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Review Article

STRENGTH MEASUREMENTS AND ASSESSMENT: A LATIN AMERICAN REVIEW ON SWIMMING ATHLETES

MEDIDAS E AVALIAÇÃO DA FORÇA: UMA REVISÃO LATINO-AMERICANA EM ATLETAS DE NATAÇÃO

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RESUMO
O objetivo foi analisar como ocorre a mensuração da força e sua utilização em estudos de revistas latino-americanas com atletas de natação através de uma revisão. A revisão seguiu os princípios do PRISMA, realizando a pesquisa nas bases de dados *Scielo* e *Lilacs*, adotando como critérios de inclusão: a) estudos com amostras de atletas de natação; b) Estudos que envolveram alguma avaliação de força em atletas. Um total de 87 artigos foram encontrados, onde 23 permaneceram para análise completa por atenderem todos os critérios. Para análise de dados foi utilizado metassumarização e análise de conteúdo. Os resultados indicaram que o principal instrumento de medida para avaliar a força foi o dinamômetro (isocinético, isométrico, portátil). Dois grupos principais de temáticas envolvidas nos estudos foram identificados, sendo estes, a análise da força para um melhor desempenho e a análise do desequilíbrio da força muscular, especialmente no ombro. O método de intervenção foi pouco utilizado, demonstrando que o uso do *parachute* durante o treino e o treinamento de força fora da piscina sob uma periodização ondulatória são eficazes no desempenho dos atletas. Conclui-se que o principal método de avaliação da força na natação é com o uso do dinamômetro, os nadadores apresentam um ombro com desequilíbrio muscular e poucas são as propostas de intervenção para a melhora da força muscular em atletas de natação.
Palavras-chave: Força. Natação. Avaliação.

ABSTRACT
This study aimed to analyze how strength is measurement and its use occurs in studies of Latin American magazines with swimming athletes. The review followed PRISMA principles, carrying out the research in Scielo and Lilacs databases, adopting as inclusion criteria: a) studies with swimming athletes samples; b) studies that involved some evaluation of strength in athletes. A total of 87 articles were found, where 23 remained for complete analysis for suit all the criteria. Data analysis will be performed by metassumarization and content analysis. The results indicated the main measuring instrument to evaluate the strength was the dynamometer (isokinetic, isometric, and portable). Two main groups of subjects involved in the studies were identified, being these, the analysis of the strength for a better performance, and the analysis of imbalance muscular strength, especially in the shoulder. The intervention method was little used, demonstrating that the use of parachute during training and strength training outside the pool under an undulatory periodization are both effective in the athlete's performance. It is concluded that the main method of strength assessment in swimming is with the use of dynamometer, swimmers have a shoulder with muscular imbalance and there are few proposals for intervention to improve muscular strength in swimming athletes.
Keywords: Strength. Swimming. Evaluation.

Introduction

Muscle strength is one of the most important variables for achieving good results in sports[1]. Beyond technique, tactics and strategy, the athlete's body needs to be physically prepared to deal with the sporting demands, having specific components being developed accordingly[2]. Muscular strength comprises one of such components, being manifested in three different ways[3]. Thus, assessing strength in its different forms is crucial for visualizing the training progress and efficacy, classifying and tracing goals for new training programs for athletes.

Swimming is a sport where strength is essential, since a hundredth of a second can determine the winners of an event[4]. In this sense, strength testing for swimming athletes can greatly contribute towards their training and development, since potency, maximum strength and resistance are crucial to any swimming competition[5].

A series of measurement mechanisms have been developed to quantify such strength-related variables. Both direct and indirect tests were created to aid coaches, athletes and researchers in the assessment of one's strength under any quality standards[6]. Direct tests are performed with specific equipment, such as isokinetic dynamometers (ID), which quantify strength with great reliability. Indirect tests are performed without the need of specific equipment, through the use of estimation equations which were developed from a series of studies that aimed to provide more viable and accessible forms of measuring strength[3]. Choosing one or other method of strength testing should depend on its viability, adopting a method that more closely resembles the actual motor gesture being performed in the sport itself, as a way to better contribute towards its transferring to sports performance. Therefore, the precept of meeting the high specificity of each sport should be taken in consideration for physical assessments as well as the training process[7].

