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Original Article

RELAÇÃO ENTRE POTÊNCIA DOS MEMBROS INFERIORES, DISTÂNCIA DE VOO DO BLOCO E DESEMPENHO DE NADO EM DIFERENTES METRAGENS

RELATIONSHIP BETWEEN LOWER LIMB POWER, FLIGHT DISTANCE FROM THE BLOCK AND SWIMMING PERFORMANCE IN DIFFERENT DISTANCES

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RESUMO
O objetivo do estudo foi correlacionar a potência dos membros inferiores com a distância de voo do bloco e o desempenho do nado crawl em diferentes metragens (25, 50 e 100 metros). Os participantes foram atletas amadores de ambos os sexos, com idade entre 17 a 33 anos. Para avaliar a potência muscular dos membros inferiores foi utilizado o sargent jump test (impulsão vertical) e o long jump test (impulsão horizontal). Análise cinemática da saída do bloco foi realizada através do Kinovea 0.9.5. Coeficiente da correlação de Pearson com nível de significância em p<0,05 foi adotado. Os resultados entre potência de membros inferiores e a distância de voo foram de correlação positiva moderada para grupo feminino e alta para grupo masculino e geral (r= 0,50 a 0,83). Enquanto os resultados entre a potência de membros inferiores e o desempenho de nado nas distintas metragens foram de correlação inversa moderada entre a maioria das análises para grupo masculino (r= -0,40 a -0,54) e alta para grupo geral (r= -0,69 a -0,83). Os resultados indicam que o treinamento de potência dos membros inferiores deve ser priorizado aos nadadores velocistas, podendo contribuir para o seu rendimento esportivo.
Palavras-chave: Natação. Desempenho. Potência

ABSTRACT
The study aimed to correlate lower limb power with flight distance and crawl swimming performance over various lengths (25, 50, and 100 meters). The participants consisted of amateur athletes of both sexes, aged between 17 and 33 years. The Sargent jump test (vertical thrust) and the long jump test (horizontal thrust) were utilized to assess lower limb muscular power. Kinematic analysis of the block start was conducted using Kinovea 0.9.5. Pearson's correlation coefficient with a significance level of p<0.05 was employed. The results indicated a moderate positive correlation between lower limb power and flight distance for the female group and a high correlation for the male group and overall (r= 0.50 to 0.83). Additionally, the results showed a moderate inverse correlation between lower limb power and swimming performance across the different distances for the male group (r= -0.40 to -0.54) and a high correlation for the general group (r= -0.69 to -0.83). These findings suggest that lower limb power training should be prioritized for sprinter swimmers and may enhance their athletic performance.
Keywords: Swimming. Performance. Power.

Introduction

The analysis of sports performance has become a subject of intense study across various fields of knowledge. Understanding factors such as physiology and biomechanics is closely linked to athletic performance and is crucial for athletes, coaches, and researchers aiming to improve athletes' efficiency and outcomes [1,2].

Among the many sports disciplines, swimming stands out as a comprehensive and highly demanding physical activity that involves the coordinated use of various muscle groups. According to Silva[3], the front crawl stroke can be classified as a gross, continuous, and semi-closed motor skill, characterized by the simultaneous and continuous movements of the arms, legs, and head (arm stroke, leg kick, and breathing).

The lower limbs in swimming are recognized as a determining factor for performance, contributing to propulsion, support, balance, and the speed the swimmer achieves in the water [4]. Additionally, lower limb power, particularly utilized at the start and during segments of a race, such as the block start and high-intensity turns, also plays a significant role[5].

Lower limb power and block starts have been the subject of studies aimed at understanding the factors that influence an athlete's performance, as they are considered key determinants of swimming success [6,7]. Hubert et al. [8] divide swimming performance into three distinct phases: the start, the swim, and the turn. According to the authors, the block start can account for up to 26.1% of the total race time, making it a decisive component in competitive swimming, particularly in sprint events. They suggest that improving starting technique may reduce race time by at least one-tenth of a second on average.

