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# Significance of anthropometric characteristics of Olympic sailors and their functional position in boat for relation to racing success

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## Abstract

**Problem**: sailing has been a part of every Olympic Games since 1900. Two events for both men and women are organized in this sport during the Olympics. For a successful finish in the race, a sailor must have a good boat control technique, apply different tactics, possess good physical fitness, and appropriate anthropometric indicators correspond to the type of Dinghy. Body composition plays a vital role for the sailing crew on the Dinghy to effectively control the boat. This fact has been discussed in scientific literature quite often. Several studies have found the morphological indicators in the selected type of boats, but few studies showed differences in sailors in all Olympic boat classes.

**Purpose**: this research aimed to determine the significance of the anthropometric characteristics of Olympic sailors about their roles onboard and correlate it with their success.

**Method**: three hundred and forty-three Olympic sailors, members of the national teams from 66 countries, participated in the research, in which the body height, weight, and Body mass index were measured.

**Results**: the study investigated the anthropometric variables of the Olympic sailors in the seven different kinds of sailboats. The study results indicated that statistically significant differences existed in the body height and body weight between helmspersons and crew ($p < 0.05$) in double-handed dinghies. In all indicators of the Olympic class boats, the body height and bodyweight of the team were statistically higher than the helmsman except in sailors of "Nacra 17". The highest anthropometric measures in the sailors of the Olympic Games were found in the Finn class ($p < 0.05$). The BMI of Olympic sailors identified during the study was 22.9. The results also revealed that BMI measures in men were more than in women, but the differences ($p > 0.01$) were not significant. The study results indicated that the relationship between racing results (total scores) and age in many dinghy classes did exist and that older elite sailors had more success in the races.

**Conclusion**: based on the results, it can be concluded that morphological characteristics have an essential role in determining the success of top sailors in Olympic Sailing races. Sailing coaches can use this study's results to select athletes for national teams and use the findings as a model for talent identification or selection of sailors at an early age according to different classes of sailboats.

**Keywords**: morphological characteristics, Olympic sailing, functional position in sailboard, BMI.

## Introduction

Sailing has a long history in the Olympic Games. The sport made its debut in 1900, except for 1904. Sailing has appeared at every Olympic Games since then. Olympic sailing features a variety of boats, from dinghies and keelboats to windsurfing boards. The program of sailing competitions gets often changed by introducing new speed classes of dinghies. Hence, in the recent Olympic Games sailing competition, boat classes, namely Star, Tornado, Yngling, Europe, and Mistral, were replaced with new types of boats, namely Nacra 17, 49-er FX, RS: X (Ferraris et al., 2010).

The Olympic program at Rio 2016 included five events for both men and women. Three were for men only, two were for women only, and one was for a mixed crew. The boats that participated in the Rio Olympics 2016 were RS:X – Windsurfer (Men/Women); Laser – One Person Dinghy (Men); Laser Radial – One Person Dinghy (Women); Finn – One Person Dinghy (Heavyweight) (Men); 470 - Two Person Dinghy (Men/Women); 49-er – Skiff (Men); 49-er FX - Skiff (Women); Nacra 17 Foiling – Mixed Multihull.

During races, boats navigate a course shaped like an enormous triangle, heading for the finish line after they contend with the wind from all three directions (close-hauled, broad reach, and running). Participants must pass marker buoys a certain number of times and in a predetermined order. Sailing is not just a race against other boats but a battle with nature: the height of the waves, the pull of the tides, the strength of the wind, and other climatic factors strongly influence the performance of the sailors and their boats.

For a successful finish in the race, a sailor must have a good boat control technique, apply appropriate tactics, and possess excellent physical fitness and anthropometric indicators corresponding to the class of Dinghy. Many studies have confirmed that the morphological characteristics of an Olympic sailor can have a significant bearing on their success or achieving their desired result (Skripchenko, 2003; Oreb et al., 2013; Santos et al., 2016). An effective training process in sailing can be built based on the morphological characteristics of the sailor.

At the Olympic level, elite athletes in most disciplines are generally taller, heavier, and more muscular than the general population (Canda, 2012; Mac Dougall et al., 2019). However, the body weight and height data show some variation in sailors of different classes of boats (Bojsen-Møller et al., 2007; Gomez-Ezeiza et al., 2019).

Low body height is not a disadvantage in sailing, although it could significantly affect the work of the crew and their success in the race. The body's height is significant in hiking the boat (Callewaert et al., 2015; Caraballo et al., 2019; De Vito et al., 1993; Maisetti et al., 2012). Insufficient height is not a disadvantage for sailing, although it has a considerable impact on the crew's work and their success in the race. Sailors with different functions in the boat have specific morphological characteristics (Neville et al., 2009). For example, in a dinghy, the helmsman operates the mainsail and the steering gear. The crew mainly works the jib sail and spinnaker and adjusts the inclination (heel) of the vessel to the left or the right sides.

The helmsman and crew have similar body height measurements in the boat's dinghy "49-er" class. However, in all other types of dinghies, there are differences in the height among the sailors. It was observed that the crew was always taller than the helmsman. The classes of boats selected for the Olympics in Rio show that people weighing more than 83-85 kg have practically no chance of competing at the Olympics, which means that many sailors can get excluded from participation. This could especially affect the Olympic sailors in the Finn class, who are the tallest and the heaviest. The Finn remains the only class that allows such sailors to compete in the Olympics. This was confirmed in the studies by Plyley et al. (1985) and Pulur (2011), whistle that they have a body height of 187.3±6.2 cm and body weight of 97.6±7.4 kg.

Several research findings suggested that body mass was significantly related to sailing performance. It was observed in many studies that it was essential for the sailor to cope with strong winds and other constraints faced during the sailing (Callewaert et al., 2015; Oliveira et al., 2011; Oreb et al., 2013; Santos et al., 2016; Skripchenko, 2004).

Some studies have suggested that sailing in high winds requires great skill and physical effort to control the boat (Lozovina & Đukić, 2017; Vogiatzis et al., 1995, 2002). For this reason, a sailor with a heavier body tends to deal better with varying wind intensities, helping them adapt better and improve their performance during boat maneuvers (Caraballo et al., 2019). Therefore, optimal weight is a common concern for such water sports, especially sailing. Scientists' studies have also shown that athletes' cardiovascular and respiratory systems are under tremendous strain (Farley et al., 2012; Felici et al., 1999; Pezelj et al., 2019). In addition, the muscular system experiences fatigue and exhaustion when the quadriceps, back, and abdominal muscles work, especially in strong winds and large waves (Agaard et al., 1998; Allen & De Jong; 2006; Blackburn, 1994).

Body Mass Index (BMI) is an easily-administrated and inexpensive tool to monitor weight status. Researchers widely use it in various sports and games, mainly sailing. It can evaluate an athlete's body weight for a given stature and thus, contribute to weight control. Athletes need to find a perfect balance between weight and performance. Data on athletes' anthropometric markers and BMI would allow the development of a general, group, and individual morphofunctional model of sailors. This would be very important for the preparation of sailors for a sport such as sailing. In addition, trainers and researchers are constantly directing their efforts to adjust the athlete's

profile for each modality to achieve maximum performance. Research points to the positive correlation between physical characteristics and athletic performance (Day, 2017; Lozovina & Đukić, 2017).

