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Original Article

Protein intake by master swimmers: Implications for practice in Sports Nutrition—A cross-sectional study

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Abstract

Background: Proteins are essential for the maintenance, repair, and growth of muscle mass. This is particularly important for master athletes because aging has been associated with loss of muscle mass, function, and strength. Moreover, the timing of intake has been shown important for the best protein utilization. **Aim:** To analyze timing, quantity, and source of dietary protein in competitive master athletes according to current recommendations. **Methods:** Twenty-one male master swimmers (47.9 ± 10.0 years; 79.2 ± 6.5 kg; 179.1 ± 5.5 cm; 23.5 ± 4.9% body fat; 73.3 ± 4.2% lean mass) participated in this cross-sectional study. Protein intake was analyzed based on 7-day food records, regarding quantity, timing, and sources of intake. Protein intake was evaluated according to current international sports nutrition guidelines, including the International Society of Sports Nutrition Position Stand. Body fat (%) and lean mass (%) were evaluated using dual-energy X-ray absorptiometry. **Results:** Participants' mean protein intakes were 1.9 ± 0.5 g/kg/day, 0.6 ± 0.2 g/kg/meal post-training, and 33.5 ± 23.9 g during the pre-sleep period. Daily intake was within the recommended values of 1.4 and 2.0 g/kg/day ($p = 0.01$ and 0.147, respectively). Mean pre-sleep intake was within the recommendation values of 30–40 g ($p = 0.28$ and 0.147, respectively). Most of the daily protein intake was consumed at lunch (66.7 ± 6.9 g) and dinner (48.0 ± 4.5 g). Regarding protein sources, intakes from animal, vegetal, and supplements were, respectively, 65.7%, 29.2%, and 5.1%. **Conclusion:** Master swimmers presented a total protein intake within the recommendations for a daily basis, but the majority of intake was at lunch and dinner. Protein intake could be better distributed throughout the day to optimize protein synthesis. Guidance on daily protein intake distribution should be reinforced in clinical practice.

Keywords

Swimming, nutrition assessment, dietary proteins, athlete master, protein timing

Introduction

One of the main themes of interest when it comes to sports nutrition is protein intake. Such interest arises mainly from the relationship between protein intake and muscle mass, but there is more to protein intake and athletic performance enhancements than this single relationship. Acute and chronic exercise-induced adaptations that benefit from adequate protein consumption include muscle protein synthesis, lower muscle damage, inflammation markers, repair of musculoskeletal tissues, and shorter recovery time (Burke and Mujika, 2014).

This topic is particularly important for master athletes (the master category in swimming encompasses individuals as young as 25 years old and above) because aging has been associated with loss of muscle mass, function, and strength (Hurley et al., 2011). As of 30 years of age, athletic performance constantly reduces, which results in lower training volume and intensity in master athletes (Tanaka and

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Seals, 2003). Maximum oxygen consumption also decreases ~ 10% per decade as of 25 years of age, regardless of the level of physical fitness (Hawkins and Wiswell, 2003). Age-related strength loss is partly explained by the reduction in the size of myofibrils and motor units, mostly type-2 fibers (Hunter et al., 2016). After the same amount of protein intake, muscle anabolic responses have been shown to be different in master athletes (mean age of 53 years) compared to younger athletes (mean age of 27 years). Master athletes presented lower rates of muscle synthesis, resulting in slower muscle recovery (Doering et al., 2016). When master triathletes consumed higher doses of protein post-training, they reported lower fatigue perception (Doering et al., 2017). The issue of timing of protein intake and the amount of protein consumed at each eating occasion becomes an important feature for tailoring recommendations.

To maximize metabolic adaptations, the protein recommendation for athletes is 1.4–2.0 g/kg/day, an amount considered sufficient for increasing and maintaining muscle mass through a positive protein balance (Jäger et al., 2017). To guarantee the pool of blood amino acids and optimize the effects of protein in the sports context, protein intake should be distributed between 4 and 5 meals/day (Areta et al., 2013). The response of muscle protein synthesis, during a period of 12 h after exercise, seems to be maximized when four doses of 20 g of high biological value protein are ingested every 3 h after exercise (Areta et al., 2013; Churchward-Venne et al., 2013; Jäger et al., 2017). Another more precise way of expressing this recommendation is to make it relative to the athlete's body mass, that is, from 0.25 to 0.3 g/kg of the athlete's weight (Mujika et al., 2014; Shaw et al., 2014). Recent studies have also investigated pre-sleep protein intake, which comprises the period up to 2 h before sleep. Protein intake in this period seems advantageous for protein synthesis (Holwerda et al., 2016; Kinsey and Ormsbee, 2015; Kouw et al., 2017; Res et al., 2012; Trommelen and Loon, 2016).