In the context of high-performance swimming, where small differences in performance can determine medal outcomes, it is essential for athletes to maximize their performance in all phases of the race. The initial dive and the turn are among these crucial phases, as they can influence a swimmer's position at the start of the race or during the transition after turning at the wall [9]. Therefore, investigating how lower limb power correlates with flight distance from the block and swim time can offer valuable insights for refining training strategies and optimizing athlete performance.

Although some literature is available on the influence of power on swim performance, analyses that distinguish between sexes and race distances remain scarce and are necessary for a better understanding of these relationships. In fact, sex is a decisive factor in swimming competition outcomes, with male records outperforming female records by approximately 9% [10].

This study aims to analyze the correlation between lower limb power, block flight distance, and front crawl performance across different distances: specifically, 25, 50, and 100 meters for both male and female swimmers. Identifying potential correlations among these variables can provide coaches and swimmers with objective data regarding their relationship and help determine whether additional explosive lower limb strength training, beyond regular in-water practice, may be beneficial based on the targeted race distance.

Methods

This study utilizes a quantitative correlational research design to explore the relationships between variables by analyzing objective numerical data, classifying, and interpreting the results [11]. Three variables were examined: flight distance, levels of muscular power, and swim time at different distances.

Participants

The study evaluated 29 amateur-level swimmers of both sexes (16 males and 13 females), aged between 17 and 33 years (22.1 ± 4.3 years, 67.7 ± 11.7 kg, 1.73 ± 0.10 m), whose main events included freestyle swimming. Swimming teams from the municipality of Curitiba and their respective athletes were contacted and provided with informed consent forms prior to their participation. The study took place at the athletes' own training centers. All procedures received approval from the Research Ethics Committee of UTFPR (70224923.3.0000.5547).

Participants were included in the study based on the following criteria: (i) being an amateur-level swimmer with competitive experience; (ii) training at least two sessions per week; and (iii) the absence of any injury that could interfere with test performance. The exclusion criteria were: (i) failure to attend the data collection sessions and (ii) failure to complete one or more tests.

Instruments and Procedures

Two jump test protocols, vertical and horizontal, were employed to assess lower limb muscular power. Participants were familiarized with the movements before the start of each test (i.e., trial execution of the movement).

The **Sargent Jump Test** (vertical jump test) was used to assess the athletes' vertical jump capacity. Pereira and Navarro[6] explain that this test measures an individual's jump height and can serve as a control parameter for evaluating lower limb power in swimmers. This test has been widely used in various analyses and has been validated for different populations [12–14].

The test was administered according to the procedures described by Hubert et al. (2007)[8]. It took place in a spacious setting with a flat surface and a tall, smooth wall near the pool area, which allowed ample movement and easy marking of reach points. A retractable tape measure, adhesive tape for marking the standing reach point, and chalk for marking the jump reach were utilized during the test. All jumps were performed using a countermovement technique.

The test consisted of two phases. First, the athlete's standing reach was marked using adhesive tape. The athlete stood upright with one arm extended vertically, touching the wall. The standing reach was defined by the tip of the middle finger in contact with the wall. In the second phase, the athlete performed the jump. Participants used chalk to mark the wall with their fingertips, indicating the maximum height achieved during the jump (Figure 1). The movement began from an upright position with knees extended. Upon signal, the participant flexed the knees to approximately 90°, swung the arms to generate momentum, and executed a maximum jump to reach the highest possible point.

The vertical jump performance was calculated by measuring the difference in centimeters between the standing reach and the maximum jump reach. Each athlete took the test three times, and the best attempt was recorded.

Figure 1. Vertical jump test (Sargent Jump Test).
Source: The authors.

The horizontal jump test protocol (Figure 2) followed the procedures described by Caneviski, Crepaldi, and Fernandes[15]. A measuring tape and a line marked on the floor were used to conduct the test. Athletes stood behind the marked line and, upon signal, were instructed to perform partial knee flexion combined with a backward arm swing, followed by a forward arm swing and a powerful forward jump, aiming to reach the greatest possible distance. The distance in centimeters from the starting line to the landing point was measured with a measuring tape, using the heel closest to the starting line as the reference point. Each athlete made three jumps, and the longest distance was recorded.