Many experiments have been done to compare Olympic athletes involved in different boats. Even other age groups of athletes in the same sport were compared (Pezelj et al., 2016; Polato et al., 2007). A study also compared the sailors taking into account their role in the boat (Bojsen-Møller et al., 2007). The study of the influence of morphological characteristics on the effectiveness of teaching sailing was also conducted (Oreb et al., 2013). Most research in sailing and similar water sports, such as windsurfing, has focused on the importance of morphological characteristics for the competitor's success (Cortell-Tormo et al., 2010; Legg et al., 1997; Mendez & Bishop, 2005; Vogiatzis et al., 1995, 2002). However, few studies have also focused on the success of recreational athletes.

In several of the literature, researchers have presented studies of the morphological characteristics of sailors in some classes of boats. Still, there were hardly any studies that showed differences among sailors in all the types of boats in the Olympic Games. Therefore, it was identified as a gap. This study aimed to examine the variations in anthropometric parameters of Olympic sailors with diverse functions on board and their relationship to their success in sailing competitions. The study was based on the notion that sailors' anthropometric traits would alter depending on their functions. For example, in the Two Person dinghy, differences in the body height of the sailors were observed. The crew was always taller than the helmsman.

## Material and methods

*The period of study*

This study was conducted during the sailing competition at the 2016 Summer Olympics in Rio de Janeiro, Brazil, held from 8$^{th}$ to 18$^{th}$ August at Marina da Gloria in Guanabara Bay.

*Participants*

A sample of 343 Olympic sailors from the national teams of 66 countries participated in this study. Their average age was (Mean-Std.Dev.) 28.0 ± 5.4, body height was 176.15 ± 6.2 cm, body weight was 71.2 ± 10.4 kg, and BMI was 22.8 ± 1.8 kg/m$^2$. They participated in seven Olympic class boats. The sailboats that were used were, Finn - 23, Laser (m) - 44, Laser Radial (w) - 37, RS:X (m) - 36, RS:X (w) – 25, 470 (m) – 40, 470 (w) – 40, 49-er (m) – 40, 49-er FX (w) -40, Nacra 17 Mixed (m) – 21, Nacra 17 Mixed (w) – 21 dinghies. 180 male sailors with an average Age of (Mean-Std.Dev.) 29.3±5.6 years, Body Height 181.3±6.6 cm, Body Weight 77.1±9.0 kg, Body Mass Index 23.4±1.9 kg/m$^2$ and 163 female sailors had average Age of (Mean-Std.Dev.) 26.5±4.7 years, Body Height 169.3±6.2 cm, Body Weight 63.2±5.6 kg, and Body Mass Index 22.0±1.4 kg/m$^2$ were part of this study.

*Research Design*

The anthropometric variables Body Height (cm), Body Weight (kg), Body Mass Index (kg/m2)] were measured according to standard procedures of the International Society for the Advancement of Kinanthropometry (ISAK) (Marfell-Jones et al., 2012). A Stadiometer and a calibrated weighing scale were used to measure players' body height and weight with a precision of 0.1 cm and 0.1 kg, respectively. BMI was calculated by dividing the body mass by the square height of the body in meters (Blackburn, 2000). A higher score usually indicated higher levels of body fat. Therefore, the World Health Organization recommended BMI classification system was used in this study. The norms for BMI categories were underweight - <18.5; average weight – 18.5-24.9; overweight – 25-29.9.

*Methodology for calculating the total scores in the sailing race*

The Olympic racing was conducted according to the Racing Rules of Sailing (RSS) as recommended by the International Sailing Federation (ISAF).

The sailing race at the 2016 Rio Olympics was fleet racing, where all competitors started and sailed the course together. They were scored according to the low-point system, where the first place scored 1 point, the second place scored 2 points, and so on. The Final Medal Race followed a series of preliminary races. The RS: X, 49-er, 49-er FX, and Nacra 17 Mixed classes had twelve preliminary races, and other courses had ten. At the end of the primary races, the top ten boats in each category (i.e. those with the lowest total score) advanced to the Medal Race. Each boat had a choice to exclude one race from their total. The Medal Race cannot be excluded from the series score, and it counted double. The boat with the lowest overall total after all races was the winner. Any ties in the final rankings were broken, favoring the competitors/crew finishing higher in the Medal Race. (Scoring details for Fleet Racing at the Rio 2016 Olympic sailing regatta. https://www.sailing.org/olympics/rio2016/about/scoring.php)

*Statistical Analysis*

Descriptive and comparative statistics processed the data collected during the study.

Data analysis methods included calculating fundamental statistical indicators: Mean, Min - the minimum result, Max - the maximum result, SD - standard deviation, and determination of measures of sensitivity of result distribution: Skew - Skewness, Kurt - Kurtosis. In addition, differences between sailors with different roles onboard were determined using a Student's t-test for independent samples. P values lower than 0.05 were considered statistically significant. Data analysis was performed using the Statistical software SPSS (ver. 20). In addition, the statistical program for personal computers SPSS for Windows version 10 was used for data processing.

Descriptive and comparative statistics processed all the data collected during the study. From the data of descriptive statistics, for each variable, the measures of central tendency and dispersion measures were calculated:

Mean, Min, Max, and Standard Deviation. To calculate the distribution: Skewness and Kurtosis were applied.

The correlation indicators (Spearman Correlation) between anthropometric measures, namely body weight, body height, and age of the athletes, and their total scores in the sailing race were calculated.

## Results

Table 1, table 2, and figures 1, 2, 3 show the numerical quantitative indicators of the physical status of the Olympic sailors in 'Person' and 'Two-Person dinghies'. Tables 1 and 2 show the height of female and male sailors in different classes of dinghies. Differences ranged from 155 cm to 186 cm for females and 160 to 204 cm for male participants.

The Finn class sailors had the highest anthropometric measures among the participants of the Games. The average male height was 190.52±5.56 cm, and the mean weight was 96.74±2.99 kg.

