Revista ARACÊ
ISSN: 2358-2472

TIED SWIMMING: STRENGTH PRODUCTION OF SWIMMERS AT DIFFERENT LEVELS

https://doi.org/10.56238/arev6n2-113

Submitted on: 11/09/2024 **Publication date:** 11/10/2024

Ruana Serique Beija[1], Micaela Alves da Paz[2], Guilherme Tucher[3] and Francine Caetano de Andrade Nogueira[4]

ABSTRACT

Introduction: Through the force generated in tied swimming, it is possible to differentiate the level of training of a swimmer. However, comparative studies with swimmers of different performance levels still need to be carried out. Objective: To compare the production of maximum force in 10s of tied crawl swimming by recreational swimmers, base athletes and recreational athletes. Methods: A total of 94 swimmers of both sexes participated in the study, 43 recreational swimmers, with a mean age of 24.7 ± 9.26 years, 22 base athletes, with a mean age of 11.7 ± 1.3 years, and 29 high-performance athletes, with a mean age of 19.4 ± 4.3 years. The swimmers performed a maximum stimulus of 10 seconds of tied crawl swimming, after routine warm-up. For data analysis, the JASP software was used and a significance level of $p<0.05$. Results: The main results indicated that a) the performance athletes had the highest indices of Average Strength and Maximum Strength; b) the highest correlation values found were between Mean Strength and Maximum Strength ($r=0.90$) and between Mean Strength and Body Mass and Maximum Strength and Body Mass ($r=0.52$ and $r=0.57$, respectively); c) the fatigue index was not correlated with any other variable in the study; d) the variables Body Mass and Swimmer Level were significant predictors of Mean Strength and the model found in linear regression explained 60.8% of this variable. Conclusion: The equation for predicting average strength as a function of body mass and

[1] Master's student in Physical Education
Aquatics Science Research Group
Federal University of Rio de Janeiro (UFRJ)
E-mail: ruanabeija@gmail.com
ORCID: https://orcid.org/0009-0003-8436-8485
LATTES: http://lattes.cnpq.br/5895729223352233
[2] Master's student in Physical Education
Aquatics Science Research Group
Federal University of Rio de Janeiro (UFRJ)
E-mail: micaela.eefd@gmail.com
ORCID: https://orcid.org/0009-0008-4566-4077
LATTES: https://lattes.cnpq.br/3011250600591584
[3] Doctor in Sports Sciences
Aquatics Science Research Group
Federal University of Rio de Janeiro (UFRJ)
E-mail: g.tucher@eefd.ufrj.br
ORCID: https://orcid.org/0000-0001-6678-9823
LATTES: http://lattes.cnpq.br/5658776018885453
[4] Doctor in Psychology
Aquatics Science Research Group
Federal University of Rio de Janeiro (UFRJ)
E-mail: francinenogueira@eefd.ufrj.br
ORCID: https://orcid.org/0000-0001-7754-3087
LATTES: http://lattes.cnpq.br/4786557659878777

competitive level of athletes can help coaches and physical trainers in monitoring their athletes and prescribing training throughout the season, in order to increase propulsive efficiency in the water.

Keywords: Tied Swimming. Athletes. Recreational. Strength Indexes.

Revista ARACÊ
ISSN: 2358-2472

INTRODUCTION

In the field of sports performance, it is known that the adequate production and maintenance of propulsive force, as well as the reduction of resistive forces are extremely important for the swimmer's advancement (BARBOSA et al., 2015; COSTA et al., 2012), that is, it is necessary that the propulsion is greater than the resistance to favor displacement in an aquatic environment.

The formula V = P/F indicates that the velocity (V) of individuals is calculated by the ratio between the amount of propulsive power (P) produced and the amount of resistive force (F) generated against their displacement, or even V = CB x FB in which the velocity is given by the product of the average stroke length (CB) and the average stroke frequency (FB) (COSTA et al., 2012; COSTILL et al., 1991). It is important to note that these variables depend on the technique and the individual's energy contribution to the occurrence of muscle contraction (COSTA et al., 2012).