Figure 2. Horizontal jump test (long jump test).
Source: The authors**.**

The analysis of the flight phase distance during the block start was obtained from video footage recorded with a Samsung A53 smartphone camera (30 fps), fixed in a stable position at a perpendicular angle to the recording surface. Kinovea 0.9.5 software was utilized to measure the swimmer's horizontal flight distance from the block to the point where the fingertips entered the water. Calibration was based on the actual lengths of the starting blocks used by the athletes at their training centers, as shown in Figure 3.

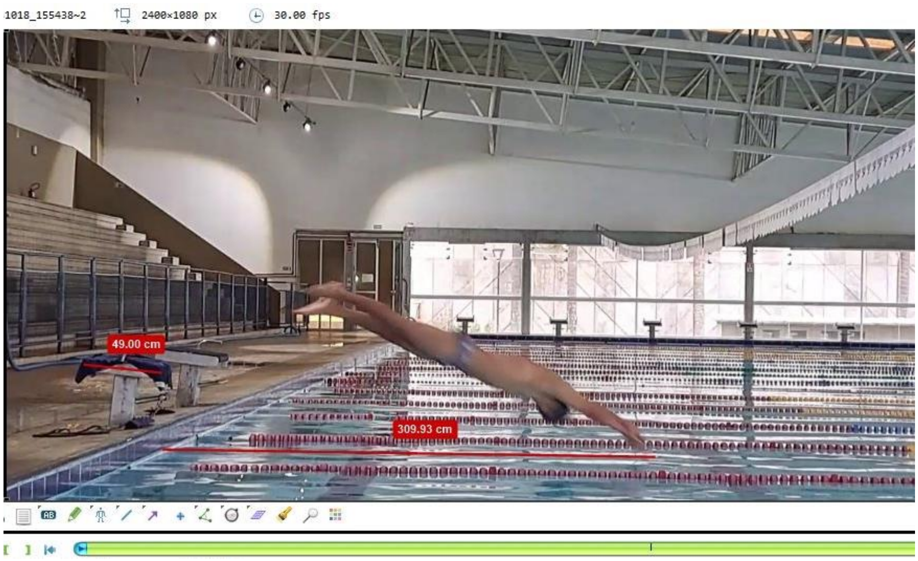


Figure 3. Kinematic analysis of the flight distance from the starting block.
Source: The authors.

A Vollo VL515 stopwatch was used to time the swimming performances over distances of 25 meters, 50 meters, and 100 meters. Two experienced evaluators conducted the measurements simultaneously, with one serving as the primary timekeeper and the other as a secondary verifier to minimize potential measurement bias. The order of the sprint trials was determined by a random draw. First, a 10-minute low-intensity freestyle warm-up was performed, followed by the sprint trials, with a 20-minute active recovery period between each distance.

Statistical Analysis

The obtained values were initially recorded on a data sheet for subsequent descriptive analysis (mean and standard deviation) using Microsoft Excel (Microsoft 365). Normality was assessed using the Shapiro-Wilk test, and after confirming this assumption, block start variables, lower limb power, and swim times were correlated using Pearson's correlation test, with the significance level set at $p < 0.05$. The strength of the correlations was interpreted according to the methodology proposed by Mitra and Lankford[16], where correlation values between 0.20 and 0.40 are considered weak; between 0.40 and 0.60, moderate; and values above 0.60 are classified as strong correlations.

Results

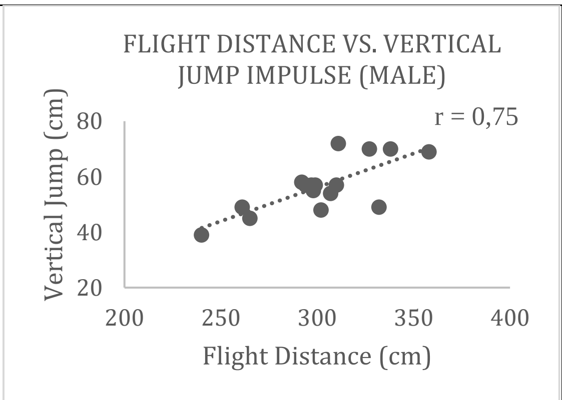
Table 1 presents the means and standard deviations of swim times, vertical and horizontal impulses, and flight distances during the block start.