**Table 1.** Descriptive parameters of Olympic sailors in 'One person' Dinghy.

| Class dinghy | Position | Variables | N | Mean | Std.Dev. | Max. | Min. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|---|
| Finn (m) | Helmsman | Body Height | 23 | 190.52 | 5.56 | 204.0 | 181.0 | .643 | .243 |
| | | Body Weight | | 96.74 | 2.99 | 102.0 | 88.0 | -1.134 | 2.612 |
| | | BMI | | 26.70 | 1.47 | 29.48 | 23.55 | -.214 | -.295 |
| | | Age | | 29.94 | 5.09 | 40.87 | 21.95 | .401 | -.387 |
| Laser (m) | Helmsman | Body Height | 44 | 182.64 | 4.48 | 193.0 | 170.0 | -.180 | -.819 |
| | | Body Weight | | 81.18 | 2.43 | 87.0 | 73.0 | -.922 | 2.741 |
| | | BMI | | 24.37 | 1.29 | 28.37 | 21.50 | .263 | 1.382 |
| | | Age | | 27.44 | 4.80 | 43.34 | 20.30 | 1.643 | 3.329 |
| Laser Radial (w) | Helmsman | Body Height | 37 | 171.54 | 5.35 | 184.0 | 160.0 | .411 | .232 |
| | | Body Weight | | 66.54 | 3.45 | 72.0 | 57.0 | -.760 | .379 |
| | | BMI | | 22.65 | 1.47 | 25.71 | 19.37 | .044 | -.113 |
| | | Age | | 25.55 | 5.08 | 37.69 | 17.48 | .384 | -.277 |
| RS:X (m) | Helmsman | Body Height | 36 | 180.6 | 6.27 | 192.0 | 167.0 | -.507 | -423 |
| | | Body Weight | | 72.5 | 3.60 | 80.0 | 63.0 | -.477 | 1.273 |
| | | BMI | | 22.23 | 1.05 | 25.26 | 19.94 | .529 | .784 |
| | | Age | | 29.40 | 6.51 | 44.79 | 17.82 | .097 | -.540 |
| RS:X (w) | Helmsman | Body Height | 25 | 166.8 | 4.79 | 178.0 | 156.0 | -.157 | .929 |
| | | Body Weight | | 58.04 | 3.78 | 65.0 | 50.0 | -.315 | .244 |
| | | BMI | | 20.68 | 1.20 | 23.51 | 17.93 | .054 | .663 |
| | | Age | | 26.60 | 5.45 | 40.55 | 17.78 | .529 | .113 |

Table 2. Descriptive parameters of Olympic sailors in 'Two person' Dinghy.

| Class dinghy | Position | Variables | N | Mean | Std.Dev. | Max. | Min. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|---|
| 470 (m) | Helmsman | Body Height | 25 | 173.44 | 4.55 | 183 | 165 | .244 | -.149 |
| | | Body Weight | | 64.40 | 2.89 | 71 | 59 | .411 | .496 |
| | | BMI | | 21.42 | 0.83 | 23.14 | 20.01 | .270 | -.486 |
| | | Age | | 28.84 | 3.70 | 35.67 | 21.95 | .227 | -.784 |
| 470 (m) | Crew | Body Height | 25 | 181.16 | 5.87 | 194.0 | 172.0 | .610 | -.172 |
| | | Body Weight | | 71.76 | 3.19 | 78.0 | 64.0 | -.774 | .915 |
| | | BMI | | 21.90 | 1.32 | 24.34 | 19.13 | -.025 | -.466 |
| | | Age | | 29.17 | 5.10 | 40.00 | 19.68 | .588 | -.005 |
| 470 (w) | Helmsman | Body Height | 20 | 164.65 | 4.74 | 174.0 | 157.0 | .118 | -.593 |
| | | Body Weight | | 57.25 | 4.48 | 71.0 | 50.0 | 1.251 | 4.112 |
| | | BMI | | 21.11 | 1.18 | 23.45 | 19.23 | .371 | -.784 |
| | | Age | | 26.73 | 4.19 | 35.77 | 20.42 | .813 | .359 |
| 470 (w) | Crew | Body Height | 20 | 173.70 | 4.07 | 180.0 | 165.0 | -.375 | -.641 |
| | | Body Weight | | 67.35 | 2.59 | 70.0 | 60.0 | -1.615 | 2.916 |
| | | BMI | | 22.34 | 1.04 | 24.51 | 20.60 | -.550 | -.287 |
| | | Age | | 26.97 | 4.72 | 36.98 | 17.56 | .382 | -.140 |
| 49-er (m) | Helmsman | Body Height | 20 | 180.45 | 3.30 | 186.0 | 174.0 | -.004 | -.345 |
| | | Body Weight | | 77.25 | 3.63 | 82.0 | 71.0 | -.195 | -1.099 |
| | | BMI | | 23.72 | 0.73 | 25.31 | 22.84 | 1.103 | .347 |
| | | Age | | 28.95 | 4.29 | 37.40 | 20.88 | .346 | .032 |
| 49-er (m) | Crew | Body Height | 20 | 182.65 | 3.57 | 190.0 | 177.0 | .549 | -.552 |
| | | Body Weight | | 80.50 | 2.65 | 84.0 | 73.0 | -1.288 | 2.171 |
| | | BMI | | 24.15 | 1.05 | 25.85 | 22.36 | -.137 | -1.058 |
| | | Age | | 28.97 | 3.96 | 36.53 | 21.58 | .186 | -.416 |
| 49-er FX (w) | Helmsman | Body Height | 20 | 164.45 | 6.64 | 175.0 | 152.0 | -.166 | -.780 |
| | | Body Weight | | 60.0 | 4.35 | 70.0 | 53.0 | .264 | .348 |
| | | BMI | | 22.19 | 1.02 | 24.97 | 20.05 | .548 | 2.523 |
| | | Age | | 26.79 | 3.89 | 33.84 | 20.35 | -.137 | -.668 |
| 49-er FX (w) | Crew | Body Height | 20 | 172.9 | 4.89 | 183.0 | 165.0 | .291 | -.366 |
| | | Body Weight | | 68.50 | 2.89 | 74.0 | 64.0 | .326 | -.541 |
| | | BMI | | 22.92 | 0.89 | 24.28 | 20.90 | -.604 | -.231 |
| | | Age | | 24.41 | 2.65 | 28.58 | 18.44 | -.410 | -.076 |
| Nacra 17 Mixed (m) | Helmsman | Body Height | 17 | 177.0 | 6.36 | 187.0 | 167.0 | -.085 | -1.303 |
| | | Body Weight | | 73.1 | 4.46 | 83.0 | 67.0 | .448 | -.038 |
| | | BMI | | 23.38 | 1.61 | 27.97 | 21.50 | 1.488 | 3.496 |
| | | Age | | 34.20 | 8.99 | 54.91 | 21.13 | .792 | .437 |
| Nacra 17 Mixed (w) | Helmsman | Body Height | 4 | 168.75 | 2.99 | 172.0 | 165.0 | -.423 | -.416 |
| | | Body Weight | | 61.0 | 1.41 | 62.0 | 59.0 | -1.414 | 1.500 |
| | | BMI | | 21.43 | 0.47 | 21.97 | 20.96 | .240 | -3.734 |
| | | Age | | 28.01 | 7.79 | 38.64 | 21.79 | 1.130 | .182 |
| Nacra 17 Mixed (w) | Crew | Body Height | 17 | 169.63 | 5.91 | 181.0 | 155.0 | -.440 | 1.952 |
| | | Body Weight | | 63.94 | 4.67 | 69.0 | 56.0 | -.588 | -1.058 |
| | | BMI | | 22.22 | 1.23 | 23.73 | 20.32 | -.551 | -1.380 |
| | | Age | | 28.67 | 4.54 | 38.62 | 22.44 | .746 | -.094 |
| Nacra 17 Mixed (m) | Crew | Body Height | 4 | 183.75 | 3.30 | 188.0 | 180.0 | .437 | 1.166 |
| | | Body Weight | | 78.5 | 6.61 | 88.0 | 74.0 | 1.560 | 2.173 |
| | | BMI | | 23.25 | 1.86 | 25.99 | 22.07 | 1.793 | 3.193 |
| | | Age | | 29.60 | 3.89 | 33.36 | 25.72 | -.028 | -5.387 |

