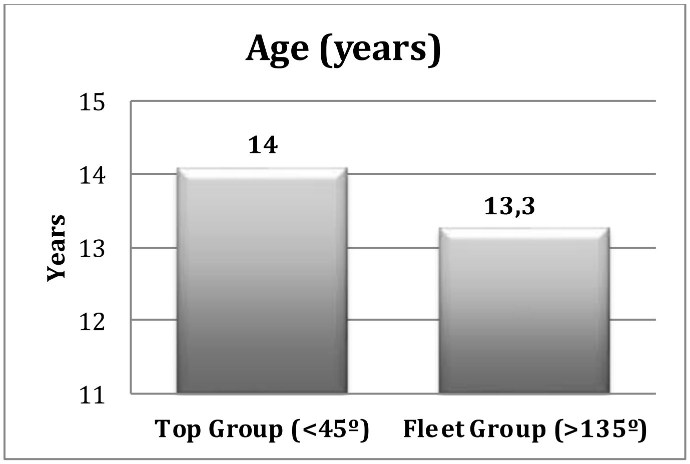


Figure 3. Age by result (TG) and (FG).

Figure 4 shows the relation between performance and weight. The values are more conclusive, as a pattern of better performance with increased weight is seen and thus the lower the weight is, the worse the result is. These data show a negative correlation (-205**).

The greater weight in higher performers is explained by increased muscle mass, as the following graphs show. Increased weight is a positive value because it is associated with increased age and muscle mass. However, excess weight is a detrimental factor and can be one of the causes affecting lower ranking sailors, as they may lack experience and talent.

Figure 5 shows the data for height, which also has a negative correlation, following the pattern of the previous variables: the greater the height is, the better the ranking is. Significance is negative (-223**).

In the variables shown, increased weight and height above the mean can be seen between the TG and the FG. The differences between the two groups are 4.6 kg (weight) and 4.4 cm (height). This means that the height and weight variables are directly related to performance and therefore more experienced, older sailors are the highest ranking. These results concur with the findings of Oliveira et al. (2011), who studied Optimist sailors competing in the Rio de Janeiro State Championship. All the results showed that senior division sailors had higher weight and height values than junior division sailors, with lower fat tissue percentages but similar fat masses.

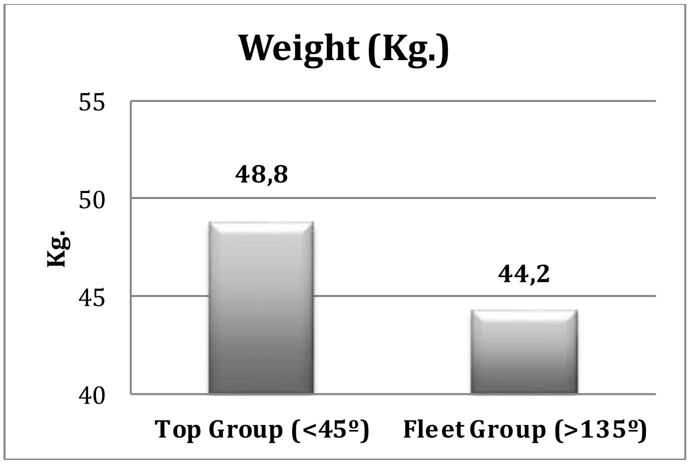


Figure 4. Weight of sailors by result (TG) and (FG).

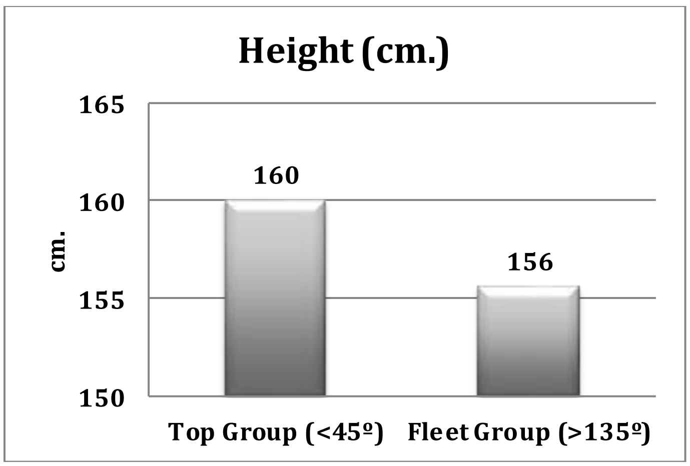


Figure 5. Height of sailors by result (TG) and (FG).