Several studies have systematically assessed the efficacy of strength testing methods for physical-performance exercise prescription in athletes' training programs. This is no different for swimming, with multiple review studies verifying different methods of testing and intervention for its specific performance enhancement[8-11]. However, these studies have paid little to no attention to Latin American journals, leaving behind a great amount of evidence and an important literature gap to be addressed. In this sense, the present study sought to analyze how strength is tested and applied in Latin-American studies of swimming athletes.

Methods

Research design

This study has performed a bibliographic review of literature in accordance to PRISMA recommendations (Preferred Reporting Items for Systematic Review and Meta-Analyses - PRISMA)[12].

Procedures

Eligibility criteria

The inclusion criteria for studies were: a) having a sample of swimming athletes; b) having any sort of strength testing involved. Then, the following exclusion criteria were defined: I) studies published in languages other than English, Spanish or Portuguese; II) literature reviews, opinion papers or editor letters; III) being published in a journal that is not peer-reviewed.

Data bases

Online searching was conducted in the two major Latin American databases, namely *Scielo* and *Lilacs*, covering the time period from the database's creation to August of 2019. These databases were selected due to its high representativity of South and Central American journals, and no language or time limits were adopted for the initial search.

Searches

Searching strategies comprised the following terms: *Strength*, *Strength Parameters, Muscular Strength*, *Strength Test, Swim, Swimmer* and *Swimming*. The Boolean operators *AND/OR* were used to compose the searching strategies.

Study selection

The titles and abstracts of the resulting records were analyzed independently by the authors, selecting studies for full-text analysis of eligibility. Records with not enough information in either its title or abstract to determine its eligibility were also kept for full-text analysis.

Data extraction

The selected studies had their data extracted by the authors. General information was collected, such as sample size, adopted methods, measurement instruments, intervention program (when present) and data analysis methods. Furthermore, variables being associated to swimmers' strength and the direction of its relationship were also recorded as primary outcomes.

Data analysis

Data was analyzed through metassummary, an approach oriented towards quantitatively aggregating and summarizing the results of both quantitative and qualitive research[13]. After extracting and grouping the relevant findings of the included studies, content analysis was performed to create first-order themes that were representative of the main outcomes.

Results

Preliminary results identified 87 records to be analyzed. Fifty of these records were excluded after title and abstract analysis, 10 of the remaining 37 records were also excluded for being duplicates, resulting in a total of 27 studies being included for full-text analysis. In this next phase, 04 studies were excluded for not meeting the inclusion criteria, resulting in the inclusion of 23 papers for final analysis and data extraction (Figure 1).