Considering that vegetable and animal proteins differ in their content of essential amino acids (Gorissen et al., 2018; Holt and Snyderman, 1965), studies that evaluated the acute anabolic response to exercise showed lower values in response to vegetable protein intake compared to animal protein intake (Burd et al., 2012; Gorissen et al., 2016; Wilkinson et al., 2013). However, when evaluating data related to performance, there is no consistent difference when animal and vegetable protein supplementation are ingested after a training session (Pohl et al., 2021; Tang et al., 2009).

Studies that have investigated the protein intake of competitive swimming athletes of younger ages, showed the inadequacy of protein intake (de Mello et al., 2015; Soares et al., 1994). When it comes to master swimmers, there is a lack of evidence regarding the investigation of protein intake. Since swimming is one of the sports most practiced by master athletes (Ferreira et al., 2016), more attention should be given to the study of protein intake, for its important role in the exercise-induced adaptations of muscle mass. Health and sports professionals should encompass a broader analysis of protein intake, with data related to optimal protein utilization. In master athletes, this analysis can aid the prevention of aging-related muscle mass loss and improve muscle-mass recovery. Therefore, this study aimed to analyze the timing, quantity, and source of dietary protein in competitive master athletes and compare it to current recommendations.

Methods

Study design and participants

This was a cross-sectional study of master swimmers. The athletes were recruited from four different sports centers in Porto Alegre, a city in southern Brazil. It was a convenience sample invited through social media (Facebook and Instagram), personal contact, or by the swimming teams' coaches. To be included athletes should be engaged in swim training at least 3 times/week, at a minimum of 2000 m/day (per training), be male, and be aged 25–65 years old. Other inclusion criteria were regular swim training for the past 2 years and participation in official swim competitions in the previous year.

We estimated a required sample size of 17 participants, with the following assumptive parameters, using G*Power version 3.1.9.7 (Düsseldorf fundinty, Düsseldorf, Germany): F test for repeated measures ANOVA (for the comparison of intake between moments of the day), sample size means the estimated effect of 0.25, alpha value of 0.05, the statistical power of 0.80, one group, seven measures, the correlation between measures of 0.5. Since the final sample had 21 participants, we calculated the statistical power a posteriori, resulting in a statistical power of 0.90.

All swimmers provided their written informed consent before their enrollment in the study, after receiving all the information about the survey. The study was conducted following the Declaration of Helsinki, and approved by the local ethics committee (n. 2.180.001).

Data collection

Data collection on protein intake occurred during a whole week of swim training. Participants were instructed to maintain their eating habits throughout the study period. They recorded the amount of all foods and supplements consumed along with the training record for the same period (1 week). The main outcome was protein intake: total daily intake, intake per meal throughout the day, post-training intake, pre-sleep intake, and source of protein intake (animal or vegetable). To enable the analyses of protein intake relative to body mass, weight (kg) was measured using a digital scale (G-Tech Glass 200®, China). For the characterization of the body composition of the master swimmers, body fat (%) and lean mass (%) were evaluated

using dual-energy X-ray absorptiometry (DXA) (Hologic Discovery W, EUA). Participants were instructed to avoid moderate to high-intensity exercise (24 h), to refrain from alcohol consumption (72 h), caffeine (24 h), or any medication containing calcium (24 h) before tests. Participants were required to have a period of fasting (≥ 4 h) before the DXA assessment. Height was measured using a portable stadiometer (Cescorf®, Brazil). All measurements were performed by qualified and trained professionals.