Weight and height can be compared using the IODA weight and height data for the top 10 sailors at the 2007 World Championships in Italy and the 2011 Worlds in New Zealand. This comparison shows an obvious relation between the mean weight of the top 10 and the mean wind during each competition. At the windiest championship (New Zealand, 2011), there is a clear difference of an average of 1.7 kg compared to the championship in our study (2003), where the mean wind intensity was lower (Table 10).

Table 10. Data for variables of age, weight and height of the top 10 in the 2003, 2007 and 2011 World Championships.

VARIABLES TOP 10				
Variable	**World Championship 2003**	**World Championship 2007**	**World Championship 2011**	**Mean**
Age (years)	14.1	14.6	14.3	14.3
Weight (kg)	48	47.3	49.7	48.3
Height (cm)	159.7	161.5	165.7	162.3
Wind (knots)	13	10	20	14.3

Arm span, foot length and lower leg length show a high correlation to finishing place: the greater the lengths are, the higher the finishing place is. The mean difference is 6.1 cm (Figures 6, 7 and 8). Similarly, lower limb length (Figure 9) shows a clear difference (nearly 4.5 cm) between the TG and the FG.

From these data we can deduce that the high correlation values correspond to technically efficient positions. This results in a greater trunk length that allows more leverage and a lower leg length of maximum significance (-2.228**). We understand that this could be a determining factor, as it allows the popliteal cavity (knee hollow) to be supported on the sheerline for better hiking. Foot length is important, as the foot is the first point of support in anchoring and this makes it possible to produce the other strength moments generated by the lengths mentioned above.

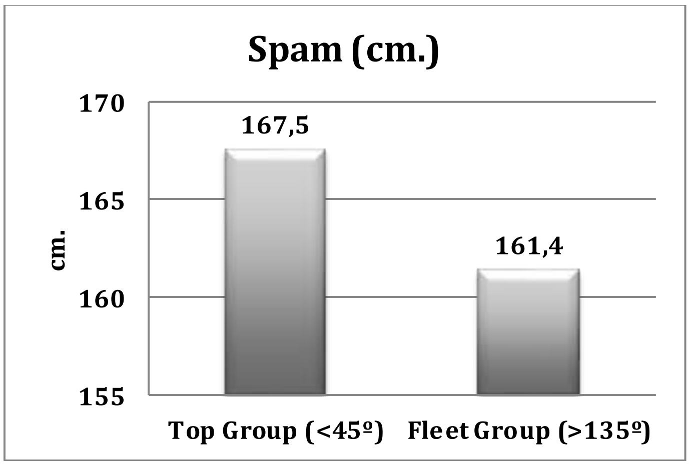


Figure 6. Arm span of sailors by result (TG) and (FG).

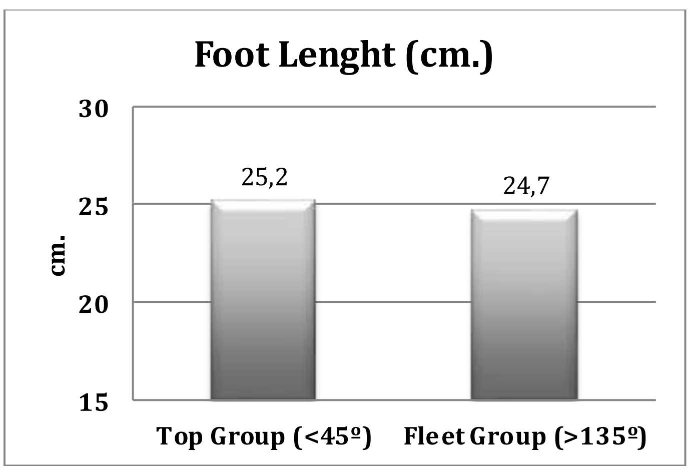


Figure 7. Foot length of sailors by result (TG) and (FG).