In swimming, the measurement of propulsive force directly becomes complex when considering the particularities of the aquatic environment. One of the ways to measure this specific propulsive force is through the knotted swim (BARBOSA et al., 2019), which consists of evaluating the swimmer's strength when swimming while attached to equipment capable of measuring strength. Several studies indicate that, among the methods used to evaluate the propulsive force during swimming, it is important to highlight the dynamometry of tied swimming (DOPSAJ et al., 2003; KJENDLIE; THROSVALD, 2006) thus obtaining, the measures of maximum strength and average strength at maximum stimuli of generally 10 or 30 s (BARBOSA et al., 2019; MOROUÇO et al., 2018).

This tool is relatively simple, but it is specific and adequate to collect data on force production (BARBOSA et al., 2019; MOROUÇO et al., 2011). Unfortunately, there is still no consensus in the literature on reference values related to strength for athletes and recreational practitioners of the sport, although it is important to analyze the production of force using the tied swimming as a way to know the effects of training and thus structure the training.

Since there are still no strength reference values established for individuals of different levels in the aquatic environment, the justification of the research is to understand the differences between athletes and non-athletes related to maximum strength and average strength, which will make it possible to elucidate questions about the training of high-performance athletes.

Revista ARACÊ
ISSN: 2358-2472

This research can contribute to establish the reference values that will allow the best knowledge and parameter of performance, thus helping the training of swimmers and also the performance of coaches, since the evaluation and monitoring from the tests and/or data collection have as their main objective to control the possible changes in the performance of individuals throughout a season, or, even at specific moments of sports training (MOREIRA et al, 2008).

Thus, the objective of this study was to analyze and compare the production of maximum force in 10 seconds of tied crawl swimming by recreational swimmers, base and performance athletes, in addition to verifying the behavior of the average strength as a function of the variables researched (age, muscle mass, competitive level, maximum strength and fatigue index).

METHODOLOGY

SAMPLE

The study included 94 swimmers, of both sexes, 43 recreational swimmers, with a mean age of 24.7 ± 9.26 years, 22 base athletes, with a mean age of 11.7 ± 1.3 years, and 29 high-performance athletes, with a mean age of 19.4 ± 4.3 years.

The inclusion criteria in this study were: 1) to be considered base athletes, swimmers should be in the process of training and regularly participating in regional, state or national championships of the modality; 2) recreational swimmers should participate in swimming lessons regularly for at least 2 times a week for at least 1 year; 3) high-performance athletes should be federated in the Brazilian Confederation of Aquatic Sports and have the index to participate in the Brazilian Championship of the category.

EXPERIMENTAL DESIGN

Signing of the ICF

All subjects and their guardians, in the case of the minor, were informed about the information pertinent to the research, as well as the procedures pertaining to the test, the possible damages and risks.

They agreed, attested to voluntary participation, allowed the use and dissemination of the information, thus signed the term contained in Appendix A and B, and voluntarily participated in this study, which was also submitted to the Research Ethics Committee under number 6.543.615/2023 according to the opinion contained in Appendix C.

Revista ARACÊ
ISSN: 2358-2472

The individuals had already had previous experiences of at least 2 years in the aquatic environment before the study and, based on this, they were familiarized with the test before the start of data collection.

Procedures

To compose the sample, the athletes were contacted from several clubs in the State of Rio de Janeiro that participate in swimming competitions. The recreational individuals were contacted from a swimming extension project that takes place at a public university in the city of Rio de Janeiro.

The tests were scheduled and applied by the researchers on different days, clubs and projects. Before conducting the research, the institutions were contacted and two days were previously scheduled with the coaches/teachers. On the first day, the swimmers received explanations about the research, signed the Free and Informed Consent Form and became familiar with the equipment. On the second day, the swimmers performed a self-selected warm-up and the Tied Swim (NA) test. The maximum stimulation time to measure NA strength was a standard of 10 seconds for all study participants, as well as the crawl test.

