



Swimming parameters of conventional and physical-motor disability swimmers across different distances

Parámetros de natación de nadadores convencionales y con discapacidad físico-motora en diferentes distancias

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Received: 09-04-26

Accepted: 30-09-26

How to cite in APA

Espirito Santo, M. L., Rucinski, P. A., Lima Gonçalves, L., Rocha Costa, R., & Borges dos Santos, K. (2026). Swimming parameters of conventional and physical-motor disability swimmers across different distances. *Retos*, 84, 225-234.
<https://doi.org/10.47197/retos.v84.119657>

Abstract

Introduction: Competitive swimming has shown significant growth in recent years, requiring increasingly objective analyses of the factors that determine performance.

Objective: Analyze and compare kinematic parameters of the front crawl stroke between para swimmers and conventional swimmers over distances of 25 m, 50 m, and 100 m.

Methods: Thirty-eight swimmers aged between 14 and 38 years participated in the study, including 20 conventional swimmers and 18 swimmers with physical-motor disabilities (classes S3 to S10). Swimming velocity, stroke length, stroke frequency, and stroke index were assessed during maximal tests at the predetermined distances. Data were analyzed using Generalized Estimating Equations, adopting a significance level of 5%.

Results: Conventional swimmers showed higher velocity, stroke length, and stroke index values at all distances. Both groups demonstrated a progressive reduction in the same variables as the distance increased. Additionally, stroke length decreased only in the conventional group across the analyzed distances, whereas in para swimmers, stroke rate appeared to play a more important role in maintaining swimming velocity. Regarding the percentage variations in distance, the reduction in velocity was similar across groups, although para swimmers showed a greater decline over the 25–100 m distance.

Discussion: Increasing swimming distance led to changes in kinematic variables in both groups, highlighting biomechanical adaptations during swimming. Para swimmers demonstrated a greater dependence on stroke frequency to maintain performance.

Conclusion: These findings reinforce the need for individualized training strategies considering functional characteristics and race distances.

Keywords

Kinematics; performance; physical-motor disabilities; swimming; swimming distance

Resumen

Introducción: La natación competitiva ha experimentado un crecimiento significativo en los últimos años, lo que ha requerido un análisis cada vez más objetivo de los factores que determinan el rendimiento.

Objetivo: Analizar y comparar los parámetros cinemáticos de la técnica de crol entre nadadores con discapacidad físico-motora y convencionales en las distancias de 25 m, 50 m y 100 m.

Métodos: Participaron en el estudio treinta y ocho nadadores de entre 14 y 38 años, incluidos 20 nadadores convencionales y 18 nadadores con discapacidad físico-motora (clases S3 a S10). Se evaluaron la velocidad de nado, la longitud de brazada, la frecuencia de brazada y el índice de brazada durante pruebas máximas a las distancias predeterminadas. Los datos se analizaron mediante Ecuaciones de Estimación Generalizadas, adoptando un nivel de significación del 5%.

Resultados: Los nadadores convencionales presentaron valores más altos de velocidad, longitud de brazada e índice de brazada en todas las distancias. Ambos grupos mostraron una reducción progresiva de las mismas variables a medida que aumentaba la distancia. Además, la longitud de brazada disminuyó únicamente en el grupo convencional a lo largo de las distancias analizadas, mientras que en los nadadores con discapacidad físico-motora la frecuencia de brazada pareció desempeñar un papel más importante en el mantenimiento de la velocidad de nado. En cuanto a las variaciones porcentuales en las distancias, la reducción de la velocidad fue similar entre los grupos, aunque los nadadores con discapacidad físico-motora mostraron una mayor disminución entre los 25 y los 100 m.

Discusión: El aumento de la distancia de nado provocó cambios en las variables cinemáticas en ambos grupos, lo que puso de manifiesto adaptaciones biomecánicas durante la natación. Los nadadores con discapacidad físico-motora mostraron una mayor dependencia de la frecuencia de brazada para mantener el rendimiento.

Conclusión: Estos hallazgos refuerzan la necesidad de estrategias de entrenamiento individualizadas que consideren las características funcionales y las distancias de competición.

Palabras clave

Cinemática; rendimiento; discapacidades físico-motoras; natación; distancias de nado.