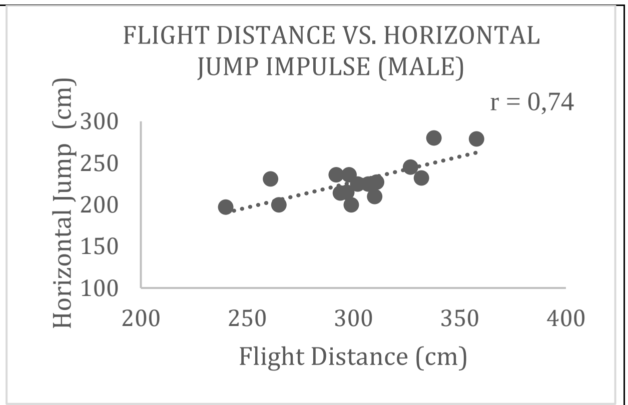
Table 1. Mean and standard deviation of the analyzed variables.

Variables	Male (n = 16)	Female (n = 13)	Total (n = 29)
Vertical Jump (cm)	56,63 ± 9,65	38,15 ± 4,71	48,34 ± 12,11
Horizontal Jump (cm)	228,25 ± 24,47	166,4 ± 17,27	200,52 ± 37,80
Flight Distance (cm)	301,94 ± 29,70	261,46 ± 32,23	283,79 ± 32,23
25 m Swim Time (s)	14,17 ± 1,20	16,87 ± 0,97	15,38 ± 1,74
50 m Swim Time (s)	30,05 ± 2,81	36,10 ± 2,01	32,76 ± 3,92
100 m Swim Time (s)	66,79 ± 8,35	78,53 ± 5,50	72,05 ± 9,25

Source: The authors.

The following graphs illustrate the correlation results between flight distance during the block start and the values obtained in the vertical and horizontal jump tests. All identified correlations were significant ($p < 0.05$) and positive. For the female group, the correlations were moderate, while for the male group, they were strong. The highest correlation values were observed in the overall group.