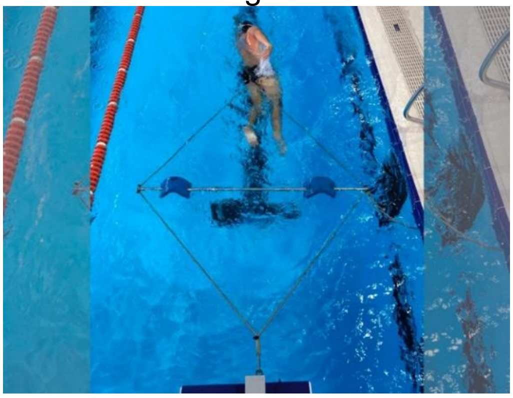
Equipment

A 200kgf load cell (Cefise®, Nova Odessa, Brazil) was used, with signal acquisition at 200Hz and calibrated using known weights of 5 kg, 10 kg and 20 kg. The data were converted into a unit of weight using a 5Hz filter (N2000PRO, Cefise®) and later transferred to Excel.

The load cell was attached to the starting block creating an angle of 5.7º degrees with the water surface. The participants wore a belt in the abdomen area that was attached to an aluminum bar with floating materials that, in turn, was attached to the load cell. Before the test, a self-selected warm-up was carried out by the athletes themselves based on what they were already used to.

Revista ARACÊ
ISSN: 2358-2472

Figure 2 – Swimmer in a swimming test tied with the equipment used.



Source: Photo taken from the Cefise website (https://cefise.com.br/produtos/natacao/)

The swimmers were instructed to adopt the horizontal position and start swimming comfortably for approximately 5 seconds so that the cable could be fully extended, until they heard a sound signal, made by means of a whistle, at which time they should swim at maximum speed. This procedure aims to avoid the inertial effect of the cable extension usually produced immediately before or during the first stroke. The end of the test was also signaled by the whistle. The swimmers were also instructed to follow their breathing pattern that they normally use during competition. For data analysis, the first second of the test was excluded.

Statistical analysis

The descriptive analysis is presented as mean ± standard deviation. Parametric assumptions were evaluated using the Shapiro-Wilk and Levene tests. To test the differences between the values of age, body mass, mean strength, maximum strength and fatigue index, the Kruskal-Wallis test was used, followed by Tukey's post hoc test when necessary.

Subsequently, the relationship between the variables Age, Average Strength, Maximum Strength, Body Mass and Fatigue Index was analyzed using Spearman's Correlation test, evaluated as proposed by Hopkins (2002), in which <0.10 (trivial), 0.10 to 0.30 (low), 0.31 to 0.50 (moderate), 0.51 to 0.70 (high), 0.71 to 0.90 (very high), 0.91 to 0.99 (almost perfect) and 1 (perfect), in addition to multiple linear regression, using the Enter method, to obtain a parsimonious model that would allow predicting the mean strength as a function of the independent variables (maximal strength, body mass, age and competitive level). The assumptions of normality and homogeneity of the errors were

Revista ARACÊ
ISSN: 2358-2472

graphically validated. The assumption of independence of errors was validated with the Durbin-Watson statistic (d = 1.65).

Bangsbo (1994) explains that the lower the fatigue index, the more tolerant the athlete is when exposed to intense exertion and, consequently, fatigue. The Fatigue Index (FI) was calculated from the formula: IF = (Fmed 1 to 4s - Fmed 7 to 10s) / (Fmed 1 to 4s) x 100.

For data analysis, the JASP statistical program was used and a significance level of 5% was used in all analyses.

RESULTS

Table 1 shows the descriptive data of the sample. The base athletes had an average age of 11.7 years, with a minimum age of 9 years and a maximum of 14 years, that is, they belong to the junior and children's swimming categories. The performance athletes, on the other hand, had an average age of 19.4, with a minimum age of 14 years and a maximum of 31 years, that is, they belong to the children's category to the senior category. However, these athletes also participate in absolute championships, in which there is no division of events by age groups. The base athletes had significantly lower mean age and body mass than the other groups of swimmers.