Nutritional intake (all foods, supplements, and beverages) was assessed on seven-consecutive-day food record (Monday to Sunday) through the Dietbox® smartphone app (Dietbox Informática Ltda, RS, Brazil) after detailed guidance on how to record portion sizes. The records were synchronized with the database daily and all notes were checked; in case of doubts or missing information, the athlete was contacted for clarification. Meals and snacks were described with quantities in household measures, times, and, if possible, the brand of the food product. The mean daily intake of energy and macronutrients over the seven days was calculated in the same app software. Protein intake was expressed in grams (g) and relative to body mass (g/kg) or meal (g/meal). Protein intake was compared to current sports nutrition recommendations as follows: total daily protein intake (1.4–2.0 g/kg/d) (Jäger et al., 2017); distribution of protein intake in each meal throughout the day (20–25 g/meal) (Areta et al., 2013; Jäger et al., 2017); post-exercise (i.e. after swimming sessions) protein intake (≤ 3 h post-training; 0.25–0.30 g/kg) (Mujika et al., 2014; Shaw et al., 2014); and pre-sleep protein intake (up to 2 h before sleep; 30–40 g) (Holwerda et al., 2016; Trommelen and Loon, 2016). Additionally, animal and vegetal protein sources, and protein supplements were identified (g/d; g/meal).

For the analysis of protein intake at each meal, meals eaten at an interval of < 2 h were grouped. For example, if the participant had breakfast at 6 a.m. and ate an apple at 8 a.m., both meals were analyzed as breakfast; however, if the apple was eaten at 10 a.m., it was analyzed as a snack.

Statistical analysis

Statistical analyses were performed using SPSS software (IBM SPSS Statistics 25.0; Chicago, IL, USA). The normal distribution was checked by using the Shapiro-Wilk test, and results are presented as mean ± standard deviation (SD). Generalized estimating equations (GEEs) were used to evaluate protein differences when comparing protein intake at each meal, with Bonferroni post-hoc to identify between which meal the differences were. One sample *t*-test was used to compare ingested protein to recommended values (current sports nutrition recommendations). Both analyses were not applied to meals with $n < 5$ participants. The effect size was identified using statistic eta squared (η^2) (Richardson, 2011), and criteria of classification according to Cohen where 0–0.13 small, 0.14–0.26 moderate, and > 0.26 large. Statistical significance was set to a level of $p \leq 0.05$.

Table 1. Anthropometric characteristics of male master swimmers (n = 21).

Characteristics	Mean ± SD
Weight (kg)	79.2 ± 6.5
Height (cm)	179.1 ± 5.5
Body fat (%)	23.5 ± 4.9
Lean mass (%)	73.3 ± 4.2

SD: standard deviation.

Results

Twenty-one male master swimmers with a mean age of 47.9 ± 10.0 years were included in the study. More than half (54%, n = 12) of the swimmers were engaged in complementary exercise (e.g. running, strength, cycling, and tennis). Table 1 presents the anthropometric characteristics of the participants.

Data regarding energy and protein intake are presented in Table 2. Daily protein intake of the master swimmers, relative to body mass, was within the recommended values of 1.4 and 2.0 g/kg/day ($p = 0.01$ and 0.147, respectively). Regarding the protein sources ingested by the master swimmers, ~ 65.7% were animal sources, 29.2% were vegetable sources, and 5.1% were derived from protein food supplements (exclusively whey protein). It is important to emphasize that only eight of the 21 swimmers (38%) consumed supplements.

Figure 1 illustrates post-training, pre-sleep, and daily protein intakes (gray lines indicate the reference values). Most of the master swimmers' post-training protein intake

Table 2. Energy and protein intake of male master swimmers (n = 21).

	n	Mean[a] ± SD
TEI (kcal/day)	21	2712.9 ± 427.6
Protein (g/day)	21	146.2 ± 40.4
Protein (g/kg/day)	21	1.9 ± 0.5
Protein (%TEI)	21	21.5 ± 4.6
Animal protein (g/day)	21	100.9 ± 6.2
Plant protein (g/day)	21	42.1 ± 2.3
Protein supplement (g/day)	8	24.0 ± 11.0
Post-exercise protein (g/kg)[b]	19	0.60 ± 0.25
Pre-sleep protein (g)[c]	18	33.5 ± 23.9

SD: standard deviation; TEI: total energy intake.
[a]Mean intake was calculated based on the average of the 7 days registered on food records.
[b]Data from post-exercise protein was the mean intake only of swimming days.
[c]Pre-sleep protein included meals with an interval between <30 min before sleep to 2 h after dinner (it could have been dinner or supper, depending on the swimmer and depending on the day of the week).