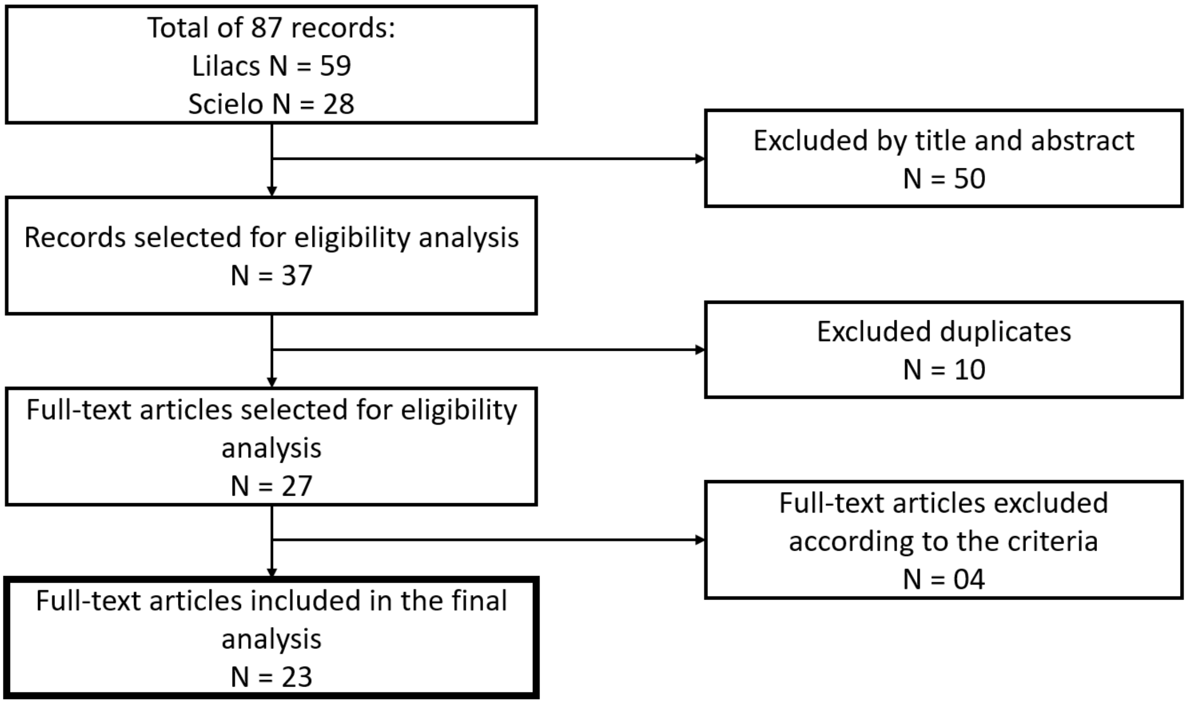

Figure 1. Flow diagram of studies' preliminary selection
Source: Authors

The total sample size summing of all studies was 577, with each study's sample size varying between 9 and 120 (Table 1). Regarding the samples' characteristics, subjects could be grouped in a variety of categories, such as: elite athletes, state and national athletes, federated athletes, college athletes, non-competitive athletes and sedentary participants. Moreover, seven studies did not present the swimmers' competitive level, only informing that they were taking part in competitions.

In regards to biological sex, nine studies had both male and female participants, nine studies were performed with an exclusively male sample, while only one study was focused on female athletes, still, there were four papers that did not present the information on participants' sex (Table 1). Looking into the average age of these samples, seven studies had a sample of under-18 athletes, thirteen studies were performed with adult samples, aging 18 and further, while three studies did not present an average age of their samples, only its range.

Table 1. Research design and sample characteristics of strength assessment studies in swimmers

	Sample size and age	Procedures	Sex	Competitive level	Intervention	Assessment method
Andrade et al.[14]	N = 16 (18.6 ± 1.3 years)	Indirect strength tests, load cell and 10' swim test	Males	National	No	Impulse generation during the front crawl stroke
Souza, Gomes, Loss[15]	N = 10 (21.3 ± 6 years)	Load cells, vídeo	Males and females	Not disclosed	No	Propulsive strength while tied
Candeia et al.[16]	N = 52 (14.0 ± 1.7 years)	Portable dynamometer (DD-300, Instrutherm)	Males and females	National	No	Medial and lateral shoulder rotation strength
Correia et al.[17]	N = 9 (23.11 ± 4.2 years)	Strength transductor, videogametry	Males	College	No	Knee extension strength and turn performance
Meliscki et al.[18]	N = 15 (20 ± 2 years)	Isometric dynamometer Globus Ergo System®	Males	Elite/national	No	Internal and external shoulder rotator muscle
Pires et al.[19]	N = 17 (15.18 ± 2.31 years)	Stroke frequency, length, average speed and index	Males and females	Not disclosed	Yes 14 weeks	Positive effect of strength training with linear (long-distance) and non-linear (short-distance) periodization
Fortes et al.[20]	N = 10 (18.7 ± 1.6 years)	10-MR test (*Leg press* 45º, front lat pulldowns, squats and bench press)	Females	National	No	Strength in different phases of the menstrual cycle
Secchi, Brech, Greve[21]	N = 81 (17 to 33 years)*	Isokinetic dynamometer Biodex®	Males and females	Competitive, non-competitive and sedentary	No	Internal and external shoulder rotator muscle
Pereira et al.[22]	N = 14 (18.4 ± 4.9 years)	Pressure sensors of the Aquanex system	Males and females	Not disclosed	No	Symmetry of Upper limbs' strength during the butterfly style
Batalha et al.[23]	N = 60 swimmers (14.55 ± 0.5 years) N = 60 non-swimmers (14.62 ± 0.49 years)	Isokinetic dynamometer Biodex System 3	Males	Competitive and non-competitive	No	Internal and external shoulder rotator muscle