Introduction

Swimming offers several benefits for people with disabilities, contributing not only to physical rehabilitation but also to psychological and social well-being (Aitchison et al., 2020). However, beyond reasons related to physical and mental health, the search for swimming as a competitive sport has become increasingly popular both nationally and internationally.

Given this context, in order to ensure fair competition in parasport, a functional classification system governed by the International Paralympic Committee (IPC) was established (International Paralympic Committee, 2025). This system aims to ensure that sporting results are determined by performance-related factors, such as skill, endurance, physical capacity, and tactics, regardless of the swimmer's physical impairment (World Para Swimming, 2022). Thus, swimmers with similar functionality, movement, or impairments are grouped into a specific sport class identified by the prefix "S" (Swimming). For these competitors, classes range from 1 (most severe limitation) to 10 (least severe limitation) (Hogarth et al., 2020). Therefore, classification is not based solely on the swimmer's motor limitations, but rather on the competitor's residual potential and, consequently, on the variables that influence swimming performance (World Para Swimming, 2022).

Among these variables, the most frequently analyzed are the biomechanical aspects of swimming: stroke rate (SR), stroke length (SL), swimming velocity, and stroke index (SI) (Hogarth et al., 2020; Santos et al., 2020; Feitosa et al., 2022). SR refers to the number of arm cycles performed over time, whereas SL refers to the distance traveled by the swimmer during one stroke cycle, and SI, the product of swimming velocity and SL (Maglischo, 2003). The relationship between these variables is complex, as it is inverse; that is, if the swimmer's SR increases, SL decreases, and vice versa. Therefore, different combinations of these variables may be adopted for each swimmer, depending on the selected strategy and the event distance. For example, studies involving para swimmers have shown that when stroke length decreases due to physical impairments, stroke rate increases to compensate for the anatomical limitation (Fletcher et al., 2021). Furthermore, there is evidence that SL is a strong indicator of swimming velocity and is associated with performance, whereas SR is more closely related to sprint performance (Kwok et al., 2021).

Although there is extensive literature on the biomechanical characterization of conventional swimmers, until the 1990s, few studies investigated these same aspects in swimmers with disabilities (Junior et al., 2018). Daly et al. (1999) were among the pioneers in evaluating the relationships among swimming velocity, SR, and SL in Paralympic swimmers and found that velocity increases primarily with increases in SL. Similarly, Pelayo et al. (1999) observed that SL is more closely associated with higher swimming velocity. Additionally, the authors found no differences in SR between high-level swimmers with and without disabilities. However, Feitosa et al. (2022) highlight that lower-class swimmers generally emphasize SR over SL, due to the swimmers' functional limitations, which restrict their capacity to increase or maintain SL.

Additionally, a study conducted by Junior et al. (2018) analyzed biomechanical parameters during front crawl swimming in swimmers with disabilities over distances of 100 m and 175 m at different swimming intensities. The results showed that, as velocity increased, swimmers reduced stroke length (SL) and increased stroke rate (SR), especially during the 175 m distance. A greater dependence on SR was observed to achieve higher velocities, compensating for the reduction in SL caused by fatigue. These findings indicate that swimmers with disabilities adjust their technique to maintain performance during fatigue, similarly to swimmers without disabilities.

Thus, swimming parameters depend on the race distance and, consequently, on its energetic contribution. Campos et al. (2017) analyzed energetic shifts in swimmers across different distances and observed that the absolute anaerobic contribution is greater in 200m and 400m events. This higher reliance on anaerobic pathways is justified by the total race duration performed above critical velocity, which impairs phosphocreatine resynthesis (Jones et al., 2008). Consequently, changes in metabolic demand and progressive fatigue may be directly linked to how swimmers adjust their technique to cope with longer exercise durations (Campos et al., 2017).



Despite the current availability of studies on the kinematic aspects of swimming among people with disabilities (Santos et al., 2021; Feitosa et al., 2022), research analyzing these parameters across different distances remains scarce and is necessary for a better understanding of behavioral changes as distance increases. In fact, analyzing variations in swimming biomechanical parameters across distances among swimmers with disabilities, compared with conventional swimmers, may help guide common or individualized training strategies to achieve combinations that optimize swimming performance. Therefore, the present study aims to contribute to the analysis of performance parameters in conventional swimmers and swimmers with physical-motor disabilities across different distances (25 m, 50 m, and 100 m). We hypothesize that para swimmers will exhibit lower kinematic values than conventional swimmers and that the effects of increasing swimming distance will differ between groups. Specifically, conventional swimmers are expected to increase SL and decrease SR, Vel, and SI as distance increases, whereas para swimmers are expected to show smaller changes in these variables.