Table 1 – Descriptive data on age and body mass (Mean ± SD) for the groups analyzed.

	Age	Body mass
Recreational	24.7 ± 9.2	68.4 ± 10.1
Base	11.7 ± 1.3*	45.2 ± 9.4*
Yield	19.4 ± 4.3	65.2 ± 10.6

*Significant difference with recreational and performance swimmers (p<0.01).

The values of Maximum Strength, Average Strength and Fatigue Index can be seen below in Table 2.

Table 2 – Mean and standard deviation of the values of Maximum Strength, Mean Strength and Fatigue Index of the groups analyzed.

	Maximum Strength	Medium strength	Fadiga Index
Recreational	180.5 ± 50.8	68.1 ± 22.1	0.16 ± 0.05
Base	123.2 ± 45.8	54.7 ± 22.3	0.18 ± 0.11
Yield	320.4 ± 178.9*	107.5 ± 33.3*	0.18 ± 1.12

*Statistically significant differences between performance athletes and recreational athletes and base athletes (p<0.001)

Revista ARACÊ
ISSN: 2358-2472

When analyzing the values of Maximum Strength, Average Strength and Fatigue Index of the swimmers surveyed, it is noticed that the performance athletes presented the highest values of Maximum Strength and Average Strength compared to the base athletes and recreational swimmers. It is worth noting that the values found for the base athletes were the lowest among the 3 groups, although no statistically significant difference was found with the recreational swimmers.

The analysis of the data also allowed us to verify that the average strength of the recreational swimmers corresponded to 37.7% of the maximum strength, while in the base athletes this percentage is 44.3% and in the performance athletes it is 33.5%. In addition, it can be observed that recreational swimmers presented 56.3% of the maximum strength and 63.3% of the average strength of performance athletes, while base athletes presented 38.4% and 50.8%, respectively, of these same athletes.

Table 3 shows the correlation values found using the Spearman Correlation test.

Table 3 – Correlation between the variables surveyed

Variable	Age	Medium Strength (N)	Maximum force (N)	Massa Corporal (Kg)
Medium Strength (N)	r=0.22* (p=0.03)			
Maximum force (N)	r=0.29* (p<0.01)	r=0.90* (p<0.001)		
Massa Corporal (Kg)	r=0.66* (p<0.001)	r=0.52* (p<0.001)	r=0.57* (p<0.001)	
Fadiga index (%)	r=0.05 (p=0.70)	r=-0.16 (p=0.25)	r=-0.02 (p=0.84)	r=0.09 (p=0.51)

*Statistically significant values for p<0.05.

Table 3 shows that the correlation was very high and positive between mean and maximum strength (r=0.90), high and positive between body mass and age (r=0.66), between maximum strength and body mass (r=0.57) and between mean strength and body mass (r=0.52). The correlation was low and positive between maximal strength and age (r=0.29) and between mean strength and age (r=0.22). The fatigue index was not statistically correlated with any of the variables analyzed.

Multiple linear regression allowed the identification of the variables Body Mass (β=0.629; t = 9.465; $p < 0.001$) and Swimmers' Level (β=0.575; t = 8.641; $p < 0.001$), as significant predictors of Mean Strength, with body mass contributing 62.9% and swimmers'

Revista ARACÊ
ISSN: 2358-2472

level contributing 57.5%. The final model Average Strength = -58.413+1.526*Body Mass + 22.114*Level

This model is highly significant, since the independent variables together explain 60.8% of the mean force (F (2.91) = 70.656; p<0.001; adjusted R2 = 0.600).