Table 1 continued...

	Sample size and age	Procedures	Sex	Competitive level	Intervention	Assessment method
Barbosa et al.[24]	N = 16 (20.4 ± 4.0 years)	Load cell "Strain Gage"	Males	National	No	Biomechanical parameters of the strength-time curve
Detanico et al.[25]	N = 10 (26.4 ± 6.6 years)	Camera (30Hz) and "Squat Jump" Kistler®	Males	State	No	Angles during diving and variables associated to vertical jump
Silveira et al.[26]	N = 11 (16 ± 3 years)	Strength plataform (peak strength and contact duration)	Males and females	Not disclosed	No	Standardization for the turn distance analysis of performance in swimming
Bocalini et al.[27]	N = 20 (24 ± 2 years)	Explosive strength of lower-body muscles, speed, strength and timing of swimming	Males	Federate athletes	Yes 12 weeks	Positive effects of parachute training over muscle strength and 50m test
Castro et al.[28]	N = 12 (18.3 ± 2.9 years)	Load cell, chronometer	-	National	No	Relate the 200m freestyle performance with stationary swimming kinetic variables
Secchi et al.[29]	N = 14 (symmetric 21.3±5.5 years; asymmetric 20.5±3 years)	Isokinetic dynamometer Cybex 6000	-	Elite	No	Trunk traction strength
Pessôa Filho[30]	N = 11 (15.45 ± 1.75 years)	Video	-	Not disclosed	No	Mechanical and metabolic parameters of performance in max-intensity freestyle swimming
Barbosa, Moraes, Andries Jr.[31]	N = 16 (21.93 ± 2.17 years)	Indirect strength tests and 10' swim test	-	Not disclosed	Yes 12 weeks	Null effect of strength training outside the pool over swimming performance
Barbosa, Andries Jr.[32]	N = 16 (21.93 ± 2.17 years)	Tests: 25m & 50 m; and 1-MR and 70% of 1-MR in 30"	Males	College	Yes 10 weeks	Null effect of strength training outside the pool over swimming performance
Schneider, Henkin, Meyer[33]	N = 26 (13.0 ± 0.8 years)	Isokinetic dynamometer (Cybex Norm)	Males and females	Not disclosed	No	Analyze isokinetic concentric strength of external and internal shoulder rotators
Papoti et al.[34]	N = 14 (15 to 18 years)*	Y-intercept and tests in the pool	Males and females	State and national	No	Y-intercept use in anaerobic capacity testing and performance prediction

Table 1 continued...

	Sample size and age	Procedures	Sex	Competitive level	Intervention	Assessment method
Schneider, Meyer[35]	N = 48 (9 to 13 years)*	Isokinetic dynamometer (Cybex Norm)	Males and females	Competitive	No	Anthropometry and isokinetic assessment of knee extension and elbow flexion
Marinho, Andries Jr.[36]	N = 19 (14.5 ± 1.12 years)	Strength dynamometer for forearm and 25m maximum tests	Males	National	No	Relationship between isometric strength and maximum speed swimming performance

Note: * Age mean and standard deviation were not available in the original manuscript.
Source: The authors

Out of the 23 analyzed studies, only four had proposed an intervention method to improve strength and performance results for swimming, which adopted the parachute method during training[27], and strength training outside of the swimming pool to improve swimming performance[19,27,31,32]. The remaining 19 studies had a cross-sectional design and have assessed subjects' strength, anthropometry and performance, as presented in Table 1.