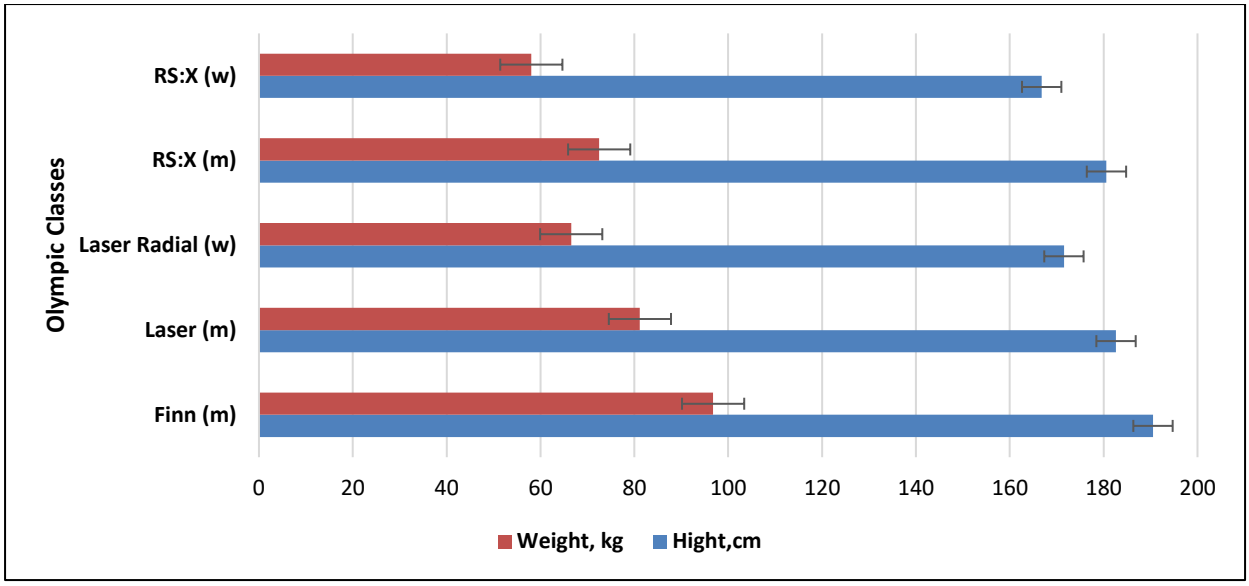
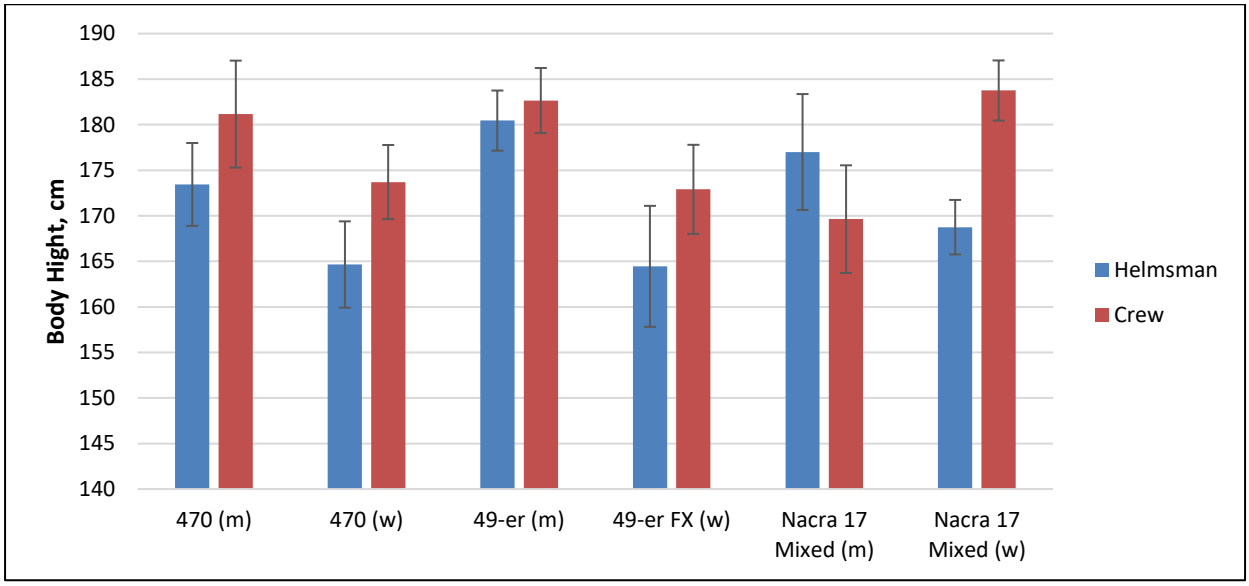
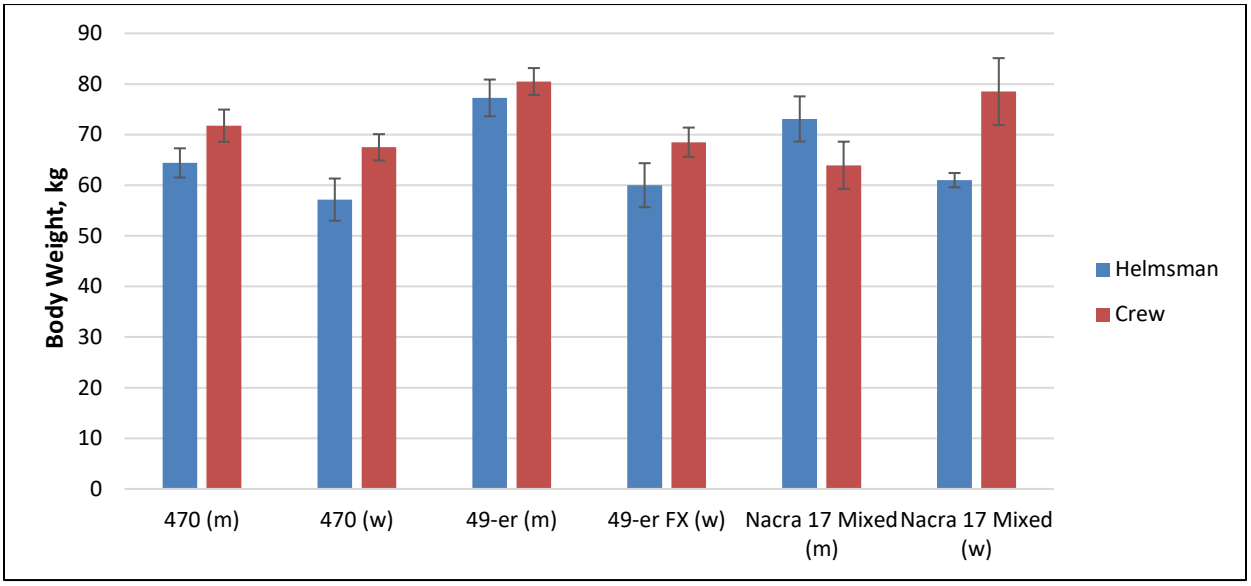



**Figure 1.** Anthropometric characteristics of the Olympic sailors in the one-person Dinghy.
Note: m – men; w – women.




A




B

**Figure 2.** Anthropometric characteristics of the Olympic sailors in two-person dinghy **(A)** Body height; **(B)**. Bodyweight. Note: m – men; w – women.