Method

A quantitative cross-sectional study was conducted. The study was approved by the Research Ethics Committee, and all participants signed an informed consent or assent form to participate.

Participants

The study included 38 swimmers aged 14-38 years, divided into two groups: conventional amateur swimmers ($n=20$) and swimmers with physical-motor disabilities competing at regional to international levels ($n=18$). The para swimmers were distributed as follows: S3 ($n=2$), S4 ($n=1$), S5 ($n=1$), S6 ($n=3$), S7 ($n=3$), S8 ($n=2$), S9 ($n=3$), and S10 ($n=3$). The established inclusion criteria were a minimum of 1 year of competitive experience and front crawl/freestyle as the primary competitive stroke. Additionally, swimmers with disabilities were required to have been previously classified by the IPC within the classes S3 and S10.

Procedure

The swimmers were monitored during three maximum-speed tests over distances of 25 m, 50 m, and 100 m front crawl, performed on a single day of data collection. Initially, a set of anthropometric measurements (height, body mass, and arm span) was obtained, followed by a dry-land warm-up consisting of joint movements and an in-water warm-up of low-intensity freestyle swimming. The order of execution of each distance was randomized. The tests were conducted in a semi-Olympic swimming pool heated to 27-29°C.

The tests were performed with an in-water start, and time was measured using a digital stopwatch. A trained evaluator timed three stroke cycles (defined as the sequence of movement from the entry of one hand into the water until the next entry of the same hand) in the middle of the pool. The values were then extrapolated over a 1-minute period to determine the stroke rate (SR). Swimming velocity (Vel) was calculated as the ratio of distance swum to elapsed time. Stroke length (SL), defined as the distance traveled by the swimmer's body during one stroke cycle, was calculated as the ratio of Vel to SR, and the stroke index (SI) was calculated as the product of SL and Vel. The swimmers routinely perform timed trials during training sessions and receive verbal encouragement during the tests.

Data analysis

Descriptive statistics were presented as mean and standard deviation for all dependent variables: stroke rate (SR), stroke length (SL), stroke index (SI), and swimming velocity (Vel). In addition to the raw values, the percentage differences of the analyzed variables between each distance were calculated, that is, the deltas of variation between distances (25-50 m, 25-100 m, and 50-100 m).

To compare raw values between groups and distances (25 m, 50 m, and 100 m), the Generalized Estimating Equations (GEE) method was used, with Least Significant Difference (LSD) post hoc analysis. Furthermore, to compare percentage differences between distances within each group, another GEE analysis was conducted, also with LSD post hoc analysis. For all analyses, the significance level was set at 5%, and analyses were performed using SPSS statistical software version 21.



Results

The general objective of the present study was to analyze and compare kinematic parameters of front crawl swimming (velocity, stroke rate, stroke length, and stroke index) between two groups of swimmers: those with physical-motor disabilities and those without disabilities, during maximal tests performed over different distances (25 m, 50 m, and 100 m).

The anthropometric characteristics of the sample are presented in Table 1.

Table 1. Anthropometric characteristics of the sample.

Group	N	Age (years)	Body Mass (kg)	Height (cm)	Arm Span (cm)
Para swimmers	18	26.33±8.88	61.04±13.41	165.92±18.71	167.62±31.76
Conventional swimmers	20	18.87±3.20	69.68±10.89	176.75±6.32	181.93±9.12

Note. Values are presented as mean ± standard deviation. N = number of participants.

The responses of each dependent variable (Vel, SL, SR, and SI) were compared between the groups (Table 2).

Table 2. Raw values of the parameters across the different distances (25 m, 50 m, and 100 m).