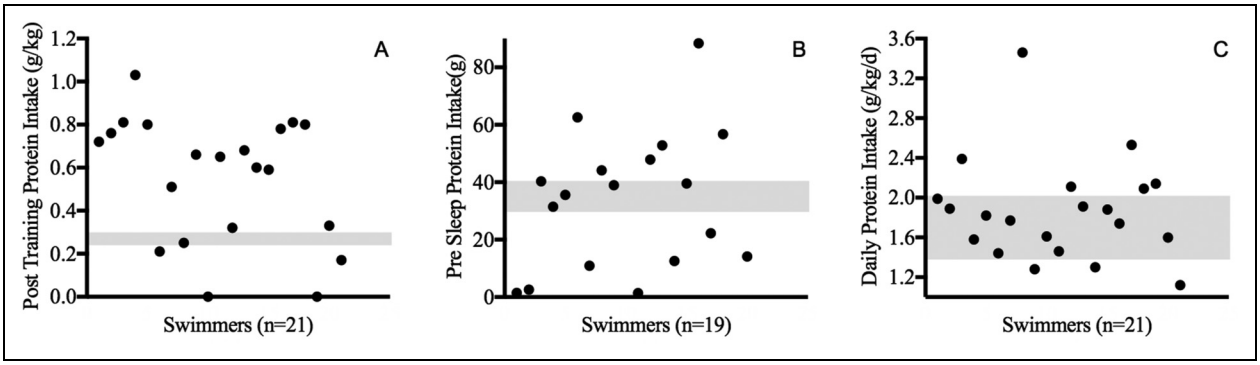


Figure 1. Post-training, pre-sleep, and daily protein intakes of male master swimmers (gray lines indicate the reference values).

was above the recommendation of 0.25–0.30 g/kg. Protein intake at the pre-sleep period showed great variability among athletes. However, the mean protein intake value of 33.5 ± 23.9 g was within the recommendation of 30–40 g of protein intake at this period ($p = 0.28$ and 0.147, respectively). At the pre-sleep period, 66.7% of swimmers met the recommendation or ate above the recommended amount of protein intake.

Table 3 shows the protein intake at meals throughout the day. The total daily protein intake of the master swimmers was concentrated on main meals, such as lunch (28.5% of TEI) and dinner (20.5% of TEI), followed by breakfast (8.8% of TEI). The amount of protein intake was significantly different between these meals, showing that the type of meal has a great effect size on protein intake (Table 3).

Table 4 describes the sources of protein intake (how much of the total protein ingested at each meal came from animal, vegetable, and protein supplements). Regarding the type of protein ingested at lunch and dinner, 80.9% and 80.6%, were of animal source, respectively. This demonstrates a higher prevalence of protein intake, predominantly from animal sources, in large meals. Protein intake in small meals (snacks and supper) was lower than the recommendation for the distribution of protein intake throughout the day ($p < 0.05$). The amount of protein ingested at breakfast differs from all other meals since protein consumption at snack 1, snack 2, and supper were similar (Table 3).

Discussion

The present study aimed to identify the protein intake of master swimmers. The results showed adequate total daily protein intake, mainly from animal protein sources. Nevertheless, protein intake was concentrated in the main meals (lunch and dinner). Athletes presented a post-training intake well above the recommendation. The protein intake during the pre-sleep period, despite presenting well-dispersed values among athletes, was within the protein intake recommendation. It is well established in the literature the importance of adequate protein intake throughout the day to maximize muscle protein synthesis. Our approach to analyzing the "timing" of protein intake of master swimmers signals the need to take this aspect into account in Sports Nutrition practice.

Besides total daily intake, guidelines for athletes recommend a protein intake of 20–25 g or 0.25–0.3 g/kg at the main meals (lunch and dinner) as well as at intermediate ones (snacks) (Areta et al., 2013; Jäger et al., 2017; Thomas et al., 2016). These recommendations are also applied to swimmers (Pyne and Sharp, 2014; Shaw et al., 2014; Tipton et al., 1996). In our study, the distribution of protein intake throughout the day was not homogeneous among master swimmers. Although swimming is an endurance sport, the training session causes muscle signaling, which evokes the need for recovery. The athletes showed great concentration of protein intake at lunch and dinner, in which the protein intake was higher than the recommendation. In smaller meals, except for breakfast, the average protein intake was below the recommendations. That is, the athletes in this study may not be maximizing protein synthesis as efficiently as they could with adequate protein intake at each meal throughout the day. Some reasons for that might include the lack of knowledge of the athletes about food combinations to provide elevated protein intake in smaller meals; the possible sources of protein intake that could be practical for a snack, if they are away from home, and other aspects related to food access and information. Again, another topic that should be oriented by the Sports Nutrition professional.