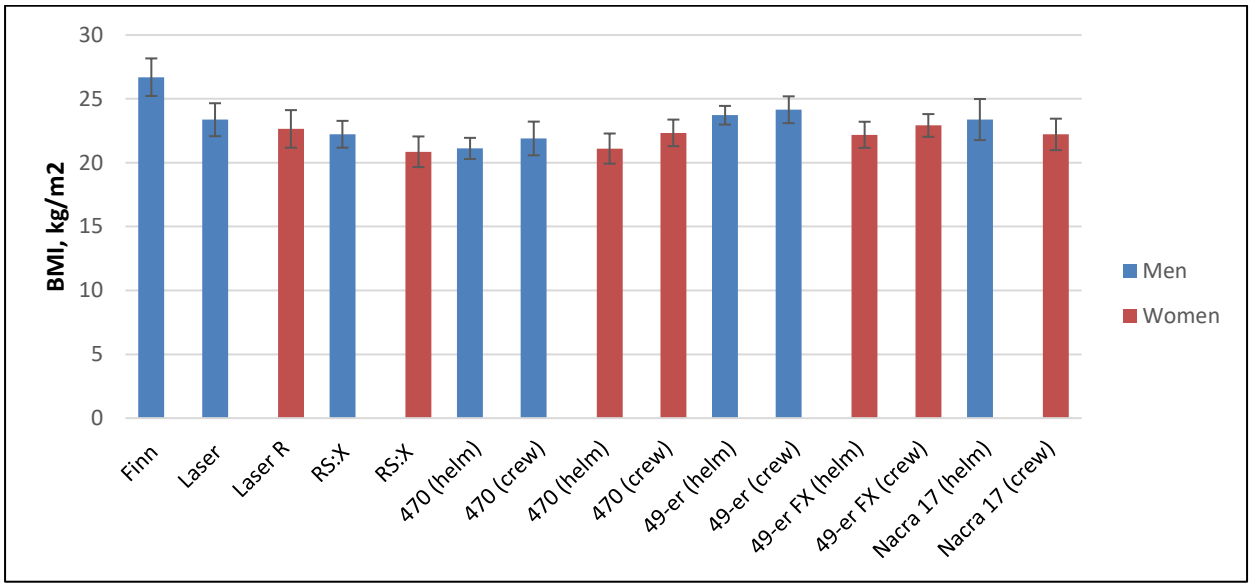



**Figure 3.** BMI of Olympic sailors in different classes of dinghies.

A comparative analysis of the height and weight of sailors in the Dinghy with the crew ("470", "49-er", "49-er FX" and "Nacra 17 Mixed"), is presented in Table 3 showed that the measures of helmsman were significantly less than that of the crew, both in weight and body height. The Bodyweight of female helmspersons ranged from 50 to 71 kg, and among the crew, it ranged from 56 to 74 kg. The female crew in "470" had a bodyweight of 10.1 kg (17.6%) more than helmsmen ($p < 0.05$), in the "49-er FX" – it was 8.5 kg (14.2%) ($p < 0.05$) and the "Nacra 17 Mixed" – it was 17.5 kg (28.7%) ($p < 0.05$) more than the helmsmen.

It can also be stated that the higher measures of body height for the crew were observed in "470" by 9.0 cm (5.5%) ($p < 0.05$), in the "49-er" by 8.4 cm ($p < 0.05$), and in the "Nacra 17 Mixed" – by 15 cm (8.9%) ($p < 0.05$).

The Bodyweight of the male helmspersons was in the range of 59 kg to 83 kg, and for the crew ranged from 64 to 88 kg.

Similar to the measures observed in females, it could be said that the crew were heavier than the helmsmen in the "470" by 7.4 kg (11.5%) ($p < 0.05$), in the "49-er FX" – by 3.2 kg (4.1%) ($p < 0.05$) and in the "Nacra 17 Mixed" – by 9.2 kg (12.6%) ($p < 0.05$). Male crew were taller in the "470" – by 7.8 cm (4.5%)($p < 0.05$), in the"49-er" – by 2.2 cm (1.2%) ($p < 0.05$) and in the "Nacra 17 Mixed" – by 7.4 cm (4.2%) ($p < 0.05$).

**Table 3.** Differences in the anthropometric characteristics between helmsmen and crew among Olympic sailors in a double-handed dinghy.

| Class of Dinghy | N | Body Height | | T | Body Weight | | T |
|---|---|---|---|---|---|---|---|
| | | Helmsman | Crew | | Helmsman | Crew | |
| **470 (m)** | 25 | 173.44±4.55 | 181.16±5.87* | 70.4 | 64.40±2.89 | 71.76±3.19* | 42.5 |
| **470 (w)** | 20 | 164.65±4.74 | 173.70±4.07* | 12.6 | 57.25±4.48 | 67.35±2.58* | 11.7 |
| **49-er (m)** | 20 | 180.45±3.30 | 182.65±3.57* | 2.39 | 77.25±3.63 | 80.50±2.65* | 3.27 |
| **49-er FX (w)** | 20 | 164.45±6.64 | 172.90±4.89* | 15.5 | 60.0±4.35 | 68.50±2.89* | 18.02 |
| **Nacra 17 Mixed (m)** | 17 | 177.0±6.036 | 169.63±5.91* | 15.5 | 73.1±4.46 | 63.94±4.67* | 25.1 |

*Note:*- (p <0.05).*

The available work of the helmsman and the crew are very well defined: the helmsman controls the board and occasionally helps in hiking the boat, and the team maintains the operation of the sail, trim, and hike the boat. In sailing, hiking is an essential technique where the sailors have to quickly act and move so that their body weight is windward (upwind) as far as possible. This decreases the boat's heeling (leans away from the wind). The crew, during such maneuvers, must take complete control of the boat's heel, which is associated with the safety and stability of the boat.

Some boats are fitted with hiking straps (or toe straps) and trapezes to make hiking more effective. This gives the crewmember more leverage to keep the boat flat by allowing the crew member's centre of gravity to balance the force of the wind caught in the sail. Boats such as 470 may have only a trapeze, where only the crew uses the trapeze. Boats, such as the 49-er, may have trapeze wires for both the helmsman and the crew.

In such boats, it is essential to consider the total weight of the crew, which should not exceed the weight recommended by the boat manufacturers (table 4). Therefore, to take maximum advantage of the weight distribution, if the helmsman has small anthropometric measures, the crew could have a large mass and body height standards complementing each other.