Distances/Groups	Groups			p-value		
	Para swimmers	Conventional swimmers	Pooled sample	Group effect	Distance effect	Group* Distance Interaction
VEL (m/s)	25m	1.39 (1.24 to 1.55)	1.95 (1.88 to 2.02)	1.65 (1.55 to 1.75)&	<0.001	<0.001
	50m	1.26 (1.11 to 1.42)	1.80 (1.74 to 1.86)	1.50 (1.41 to 1.60)#		
	100m	1.14 (1.00 to 1.29)	1.63 (1.59 to 1.67)	1.36 (1.28 to 1.45)##		
	Pooled distances	1.26 (1.12 to 1.41)	1.79 (1.74 to 1.84)*			
SL (m)	25m	1.35 (1.21 to 1.51)	1.84 (1.75 to 1.93)*&	1.58 (1.48 to 1.68)	0.001	<0.001
	50m	1.34 (1.20 to 1.50)	1.65 (1.59 to 1.72)*#	1.49 (1.40 to 1.58)		
	100m	1.38 (1.23 to 1.55)	1.50 (1.38 to 1.63)##	1.44 (1.34 to 1.55)		
	Pooled distances	1.36 (1.22 to 1.51)	1.66 (1.60 to 1.72)			
SR (Cycle/min)	25m	62 (56 to 69)	67 (64 to 71)	65 (61 to 68)&	0.284	<0.001
	50m	58 (51 to 65)	62 (59 to 65)	60 (56 to 64)#		
	100m	49 (43 to 55)	51 (49 to 54)	50 (47 to 53)##		
	Pooled distances	56 (50 to 63)	60 (57 to 62)			
SI	25m	1.94 (1.61 to 2.34)&	3.60 (3.41 to 3.80)*&	2.65 (2.40 to 2.92)	<0.001	<0.001
	50m	1.74 (1.44 to 2.09)#	2.99 (2.82 to 3.18)*#	2.28 (2.07 to 2.52)		
	100m	1.62 (1.33 to 1.98)##	2.47 (2.24 to 2.73)*##	2.00 (1.79 to 2.24)		
	Pooled distances	1.76 (1.46 to 2.13)	2.99 (2.82 to 3.17)			

Note: * indicates a significant difference between the para swimmers and conventional groups; # indicates a difference compared to the 25 m distance; & indicates a difference compared to the 50 m distance.

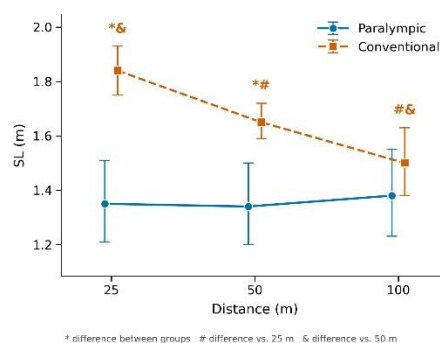
Table 2 presents the mean values of the swimming kinematic variables (Vel, SL, SR, and SI) obtained over the 25 m, 50 m, and 100 m distances for the conventional and para swimmers groups. Regarding velocity, the conventional group showed higher values across all analyzed distances. Both groups exhibited a progressive reduction in velocity with increasing distance ($p < 0.001$). The absence of a significant group × distance interaction ($p = 0.475$) indicates that, although the absolute values differed, the pattern



of velocity reduction was similar between groups, and the velocity difference between them was independent of the distance covered.

Regarding stroke length, it was also observed that the conventional swimmers had higher values than the para swimmers across all distances. A reduction in SL with increasing distance was verified only in the conventional group (Figure 1).

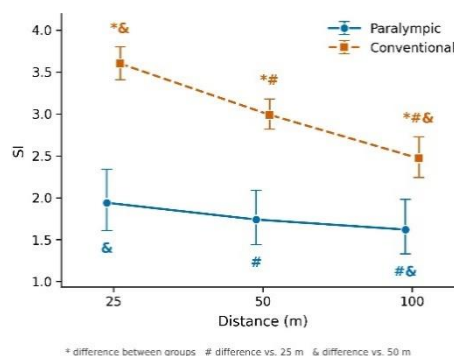
Figure 1. Interaction between group and distance for stroke length (SL).



Concerning stroke rate, no significant difference was found between groups ($p = 0.284$), but both groups showed a progressive reduction as distance increased ($p < 0.001$).