It was demonstrated in the present study that, on average, the post-training protein intake was higher than the recommendation of 0.3 g/kg of weight, that is, the swimmers ingested approximately twice the recommended amount. It should be noted that many of the post-training meals were included in the main meals (lunch or dinner) and these had higher protein consumption than the snacks. It is known that excessive consumption of protein in a single meal does not bring additional benefits and that fractionation is more effective in promoting protein synthesis (Churchward-Venne et al., 2020). However, Doering et al. (2016) demonstrated a different muscle anabolic response in master triathletes (53 years old) compared

Table 3. Distribution and comparison of total protein intake at each meal throughout the day, of male master swimmers (average of 7 days, presented as mean ± SD).

	Breakfast ($n = 20$)	Morning Snack ($n = 9$)	Lunch ($n = 21$)	Afternoon Snack 1 ($n = 12$)	Afternoon Snack 2 ($n = 5$)	Dinner ($n = 21$)	Supper ($n = 13$)	p	η^2
Protein intake (g)	19.7 ± 10.4^a	8.3 ± 11.8^b	65.0 ± 17.3^c	7.2 ± 4.8^b	7.8 ± 5.8^b	46.2 ± 11.7^d	7.5 ± 5.8^b	<0.001	0.53

TEI: total energy intake; SD: standard deviation; n: number of athletes who had the meal.
Generalized estimating equations (GEEs) were applied to identify differences between meals. Different letters (a, b, c, and d) indicate the difference between meals ($p < 0.001$). When the letters are the same, it indicates that there is no difference between these meals. The effect size was identified using statistic eta squared (η^2) and the classification was large (> 0.26).

Table 4. Descriptive data of protein intake sources, at each meal throughout the day, of male master swimmers (average of 7 days, presented as mean ± SD).

	Animal protein		Supplement		Vegetable protein	
Meal	g/day	(%TPI)	g/day	(%TPI)	g/day	(%TPI)
Breakfast ($n = 20$)	8.3 ± 6.4	40.1	4.2 ± 9.0	20.0	8.6 ± 5.1	41.7
Morning snack ($n = 9$)	1.4 ± 2.5	23.0	3.2 ± 2.2	49.0	1.9 ± 4.5	29.7
Lunch ($n = 21$)	54.0 ± 21.3	80.9	0.0 ± 0.0	0.0	13.5 ± 7.1	20.2
Afternoon snack 1 ($n = 12$)	3.5 ± 4.6	45,4	0.6 ± 2.0	8.0	3.5 ± 1.8	45.2
Afternoon snack 2 ($n = 5$)	3.2 ± 4.8	39.7	0.6 ± 2.0	7.6	4.7 ± 2.9	58.1
Dinner ($n = 21$)	38.6 ± 14.0	80.6	3.0 ± 6.4	6.3	9.2 ± 4.4	19.1
Supper ($n = 13$)	2.6 ± 3.5	34.0	1.8 ± 6.7	23.6	3.0 ± 3.4	39.7

TPI: total protein intake; *n*: number of athletes who had the meal; SD: standard deviation.

to younger ones (27 years old), with lower rates of muscle protein synthesis, resulting in a slower recovery in master athletes compared to younger triathletes (Doering et al., 2016). The triathletes consumed 20 g of whey protein immediately after training, followed by a diet containing ~1.6 g/kg/day of protein (0.3 g/kg/meal) (Doering et al., 2016). Considering these findings, it may be positive for master athletes to have a higher protein intake than the current recommendations for athletes, after a training session (Doering et al., 2016; Yang et al., 2012).

In our study, we analyzed the protein intake of the master swimmers during the pre-sleep moment (Kinsey and Ormsbee, 2015; Trommelen and Loon, 2016). It is worth noting, however, that the literature is controversial regarding the benefits of ingesting protein before bedtime. Studies have shown that ingesting pre-sleep protein did not further improve muscle damage biomarkers on the next morning or maximal strength performance in trained men compared to a non-caloric placebo (Ormsbee et al., 2022), and that protein supplementation after exercise and before sleep did not further increase skeletal muscle mass or strength gains during resistance training in active older men (Holwerda et al., 2018). A systematic review evaluated the acute effects of pre-sleep protein consumption on overnight muscle protein synthesis and the chronic effects on muscle mass and strength. They concluded that 20–40 g of casein, ~ 30 min before bedtime, improves the synthetic protein response during the overnight recovery period in healthy young adult men, with possible positive effects on muscle mass and strength after prolonged resistance exercise (Ferreira et al., 2016). Although the existing evidence comes from studies with resistance training, and swimming is an endurance sport, our results showed that the master swimmers presented a mean pre-sleep protein intake within the recommendation. From the available evidence, it is plausible to assume that meeting the recommendation of protein intake at this moment would be beneficial for master athletes' muscle mass synthesis and recovery. Nonetheless, the lack of evidence in master swimmer athletes regarding protein intake and muscle mass responses warrants further studies.