The results in Table 1 also show that only two studies[21,23] compared the strength of swimmers and non-athletes, which indicated that swimmers had greater strength of shoulder internal rotators and higher imbalance related to the external shoulder rotators when compared to non-athletes. Taking a look at the studies' procedures it was possible to identify that the main assessment tool was the dynamometer (isokinetic, isometric or portable), being used in 08 of the 23 studies.

Through content analysis, two objects of study were identified: 1) strength testing for performance and 2) testing of strength balance. The first group comprised 16 studies of performance-related strength, having an intervention method present in four of these works. For these four interventions, Pires et al.[19] found that a strength training intervention with a non-liner/undulated periodization improved swimming performance for short-distances, while a linear periodization favored long-distances. Bocalini et al.[27] used the parachute as a strength training tool for swimmers and found improvements for the athletes' strength and 50-meter performance. Barbosa et al.[31] and Barbosa & Andries Júnior[32] found that adopted land strength-training method was not effective for improving aerobic performance while swimming.

The remaining 12 studies have tested muscle strength in relation different factors. Strength was related to a better impulse, leading to better performance: Andrade et al.[14] observed that kinetic parameters (e.g., maximum strength, average strength, strength development rate) were better associated to an improved impulse for crawl swimming; total impulse in stationary swimming was positively correlated to the 200m performance[28]; muscular and propulsion potency were correlated to maximum performance, while mechanical efficacy becomes essential when there are swimming restrictions (dragging strength)[30]. Strength was also tested in regards to stationary (steel cable) and semi-stationary swimming (elastic tube), evidencing that both conditions contributed to strength improvements in its specificities[15] and that strength and biomechanical patterns were reproducible between tied swimming and short-duration protocols[23].

Both time and strength of the turning movement were assessed in two studies, which verified that the athletes' capacity to produce maximum strength in a knee and hip extension angle of 116º can greatly contribute to a better turning performance[17], and athletes' strength increases can reduce the time to complete a turn[26]. Other aspects of strength and swimming performance were also investigated: preliminary evidence found that different phases of the menstrual cycle can slightly modify the production of muscle strength and perceived rating of exertion, with declines in strength during the follicular phase[20]; muscle strength did not interfere in the diving performance[25]; pubescent athletes presented higher strength compared to pre-pubescent ones[35]; the y-intercept was not a good parameter for predicting performance and anaerobic capacity[34]; and the measurement of isometric strength was not a good parameter for estimating performance in swimming[36].

The second group of studies aimed to test strength and its balances and imbalances. The majority of these studies have tested the shoulders' internal and external rotator muscles as well as shoulder adductors[16,18,21,23,33], while only Secchi et al.[29] tested trunk traction strength. For the shoulder muscles: Candeia et al.[16] observed that medial rotator muscles were stronger than the lateral ones, but there is a balance between the dominant and non-dominant member in regards to the strength and amplitude of these muscles' movements in the study sample; Meliscki et al.[18] found that right rotator muscles were stronger than the left ones, and internal rotators were stronger in both arms; Batalha et al.[23] found a greater capacity to generate strength in the internal rotators, with a higher imbalance between internal and external portions for athletes compared to sedentary subjects; Schneider, Henkin and Meyer[33] observed that the imbalance between internal and external rotators was higher in the non-dominant member of these athletes, with an even more evident difference for females; Secchi, Brech and Greve[21] found no strength differences in shoulders' adductor and internal rotator muscles between athletes of an asymmetric style (freestyle and backstroke) and those who compete in symmetric-styles (breaststroke and butterfly).

Secchi et al.[29] compared the strength of symmetric and asymmetric style swimmers in their trunk traction, finding that asymmetric-swimming athletes could better recruit trunk muscles, which could be due to the isometric contraction of the dorsal region during the swim. Lastly, Pereira et al.[22] found that propulsion strength and average and maximum strength in the hands of athletes during the butterfly swim is higher in the dominant hand.