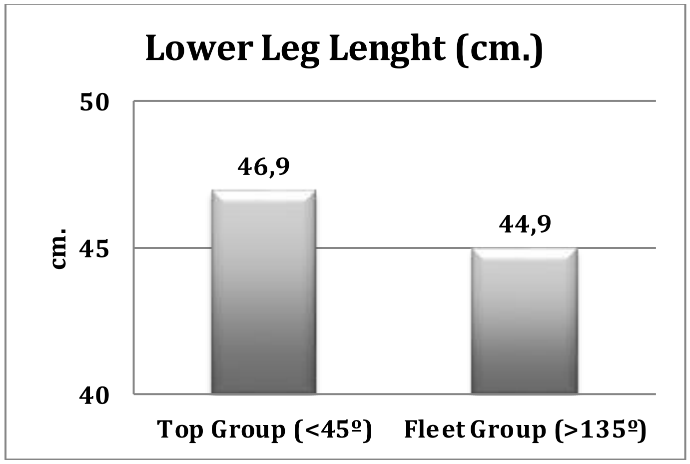


Figure 8. Lower leg length of sailors by result (TG) and (FG).

The results for breadths are disparate, ranging from no significance for bistyloid breadth (Figure 9), high significance for the femur (Figure 10) and maximum significance for the humerus (Figure 11). All these measurements show a similar trend, although humerus breadth can be associated with the greater pulling strength of top sailors. This indicates that increased humerus breadth and subsequent muscle development are an advantage for the best sailors when it comes to trimming the mainsheet and controlling the rudder.

This value concurs with arm girth (Figure 12), which increases with performance, making the upper body important in technical actions. For the significance of the femur, we related it to the age variable. All increments are associated with increased age.

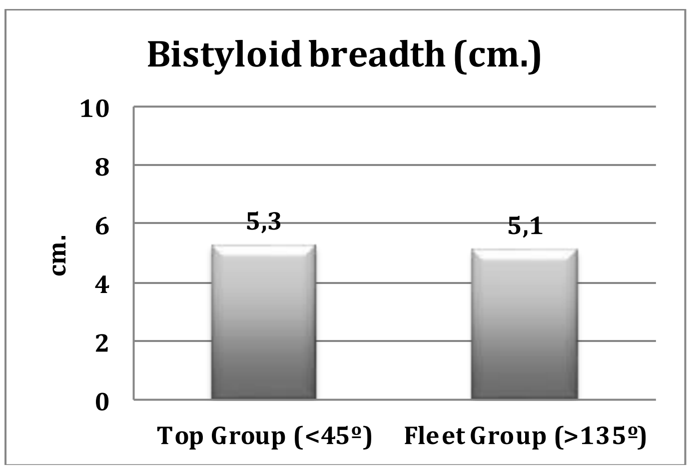


Figure 9. Bistyloid breadth of sailors by result (TG) and (FG).

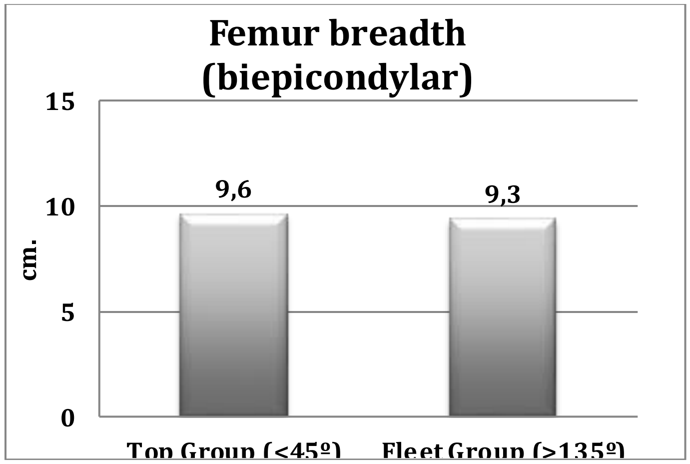


Figure 10. Femur breadth (biepicondylar) of sailors by result (TG) and (FG).