DISCUSSION

The present study aimed to analyze and compare the production of maximum force in 10 seconds of tied crawl swimming by recreational swimmers, base and performance athletes, in addition to verifying the behavior of the average strength as a function of the variables researched (age, muscle mass, competitive level, maximum strength and fatigue index). The main results indicated that a) the performance athletes had the highest indices of Average Strength and Maximum Strength; b) the highest correlation values found were between Mean Strength and Maximal Strength (r=0.90) and between Mean Strength and Body Mass and Maximal Strength and Body Mass (r=0.52 and r=0.57, respectively); c) the fatigue index was not correlated with any other variable in the study; d) the variables Body Mass and Swimmer Level were significant predictors of Mean Strength and the model found in linear regression explained 60.8% of this variable.

One of the possible ways to evaluate swimming performance, in addition to time, is to measure the force generated by the swimmer and quantify the maintenance of strength throughout the race, as well as to determine the resistance forces found and their relations with the technique (AKIS, 2004). Within this concept, a study carried out by Morouço et al. (2011) sought to investigate the relationship between force production and performance. To do this, the authors evaluated 32 swimmers of international level, with an average age of 17.5 years and a body mass of 66.7 kg, who performed a 30-second test in the tied swim and competed 25 days after collection. The forces produced by the swimmers evaluated in tied swimming were related to the competitive performance in all the styles investigated. In the present study, the performance of the swimmers was not evaluated, which is a limitation. However, the results show that athletes with a higher competitive level, that is, performance athletes, have higher levels of average and maximum strength in relation to recreational swimmers and base athletes, a fact that can infer that the force produced in tied swimming is related to performance.

Multiple linear regression indicated that the variables body mass, age, and swimmer level are the predictors of mean strength for the sample studied. Previous studies indicate that swimming performance is determined by the interaction between anthropometric, biomechanical and physiological factors (BARBOSA et al. 2010; COSTA, 2012). The results of the present study are in agreement with this statement, as it shows the interaction between body mass, which is an anthropometric variable, and average strength, which is a physiological and biomechanical variable, as the application of force depends on the technique.

Another important result of the present research was the discovery of which variables directly influence the average force, obtaining a prediction equation that explains 78.5% of this variable. It is worth mentioning that the insertion of maximum force as a predictive variable was not considered as the best model by the statistical software, a fact that allows us to infer that the maintenance of average strength throughout a competitive event is much more important for the swimmer's performance than his capacity for maximum force production (AKIS, 2004).

The mean strength values for the crawl swim found by Morouço et al. (2011) were 92.8 ± 33.7 (N) and maximum strength values were 232.6 ± 63.2 (N). These values are higher than those found in recreational swimmers and base athletes, but lower than those found in the performance athletes of the present study. These differences may be linked to the level of the athletes, because, although the athletes of Morouço et al. (2011) are of international level, the performance athletes analyzed are a little older and some compete at a world level, a fact that may justify the higher rates. In addition, variations in the collection methodology and in the equipment used can also justify the differences.

In addition to the average strength being related to performance, the analysis of this variable is also related to propulsive efficiency. Barbosa et al. (2009) conducted a study that sought to evaluate the propulsive efficiency of amateur swimmers. To do this, the authors used swimming speed, distance traveled, and time spent to cover the distance. The results indicated that the values of propulsive efficiency of the amateur athletes investigated were approximately 50% lower than the values reported in the literature for performance athletes and approximately 33% lower than the values reported in the literature for swimmers of the same age, but of higher competitive level. These results may be related to the propulsive force evaluated in the present research. The average strength values found among recreational swimmers and base athletes were 66.2% and 56.9%, respectively, of the average strength of performance athletes. When we analyzed the Maximum Strength, the percentages were even lower, with 48.2% and 39.9%, respectively, of the Maximum Strength of the performance athletes.