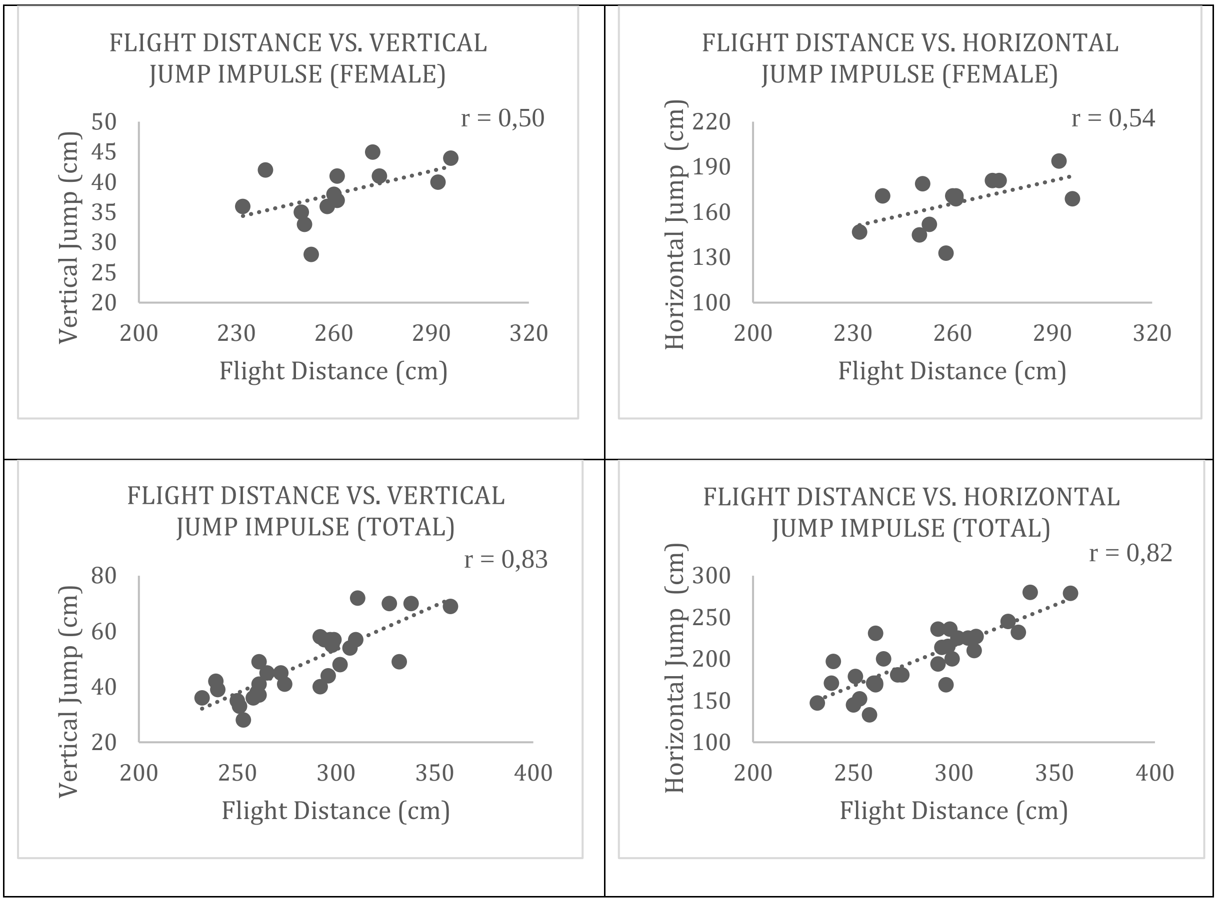


Figure 1. Correlation between flight distance during the block start and vertical and horizontal jump impulse.
Source: The authors.

Finally, Table 2 presents the correlation data between power-related variables and front crawl swimming performance over distances of 25, 50, and 100 meters. In the female group, a moderate inverse correlation was found between the horizontal jump and the 100-meter swim time. In the male group, a moderate inverse correlation was observed between the horizontal jump and performance across all distances. Once again, the overall group showed the strongest associations, with all variables and distances demonstrating a high level of inverse correlation.

Table 2. Correlation between power-related variables and performance in the 25 m, 50 m, and 100 m front crawl events.

Variable	Event	MALE (N = 16)			FEMALE (N = 13)			TOTAL (N = 29)		
		R	*p*	r^2	r	*p*	r^2	r	*p*	r^2
Vertical Jump	25m	-0.40	0,12	0,16	-0.07	0,81	0,00	-0.73	0,00	0,53
	50m	-0.34	0,20	0,12	-0.14	0,65	0,02	-0.72	0,00	0,52
	100m	-0.42	0,10	0,18	-0.31	0,30	0,10	-0.69	0,00	0,48
Horizontal Jump	25m	-0.52	0,04	0,27	-0.49	0,09	0,24	-0.83	0,00	0,69
	50m	-0.54	0,03	0,29	-0.31	0,30	0,10	-0.81	0,00	0,66
	100m	-0.50	0,03	0,25	-0.48	0,09	0,23	-0.74	0,00	0,55

Source: The authors.

Discussion

The primary aim of this study was to investigate the relationship between lower limb muscle power, block start flight distance, and front crawl performance over different race distances.