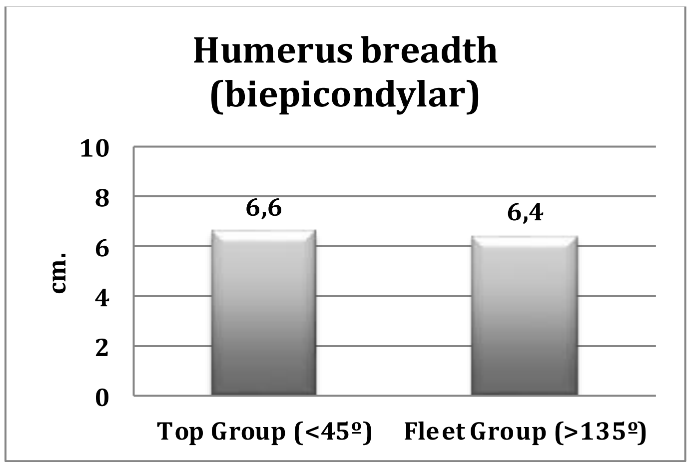


Figure 11. Humerus breadth (biepicondylar) of sailors by result (TG) and (FG).

Arm girth and calf girth show a similar pattern: the top sailors have higher values, although the differences are slight (Figure 12 and Figure 13).

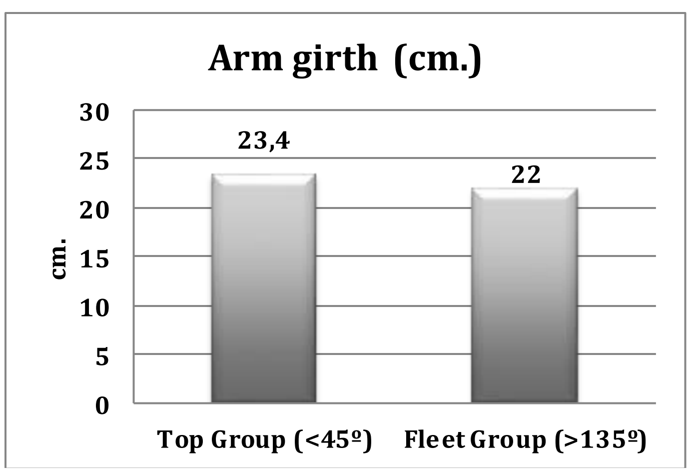


Figure 12. Arm girth of sailors by result (TG) and (FG).

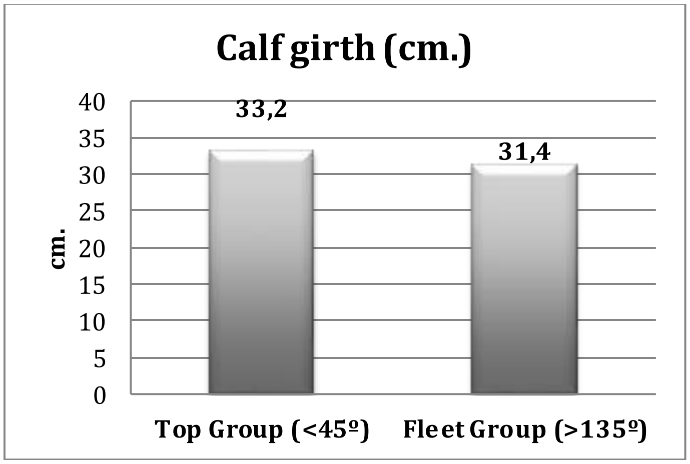


Figure 13. Calf girth of sailors by result (TG) and (FG).

The sum of skinfolds shows ascending values (Figure 14). Better performance shows a tendency for decreased adipose tissue in general. This value is lower in the TG.