**Table 4.** Basic characteristics of the Olympic classes of dinghy boats.

| Basic characteristics | Finn | «470» | «49-er» | «49-er FX» | Laser | Laser Radial | Nacra 17 | RS:X |
|---|---|---|---|---|---|---|---|---|
| Men/women | M | M/W | M | W | M | W | Mix | M/W |
| Crew number | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 1 |
| Overall length, m | 4.5 | 4.7 | 4.995 | 4.995 | 4.23 | 4.23 | 5.26 | 2.86 |
| Width, m | 1.5 | 1.7 | 2.9 | 2.9 | 1.37 | 1.37 | 2.59 | 0.93 |
| Hull weight, kg | 107 | 120 | 70 | 130 | 59 | 59 | 142 | 15.5 |
| Sail surface, $m^2$ | 10.2 | 13.04 | 21.2 | 19.6 | 7.06 | 5.76 | 18.45 | 9.5 (8.5) |
| Spinnaker, $m^2$ | No | 12.16 | 38 | 21.5 | No | No | 18.5 | No |
| Recommended crew weight, kg | Free (75-110) | 110-145 | 145-165 | 145-165 | 72-83 | 72-83 | 120-140 | Free (65-85) |

The following anthropometric measures were observed in 'RS: X' boat class. Females had lower body weight and height when compared to males. Bodyweight in women ranged from 50 to 65 kg, and mean weight was 58.04±3.78 kg. In men, body weight was 63 to 80 kg, and the mean weight was 72.5±3.60 kg. The height of male sailors was 13.8 cm (7.6%) higher than that of women. The additional height was required for men to effectively control the sail, which was 1 $m^2$ more than the sail used by the women.

By analyzing the correlation between anthropometric characteristics, age Olympic sailors, and their racing results (table 5) it can be observed that body height had a greater effect on the final result in a sailing race concerning helmsman in "Nacra 17" dinghy it had a strong correlation ($p \leq 0.01$). Olympic class boats "Finn", "Laser", "Laser Radial", "470" (w), "49-er FX", "RS:X" (w) revealed moderate negative correlation ($p \leq 0.05$), but in other classes, a weak correlation was discovered($p \leq 0.10$).

A strong negative correlation was revealed between race results and the Bodyweight of helmsmen in classes of dinghies such as "Finn," "Laser Radial" (w), and the Bodyweight of the crew in "49-er FX" (w). In other Olympic class boats, a weak negative correlation was noticed.

A strong negative correlation between the race results and the sailor's age was discovered in "470" (men and women), Laser Radial (w). However, in all the Olympic class boats, it was found that the older helmsman had obtained better results in the competition, including the final. Hence, it can be said that experience is often an essential factor in winning a sailing competition.

Both negative and positive correlations were observed when BMI and race results were analyzed depending on their dispersions.

Table 5. Correlation of anthropometric characteristics and age indicators of Olympic sailors with sailing race results (total scores) Spearman Correlation ($p<0.001$).

| Class dinghy | Position | Anthropometry | | | |
|---|---|---|---|---|---|
| | | Body Height | Body Weight | BMI | Age |
| Finn (m) | Helmsman | -.386 | -.497 | -.485 | .252 |
| Laser (m) | Helmsman | -.368 | -.126 | .274 | -.310 |
| Laser Radial (w) | Helmsman | -.395 | -.515 | -.022 | -.506 |
| 470 (m) | Helmsman | -.234 | -.033 | .344 | -.607 |
| 470 (m) | Crew | -.212 | .124 | .293 | -.267 |
| 470 (w) | Helmsman | .385 | .210 | -.101 | -.495 |
| 470 (w) | Crew | -.337 | -.011 | .343 | -.466 |
| 49-er (m) | Helmsman | -.174 | -.092 | .042 | .030 |
| 49-er (m) | Crew | -.143 | .004 | .144 | .281 |
| 49-er FX (w) | Helmsman | -.412 | -.350 | .192 | -.252 |
| 49-er FX (w) | Crew | -.461 | -.510 | .131 | -.393 |
| Nacra 17 Mixed (m) | Helmsman | -.615 | -.210 | .506 | -.092 |
| Nacra 17 Mixed (w) | Crew | -.040 | .130 | .244 | .124 |
| RS:X (m) | Helmsman | -.296 | -.060 | .353 | -.271 |
| RS:X (w) | Helmsman | -.387 | .010 | .384 | -.380 |

In table 6 the differences in the anthropometric characteristics of Olympic sailors concerning their gender are presented. As recommended by the world health organization, BMI classification system was applied for analysis. The norms applicable for the general population were used. The average BMI observed among Olympic athletes of various sports was 22.9. But in sailing, the BMI recorded for males and females had some differences. Results indicated that the BMI in men was higher than in women, but the difference was not significant ($p > 0.01$) at all. In figure 4, it can be observed that indicators of BMI in Sailing had minimal dispersion, similar to many other Olympic-type sports.

Table 6. Comparison of Anthropometric characteristics among Olympic sailors.

| Class | N | Anthropometry | | | |
|---|---|---|---|---|---|
| | | Age (years) | Body Height (cm) | Body Weight (kg) | BMI |
| Average (all sports) | 10384 | 26.8 | 1.77 | 72.0 | 22.9 |
| Sailing (all) | 343 | 28.0±5.4 | 176.15±6.2 | 71.2±10.4 | 22.8±1.8 |
| Sailing (females) | 163 | 26.5±4.7 | 169.3±6.2 | 63.2±5.6 | 22.0±1.4 |
| Sailing (males) | 180 | 29.3±5.6 | 181.3±6.6 | 77.1±9.0 | 23.4±1.9 |

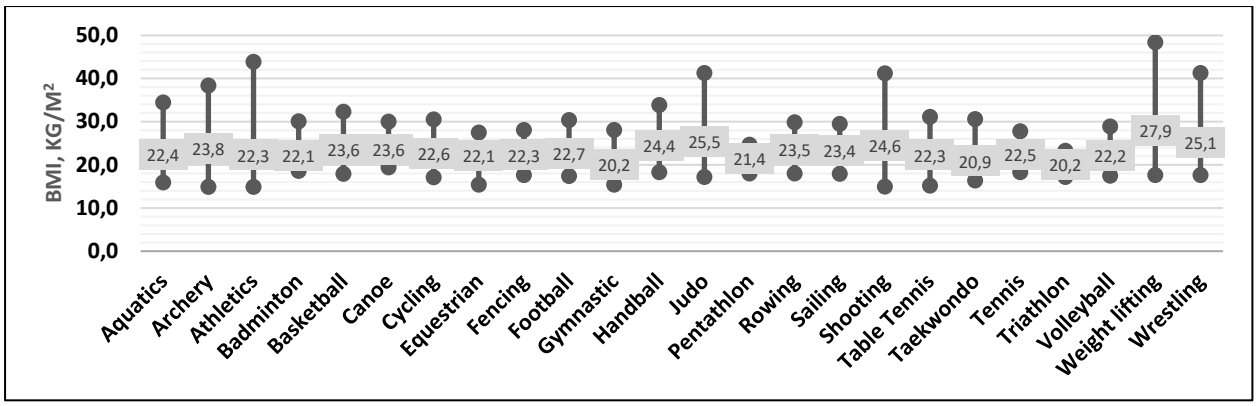



**Figure 4.** BMI Indicators of the Olympic athletes in various sports during Rio Olympics -2016.

The research data shows that the average age of participants in the Rio Olympic Games in sailing was 26.5±4.7 years. The minimum age of female sailors was 17.5 years, and the maximum age was 38.6 years (primarily in the boat class "Nacra 17"). In men, the average age was 29.3±5.6 years, the minimum age was 17.8 years, and the maximum age was 54.9 years. Nacra sailors were the oldest of all sailing participants. The average age of male helmspersons in Nacra was 29.6±3.89, and that of women crew was 28.7±4.54 years.