Discussion

The present work reviewed Latin American databases with the goal of identifying possible relationships in strength testing for swimming athletes. A total of 23 studies met the eligibility criteria and were analyzed in its entirety. Our results revealed that the dynamometer was the most common method of strength testing. The main study themes were related to swimmers' muscular balance and strength testing for performance. The parachute was considered an efficient tool for strength and performance improvements, as well as a non-linear periodization.

The most predominant measurement instrument in these studies was the isokinetic dynamometer (ID) (Table 1). Considered as a gold-standard, the ID is an adjustable equipment for a diversity of movements. Programming the movement speed, the ID can identify the strength, torque, potency, contraction speed and resistance to fatigue of the target muscle group[37]. Thus, it is possible to find the use of ID in multiple contexts and sports. In the present review, shoulders' adductor and rotator muscles, legs and trunk muscles were the most tested.

The ID usage is especially important for high-performance athletes, who are subjected to high levels of physical exertion during training and competition, setting them at a higher risk for injuries[8]. In this sense, muscle imbalances testing is needed to evaluate and prescribe training for the athlete's specificity and weak points that the ID can identify.

The evaluation of muscular balance is deemed important for being an essential factor for high performance in swimming as well as other sports[38]. A strength-balanced body is better equipped to handle the sporting demands, while imbalances can contribute to technical disarrangements and athletes' performance. Besides, some muscular imbalances can increase the likelihood of injuries, which could also keep an athlete away from training/competing, consequentially leading to decreases in performance[39].

For swimming athletes, a shoulder injury can be very detrimental, due to its essential participation in this sport as the main generator of propulsive strength[8,39]. We also observed that despite this notion, there were still significant differences in strength production in swimmers' shoulder muscles. These differences were mostly related to internal and external rotators[23], medial and lateral[16], between-arms strength of these muscles[28] and dominant versus non-dominant arm[16,33]. This could reveal a lack of training balancing external and lateral shoulder rotators in the Latin American context of swimming. Even though these are not the main muscles used for swimming, it is of extreme importance to keep these muscles strong due to their support to the internal and medial rotators during swimming, which are one of the main cases of injury in swimmers[10].

The present study verified that there are few articles assessing intervention processes for strength improvement in swimming athletes. Only two studies were found to adopt this research design, one performing a training program using the parachute[27], a material tied to the hip in order to slow down the swimmer during its activity and the other performing a strength training outside the pool with an undulated periodization[19]. Both studies resulted in better performances, and these training programs were efficient for improving strength and 50m-freestyle performance.

It was also possible to verify that using a palmar along with the parachute is another possibility for strength and propulsion improvements[40]. Beyond its benefits for swimming, the parachute has also been proved to be beneficial for athletics and football performances, showing its important role in sports[41,42]. On the other hand, two other studies[31,32] that adopted a land strength training program did not find differences in athletes' performance, suggesting that different intervention methods must be used in order to improve performance.

Despite our contributions, some limitations were present and deserve to be highlighted. Firstly, our study has been limited towards reviewing only two scientific databases (Scielo and Lilacs), not analyzing the majority of publications at a global scale. However, such restriction was set in order to survey the specific context of Latin America, while other systematic reviews have already evaluated the overall international literature on strength testing in swimming[10,11]. Second, the present work has been limited to analyzing samples of competitive swimmers, excluding studies with only non-competitive swimming practitioners or other sports. Future studies should bring up these discussions even further, for a better comprehension and improvement of strength training for swimming athletes.

Conclusions

The present review verified through the analyzed studies that the main method for strength testing in swimmers is the dynamometer, there are few intervention propositions for strength training with swimmers and most of these athletes have presented muscular strength imbalances in their shoulders, which could be a risk factor for future injuries.

Future studies could use the present work as a reference for advancing the analysis of muscle strength in athletes, for example, by developing intervention programs aiming at solving muscular imbalances in the shoulders and other muscle groups. Our present work has also a practical implication towards the improvement of the overall knowledge in swimming, benefiting the work of coaches and their athletes.

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