The International Society of Sports Nutrition Position Stand: Protein and Exercise recommends that protein intake with adequate levels of leucine and branched-chain amino acids be prioritized, as higher doses of leucine have been shown to independently stimulate increases in protein synthesis. Products containing animal and dairy proteins contain the highest percentage of branched-chain amino acids (Jäger et al., 2017). Some acute anabolic response studies have shown that animal protein intake elicits greater responses to muscle protein synthesis than plant-based protein intake (Phillips et al., 2009; Wilkinson et al., 2013). However, Hevia-Larraín et al. (2021) demonstrated that, in the chronic adaptive response, a diet with exclusively vegetable proteins is no different from a mixed vegetable and animal protein diet, concerning

muscle strength and lean mass accumulation (Hevia-Larraín et al., 2021). From this perspective, we also evaluated the sources of protein intake of master swimmers. Their protein intake was most from animal sources, which reflects the cultural habits of the region studied (with a traditionally high consumption of meat) and the composition of the supplements used (whey protein).

This study has some limitations. First, the protein intake was assessed through food records, a tool that is subject to the participant's reporting, requires more engagement from the participants, and might alter one's consumption. Nevertheless, the participants were well instructed about the proper way to fill in the records, and daily checks were made by the research team to guarantee the full details on the foods and beverages consumed and also to motivate participants to keep filling in their records. The use of pictures attached to the records was a methodological approach to increase the accuracy of the information recorded. On the other hand, it was a strength of this study to have applied a 7-day food record, which accounts for daily variations in intake during weekdays and weekends and characterizes one's habitual intake. Another limitation might concern the sample size, these results may not be generalizable to all swimmers. Moreover, studies with master athletes typically do not present large samples (Doering et al., 2016, 2017).

Our study sheds light on the importance of a comprehensive analysis of the protein intake of master athletes. In conclusion, the studied male master swimmers ingested protein from predominantly animal sources, in an adequate total amount, but with inadequate fractionation, concentrated in large meals (lunch and dinner). In addition, pre-sleep intake, although variable among athletes, remained in line with recommendations. Moreover, after the training session, the intake reached almost twice the recommendation for adults, however, master-category athletes, perhaps, have a greater need for post-training protein intake. These results open the door to studies with a more detailed analysis of protein intake regarding not only total intake but also the timing of the protein being ingested to maximize its effects on muscle mass recovery and synthesis. These results are relevant for sports nutrition practice, as the timing of protein ingestion should also be observed, especially in master athletes.

Authors' note

The corresponding author on behalf of any co-authors states that the article is original, has not been submitted for publication in other journals, and has not yet been published either wholly or in part. They state that they are responsible for the research that they have designed and carried out; that they have participated in drafting and revising the manuscript submitted, whose contents they approve.

Authors' contributions

CDZT, FSC, MSS, CB, and CDS: conceptualization; CDZT and MSS: data curation; CDZT and MSS: formal analysis; CDZT and MSS: investigation; CZDT, FSC, CDS, MSS, and CB: methodology; FSC and CDS: project administration; FSC and CDZT: resources; MSS, CDZT, CDS, and CB: writing–original draft preparation; CB, CDS, FSC, CDZT, and MSS: writing–review and editing; CDS, FSC, and CB: supervision; CDZT and FSC: funding acquisition. All authors have read and agreed to the published version of the article.

Availability of data and materials

Research data will be available upon email request to the corresponding author or by accessing the following link: https://drive.google.com/drive/folders/1GBVJimV8Wsq1UfRgzNa2ITYqFnW0m8kK?usp=sharing.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical statement

All swimmers provided their written informed consent prior to their enrollment in the study, after receiving all the information about the survey. The study was conducted in accordance with the Declaration of Helsinki, and approved by the local ethic committee of Universidade Federal do Rio Grande do Sul (n. 2.180.001).

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