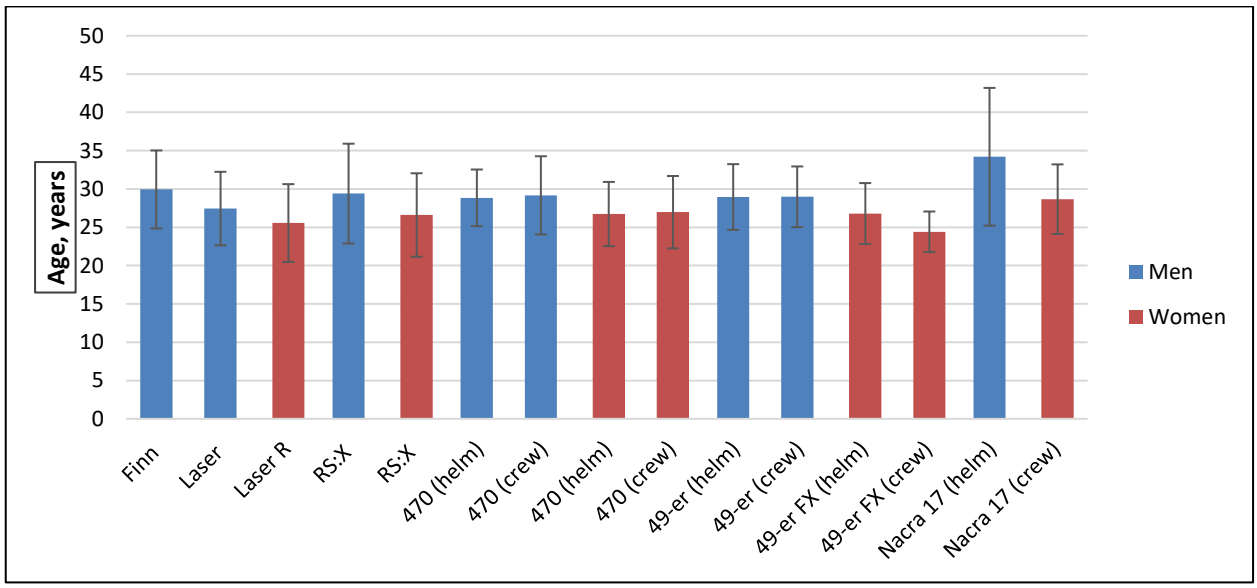



**Figure 5.** The average age of the Olympic sailors in the various classes of boats during Rio Olympics-2016.

In general, it was observed that women were younger than men among all participants of the sailing race in the Rio Olympic Games (figure 5). The crew's average age in the Laser Radial and RS: X boats was almost the same as that of the helmspersons. The boats "470" and "49-er" were 28 to 29 years for men and 24 to 27 years for women. Male yachtsmen were older than the athletes from other Olympic sports (table 6). The sport of sailing shows that many great yachtsmen performed well at the Olympic Games at an older age such as Paul Elvstrøm (Denmark), Andrei

Balashov, Larisa Moskalenko, Iryna Chunykhovska (Soviet Union), Henrik Robert (Norway), Iain Percy, Ben Ainslie (Great Briton), Nikolaos Kaklamanakis (Greece), Yevhen Braslavets, Ihor Matviyenko, Ruslana Taran, Olena Pakholchik, Rodion Luka, George Leonchuk (Ukraine), Alessandra Sensini (Italy), Robert Scheidt (Brazil), Xu Lijia (China) and many others. Figure 6 shows that age dispersion in sailing was very minimal when compared to sports such as equestrian, rowing, shooting, and table tennis.

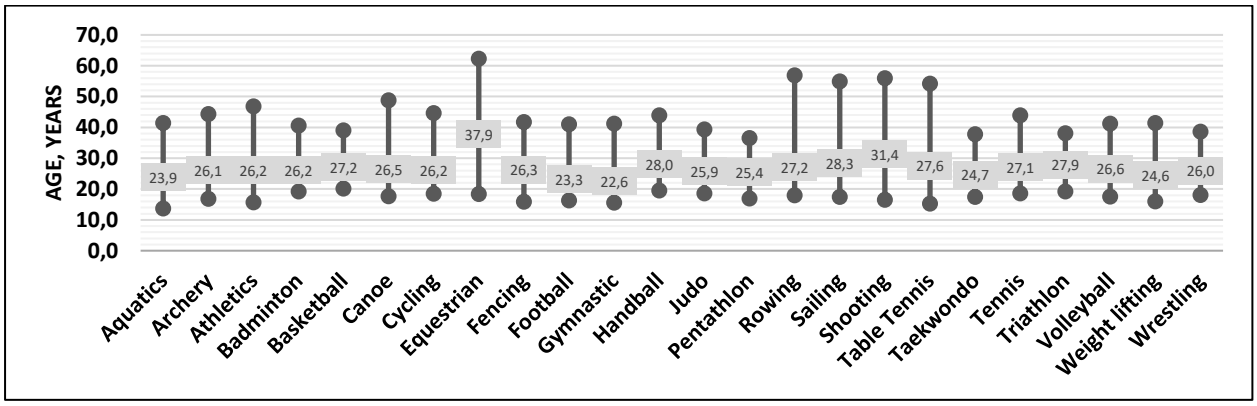



**Figure 6.** The average age of the Olympic athletes in various sports in Rio Olympics -2016.

At the Olympic level, elite athletes in most disciplines are generally taller, heavier, and more muscular than the general population. A comparative analysis of body weight and body height of athletes participating in the 2016 Olympic Games showed that the height of the Olympians was in the range from 163.8 to 192.1 cm, and body weight was in the field from 54.3 to 87.0 kg (Figure 7, 8). The Bodyweight and height of sailors were 74.2 kg and 177.9 cm, respectively. It was evident that taller athletes prevailed in most sports. Height is significant in sailing when managing the boat and sharing functional duties as crew on their sailboats.