These results are interesting as they show how far performance athletes are from base athletes and non-athletes. Although the group of recreational swimmers and performance athletes have a similar mean age (p=0.85), the average and maximum strength of the athletes is much higher, a fact that can be explained by the specific training that the performance athletes perform. In addition, it is worth mentioning that the group of recreational swimmers had higher levels of strength compared to the base athletes. One of the main differences between these two groups is body mass, which is an important factor in predicting average strength, as indicated by regression analysis. Base athletes are also younger and training is still in the consolidation phase, factors that may justify the differences found between the groups.

The average and maximum strength values reported in this study become important as they can help swimming professionals such as coaches, teachers and physical trainers to understand if the strength indices applied in the water by their athlete are in accordance with their age, body mass and competitive level. The prediction equation will allow estimating the average strength of swimmers as a function of body maximum and competitive level, in a practical and accessible way, without the need for gold standard equipment. However, further studies are needed for the equation to be tested in other groups of athletes and to verify its effectiveness.

CONCLUSION

It was concluded that performance athletes had higher levels of Average Strength and Maximum Strength in relation to recreational athletes with similar body mass and ages and in relation to base athletes, from categories with younger age groups. It is also concluded that the equation for predicting the average strength as a function of the body mass and competitive level of the athletes can help coaches and physical trainers in monitoring their athletes and prescribing training throughout the season, in order to increase the propulsive efficiency in the water.

ACKNOWLEDGMENTS

We thank all athletes and swimmers who participated in this study and contributed so that the research could be carried out.

Revista ARACÊ
ISSN: 2358-2472

REFERENCES

1. Akis, T. O. (2004). Experimental and analytical investigating trons of the mechanics of crawl swimming. *Mechanics Research Communications, São Paulo*.

2. Bangsbo, J. (1994). The physiology of soccer, with special reference to intense intermittent exercise. *Acta Physiologica Scandinavica, Supplementum, 619*, 1-155.

3. Barbosa, T. M., Lima, V., Mejias, E., Costa, M. J., Marinho, D. A., Garrido, N., Silva, A. J., & Bragada, J. A. (2009). A eficiência propulsiva e a performance em nadadores não experts. *Motricidade, 5*(4), 27-43.

4. Barbosa, T. M., Morais, J. E., Forte, P., Neiva, H., Garrido, N. D., & Marinho, D. A. (2015). Comparison of experimental and analytical procedures to measure passive drag in human swimming. *PLOS ONE*. https://doi.org/10.1371/journal.pone.0130868

5. Costa, M. J. B., Mejias, H. E., Louro, H., & Barbosa, T. M. (2012). Contributo dos factores antropométricos, bioenergéticos e biomecânicos para a performance de nadadores de elite no pico de forma na época de visão. *Revista Motricidade, São Paulo*.

6. Dopsaj, M., Matkovi, I., & Zdravkovi, I. (2003). The relationships between 50m freestyle results and characteristics of tethered forces in male sprint swimmers: A new approach to tethered swimming test. *Facta Universitatis: Physical Education and Sports, 1*(7), 15-20.

7. Lätt, E. J. (2010). Physiological, biomechanical and anthropometrical predictors of sprint swimming performance in adolescent swimmers. *Journal of Sports Science and Medicine, 9*, 309-404.

8. Morouco, P. (2009). *Force production in tethered swimming and its relationship with performance: A new approach to evaluate the anaerobic capacity of swimmers* (Master's thesis). Universidade do Porto, Porto, Portugal.

9. Morouço, P. G., Barbosa, T. M., Arellano, R., & Vilas-Boas, J. P. (2018). Intracyclic variation of force and swimming performance. *International Journal of Sports Physiology and Performance, 13*(7), 897-902.

10. Morouco, P., Keskinin, K., Vilas-Boas, J. P., & Fernandes, R. J. (2011). Relationship between tethered forces and the four swimming techniques performance. *Journal of Applied Biomechanics, 27*(2), 161-169. https://doi.org/10.1123/jab.27.2.161

11. Papoti, M., et al. (2007). Uso de células de carga para mensuração da força dos membros inferiores em nado ondulatório. *Revista Portuguesa de Ciências do Desporto, 7*(3), 313-318.