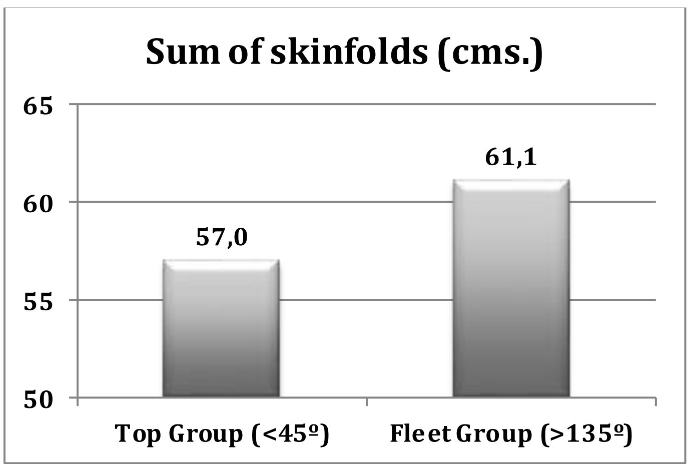
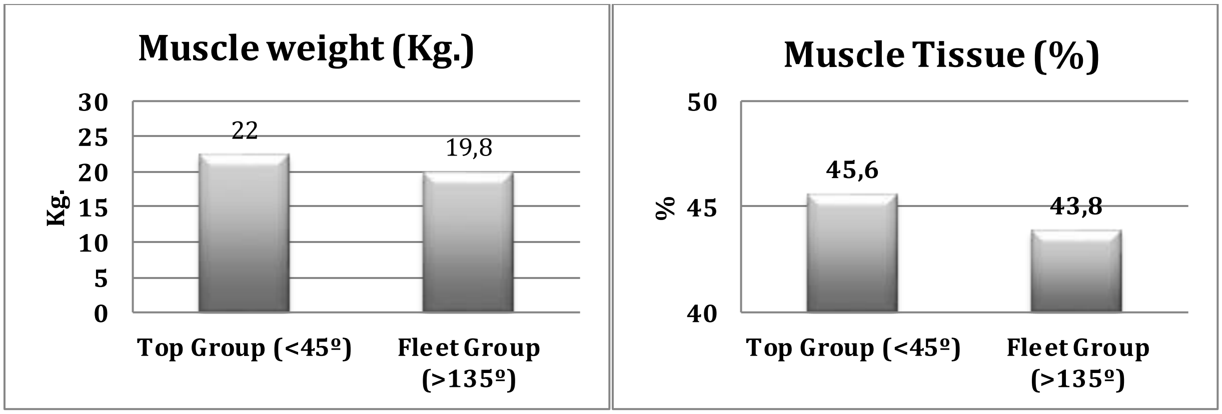
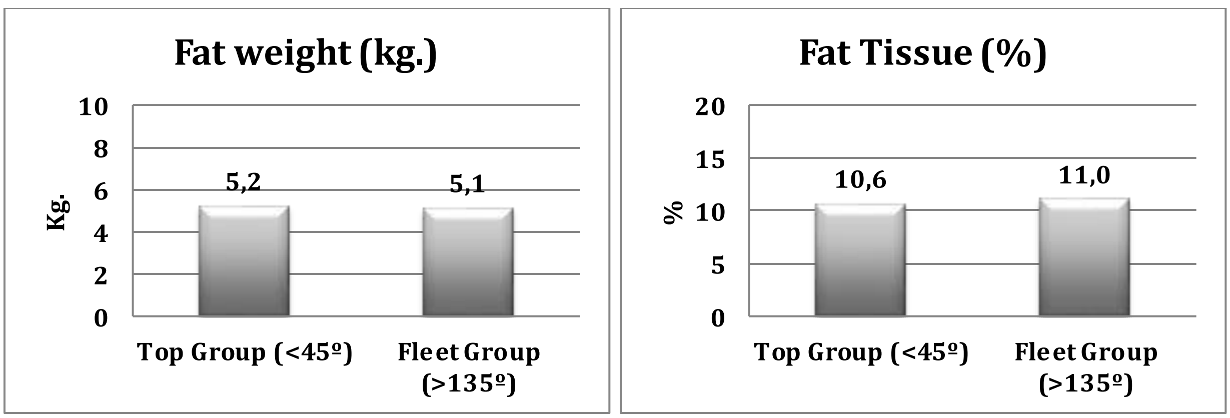


Figure 14. Sum of skinfolds of sailors by result (TG) and (FG).