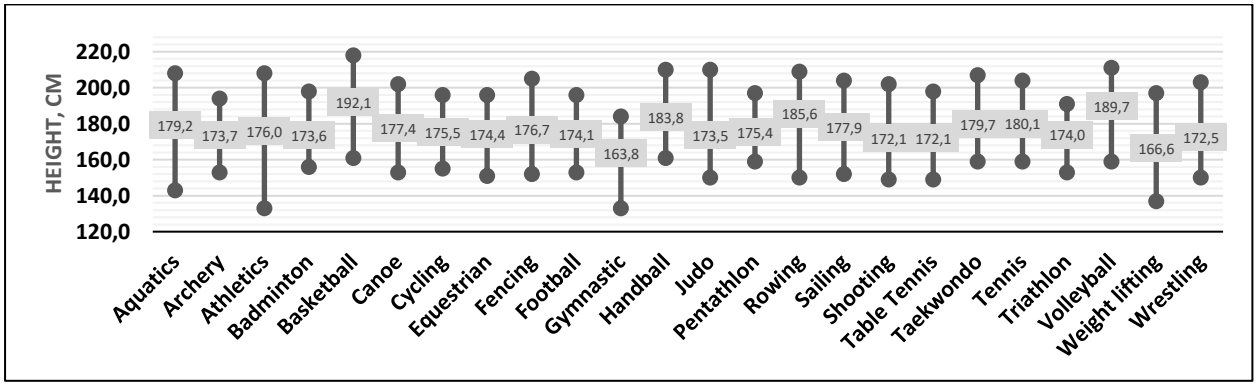



**Figure 7.** The average height of the athletes in various sports in Rio Olympics-2016.

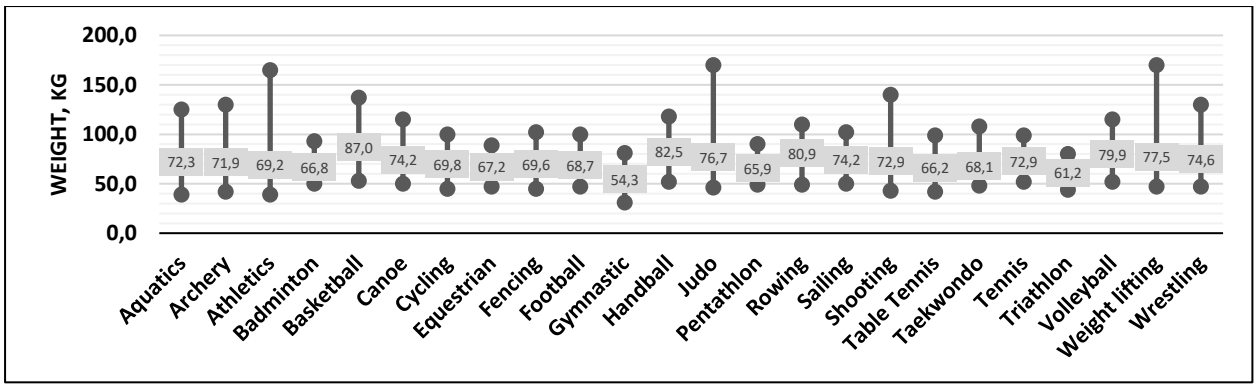



**Figure 8.** The average weight of the athletes in various sports in Rio Olympics-2016.

## Discussion

This research aimed to analyze the significance of the anthropometric characteristics of Olympic sailors according to the different functional positions on board with their success in the race.

The study results confirmed the hypothesis that there would be statistically significant differences in anthropometric characteristics in body height and Bodyweight of sailors in Olympic class dinghy boats. However, the study did not turn up any statistically significant differences in BMI of sailors in all classes of boats except the "Finn" class. The current athletes are getting increasingly younger, taller, and heavier than their counterparts from the past Olympic cycles. Our research confirms the findings of Pezelj et al. (2019), It is shown that Finn dinghy athletes have a height of about 200 cm and a bodyweight of more than 90 kg. Bojsen-Moller et al. reported that Laser sailors' mean (SD) weight was 80.3±2.7 kg, and Finn sailors was 93.5 kg (Bojsen-Møller et al., 2007).

Maisetti et al. (2002) presented values of body height and body mass of the participants at the 2000 Olympic Games. The values of body height and body mass recorded for Finn sailors in this study were 187±6.00 cm and 97.5±7.5 kg, respectively, which is almost identical to the values of the observed sample.

In their research, Sánchez & Baños (2018) said that the mean somatotype of the sailors is mesomorph, except for the Laser Radial class, which leaned on endomorphic values. Researchers have concluded an ideal anthropometric and somatotype profile for each type of boat, which depended on the position occupied by the sailors on the boat. Therefore, it could be concluded that the sailors closer to this ideal were more likely to succeed.

In practice, lightweight sailors tend to sail lighter displacement boats, whereas heavier sailors predominate in the heavier classes. There is much speculation about ideal sizes. Plyley et al. (1985) are say height may provide a competitive advantage (mainly if linked to a high center of gravity), whereas mass increases the frictional resistance of the vessel.

Not all dinghies show the influence of an athlete's weight on athletic performance. The highest values of dependence are observed in dinghies such as "Finn," "Laser Radial" (w), and with the

Bodyweight of the crew in "49-er FX" (w). In other Olympic class boats, a weak negative correlation was noticed.

Caraballo et al. (2019) in their study have same described the relationship between performance and age of elite male sailors. Age seemed to be a key factor in choosing the most suitable route during the competition. A strong negative correlation between the race results and the sailor's age was discovered in "470" (men and women). Laser Radial (w), revealed that the older helmsman had obtained better results in the competition, including the final. Hence, experience is often an important factor in winning a sailing competition, as mentioned in their works by Allen & De Jong (2006), Bojsen-Møller et al. (2007).

The values of BMI in male and female sailors had not changed much. This was confirmed based on the data analysis, which showed that the BMI norms ranged from 22 to 24. The values of BMI in male and female sailors were in the range from 22 to 24. However, the BMI indicators in men were a little more than their women counterparts. A few other Olympic sports also recorded similar values of BMI: rowing, basketball, canoe, archery.

We have determined a high correlation between the helmsman's height and the sporting result in a race in the class of yachts "Nacra 17" ($p \leq 0.01$). In other yacht classes, "Finn", "Laser", "Laser Radial", "470" (w), "49-er FX", "RS: X" (w) revealed moderate negative correlation ($p \leq 0.05$), which confirmed by research by Caraballo et al. (2019) in dinghy Laser, Pan et al. (2022) in single-handed Dinghy 470 classes, Santos et al. (2016), Bojsen-Møller et al. (2007), Gomez-Ezeiza et al. (2019), Plyley et al. (1985) in other Olympic dinghy classes.

As a result of the research, we for the first time obtained the anthropometric indicators of yachtsmen who perform in the classes of the dinghi "Nakra17", "49-er", "49-er FX", which were temporarily included in the program of the Olympic Games. It was revealed that their indicators have both similar data and several differences. This is especially true of the dinghy "Nakra 17" involving a mixed crew.

## Conclusion

Based on the results of the research and detailed analysis, it can be concluded that morphological characteristics have an essential role in determining the success of top sailors in Olympic Sailing races. Sailing coaches can apply the results of this study to selecting sailors for their national teams. They can also use the findings as model characteristics for talent identification or selection at an early age for different classes of sailboats, especially the new classes as "Nakra17", "49-er", "49-er FX", which were recently included in the Olympic Games program.

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