The mean vertical and horizontal jump values for both female and male groups were higher than those reported by Sammoud et al.[17,18] for prepubescent swimmers of the same sex. However, the overall mean vertical jump in this study was comparable to the results obtained by Pereira and Navarro[6] (44,67 ± 4.09 /50 m) for sprint swimmers. Similarly, the overall mean horizontal jump distance was close to the values reported by Caneviski, Crepaldi, and Fernandes (2017)[15] (197.10 ± 45,60) for physically active youth. On the other hand, the flight distance was slightly shorter than that reported by Detanico et al.[19] for male swimmers (3.30 m versus 3.02 m in the present study), which may be explained by the different techniques used. Specifically, while Detanico and colleagues employed the grab start in their protocol, the present study used the track start, which is currently more commonly adopted by competitive swimmers. Nevertheless, the data were similar to those Hubert et al.[8] reported for the same starting technique (2.98 m).

The results revealed positive correlations across all groups between flight distance and performance in vertical and horizontal jumps. In the female group, the level of correlation remained moderate, while in the male and overall groups, a strong correlation was observed. These findings underscore the importance of propulsive strength during the start phase of competitive swimming, particularly in the 50 m and 100 m events, and contrast with the results reported by Hubert et al.[8] and Detanico et al.[19], who found no significant correlation between flight distance and lower limb muscle power. These discrepancies may be explained by methodological differences, including the use of a force platform and the small sample sizes in those studies, which included only 4 and 10 swimmers, respectively.

Only the male group showed a moderate inverse correlation with swim times over 25 m and 100 m when analyzing the relationship between vertical jump and swimming performance. Regarding the horizontal jump, the female group demonstrated a moderate inverse correlation for the 100 m distance, while the male group presented similar correlation levels across all three predefined distances. The strongest evidence was observed in the overall group, with strong inverse correlations between jump tests and swim performance times (ranging from -0.69 to -0.83). It is important to note that the participants were amateur athletes, and this may have influenced the sex-specific analyses, which might not have revealed stronger associations due to factors such as sample size, differences in physical fitness levels, anthropometric characteristics, training frequency, and technical execution.

Nevertheless, the results from the overall group indicate that greater lower limb propulsion is associated with shorter swim times, particularly in the shorter distances of 25 and 50 meters. These findings are consistent with those reported by Hubert et al.[8], Veliz et al.[20] and Sammoud et al. (2019)[18], which indicated that greater power gains are associated with improved sprint times at these distances. The slightly lower correlation observed for the 100-meter performance may be related to factors such as race strategy and anaerobic endurance, suggesting that the shorter the distance, the greater the influence of propulsion on performance. The present study's findings support the inference that lower limb muscle power plays an important role in kicking rhythm, the push-off at the start block, and wall turns, and, when combined with technical skills, can enhance overall swimming performance. [17,21,22].

However, this study does not allow for conclusions about the effect of lower limb power training on swimming performance because it did not include an intervention aimed at developing the studied variable, which represents a limitation of the research. Additionally, factors such as BMI, training history, and pre-test nutrition were not controlled and may represent confounding variables in interpreting the results. Therefore, future studies are recommended to further explore this topic, including analyses involving athletes of higher competitive levels and from different specializations (e.g., sprinters vs. distance swimmers), to advance the science related to competitive swimming further.

Overall, the results of this study highlight the importance of plyometric training for performance in short-distance swimming events. The significant correlations between lower limb power and swim times indicate that coaches should prioritize dry-land exercises like vertical jumps, horizontal jumps, and drop jumps to enhance explosive strength for starts and turns. These should be complemented by water-based drills, such as strong kick sets and repeated block starts, to ensure a direct transfer of plyometric capacity to technical execution. Finally, regular assessments (e.g., vertical and horizontal jump tests) are recommended to monitor the development of muscular power and adjust training loads accordingly. When combined with technical refinement and individualized programming, these strategies may optimize performance in short-distance swimming events.

Conclusions

This study analyzed the correlation between lower limb power, block start flight distance, and front crawl performance across different distances. The observed correlations suggest that developing muscular power may enhance performance. Therefore, including plyometric training sessions (such as vertical jumps, horizontal jumps, and drop jumps) is recommended as a valuable part of physical preparation. Additionally, regularly implementing simple field tests (vertical and horizontal jumps) can help monitor potential adaptations, enabling individualized adjustments to training programs.

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