Looking at the skinfolds individually, we find high significance in relation to performance only for the triceps, suprailiac and anterior thigh skinfolds. This suggests homogeneous distribution of adipose tissue and Figure 19 (Endomorphy) confirms this pattern: the better the finishing place, the less adipose tissue sailors have. Similarly, adipose tissue shows high significance. Figures 17 and 18 show the values of fat weight and fat tissue. These would be expected to be similar to the previous Figures, but the pattern is descending. This indicates a higher finishing place with increased fat weight, which can be related to the higher age of the sailors rather than their body composition. Figures 15 and 16, corresponding to weight and muscle tissue, have a clearly descending pattern. TG sailors have greater muscle mass. However, if we examine the muscle component by percentages, we observe that it is less important in relation to performance. This is confirmed with the high significance of muscle weight and the null significance of muscle tissue. These results explain why fat weight did not have an ascending pattern. This shows that body composition has an influence but is less of a determining factor for performance than the total mass increases. That is, having a high value in muscle weight obtained by increased weight and therefore related to age leads us to think that sailors' performances are obtained through increased age and experience rather than their physical condition. The study by Tejada-Medina (2013) in the Optimist junior division found no correlations between anthropometric variables and performance in either sex. They did, however, find a correlation in the age of the girls. This was the best correlated variable: at higher ages, the girls' results were better.



Figures 15 and 16. Muscle weight and muscle tissue of sailors by result (TG) and (FG).



Figures 17 and 18. Fat weight and fat tissue of sailors by result (TG) and (FG).

Figure 19 shows the endomorphy, mesomorphy and ectomorphy values. The profile of top competitors shows a meso-ectomorphic pattern (2.6-4.1-3.5), which is clearly seen in muscle mass and linearity, with low fat content. This fat content confirms the descending pattern of the top sailors. A descending pattern is also seen for muscle value and shows that increased linearity is detrimental to performance. In terms of correlations, only one significance is confirmed, in endomorphy: sailors' shape tends towards reduced fat. The study of junior Optimist sailors by Tejada-Medina (2013) confirms this meso-ectomorphic pattern, with a tendency in girls towards a central somatotype and no clear predominance of any one component.

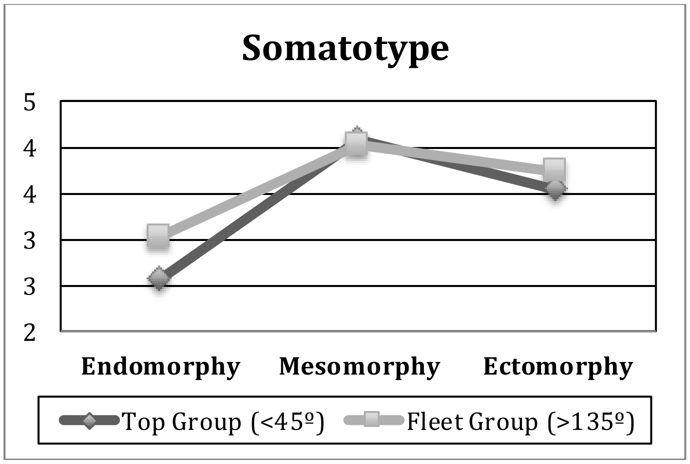


Figure 19. Somatotype of sailors by result (TG) and (FG).

CONCLUSIONS

This study shows that the performance of top Optimist competitors is improved through increased age rather than their body composition, although within the TG, age is less of a determining factor in performance than weight and height.

The study also shows that greater body lengths enhance performance, leading to greater efficiency in technical actions such as hiking, trimming and controlling the rigging, and handling the rudder. The results show that, in body composition, masses have greater influence than percentages. Similarly, the profile of top Optimist competitors tends to be meso-ectomorphic (2.6-4.1-3.5), which is clearly manifested in muscle mass and linearity, with low fat content. Sailors' performance in competition is affected by numerous variables such as technical aspects, tactics, strategy, rules, physical and psychological condition, weather conditions, experience, maturity and talent. We examined the characteristics of the anthropometric profile directly related to the wind conditions of the competition studied (13 knots). In future research, however, it will be necessary to study another top level competition with a different wind range to compare the performance of these types of competitors. This would help us to determine the aim of the study more accurately.

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