The stroke index showed a significant group $\times$ distance interaction ($p = 0.015$). Post hoc analysis revealed that both groups showed a progressive reduction in SI as distance increased. In addition, the conventional group presented significantly higher values than the para swimmer group across all analyzed distances (Figure 2).

Figure 2. Interaction between group and distance for stroke index (SI).



The percentage deltas in variation across the different distances were also compared between groups (Table 3).

Table 3. Variation of the parameters across distances.

	Distances/Groups	Groups			p-value		
		Para swimmers	Conventional swimmers	Pooled sample	Group effect	Distance effect	Group* Distance Interaction
VEL ($\Delta\%$)	25-50m	11.05 (9.11 to 13.39)	8.56 (6.25 to 11.73)	9.73 (8.09 to 11.70)	0.253	<0.001	0.006
	50-100m	11.05 (8.36 to 14.61)	10.43 (8.50 to 12.81)	10.74 (9.03 to 12.77)			
	25-100m	23.55 (18.54 to 29.92)#&	19.67 (16.68 to 23.19)#&	21.52 (18.62 to 24.89)			
	Pooled Distance	14.22	12.07				

		(11.34 to 17.83)	(10.21 to 14.26)				
SL (Δ%)	25-50m	5.45 (4.01 to 7.39)	13.43 (9.89 to 18.25)	8.55 (6.89 to 10.62)			
	50-100m	5.66 (3.64 to 8.80)	20.91 (15.48 to 28.26)	10.88 (8.33 to 14.21)			
	25-100m	8.34 (5.78 to 12.03)	31.93 (23.08 to 44.17)	16.32 (12.78 to 20.84)#&	<0.001	<0.001	0.221
	Pooled Distance	6.36 (4.92 to 8.23)	20.78 (16.33 to 26.44)*				
SR (Δ%)	25-50m	10.10 (7.34 to 13.90)	10.58 (7.67 to 14.59)	10.34 (8.24 to 12.97)&			
	50-100m	14.58 (10.85 to 19.59)	21.07 (16.94 to 26.21)	17.53 (14.59 to 21.06)#	0.139	<0.001	0.327
	25-100m	25.87 (20.38 to 32.85)	31.61 (26.79 to 37.31)	28.60 (24.73 to 33.07)#&			
	Pooled Distance	15.62 (12.49 to 19.54)	19.17 (16.44 to 22.35)				
SI (Δ%)	25-50m	13.20 (9.73 to 17.91)	21.69 (16.07 to 29.28)	16.92 (13.66 to 20.96)			
	50-100m	11.85 (8.56 to 16.41)	27.52 (19.86 to 38.14)	18.06 (14.34 to 22.74)			
	25-100m	25.69 (18.68 to 35.32)	50.71 (39.30 to 65.43)	36.09 (29.43 to 44.26)#&	<0.001	<0.001	0.526
	Pooled Distance	15.90 (12.01 to 21.05)	31.17 (25.27 to 38.44)*				

Note: * indicates a significant difference between the para swimmers and conventional groups; # indicates a difference for the 25-50 m distance; & indicates a difference for the 50-100 m distance.

Table 3 presents the percentage changes (Δ%) in the swimming kinematic variables (Vel, SL, SR, and SI) across distances (25-50 m, 50-100 m, and 25-100 m) and between the para swimmers and conventional groups. Regarding velocity, the findings revealed that the pattern of percentage variation did not differ between groups at different distances; that is, both responded similarly to increasing distance. In both groups, the percentage reduction in velocity was significantly greater in the 25-100 m comparison than in the 25-50 m and 50-100 m comparisons ($p < 0.001$), with no difference between the reductions observed in the 25-50 m and 50-100 m distances.

For stroke length, the percentage variations were more pronounced in the conventional group ($p < 0.001$), regardless of the distance covered. There was a significant effect of distance ($p < 0.001$ in both groups), with the 25-100 delta significantly greater than the others, and no difference between 25-50 and 50-100.

Regarding stroke rate, both groups showed percentage increases in variation with distance, indicating a decrease in SR as distance increased. The conventional group presented slightly greater deltas, particularly in the 25-100 m comparison (31.61%), compared with the para swimmers group (25.87%). However, there was no significant difference between groups or in the interaction, with only a significant effect for distance being observed ($p < 0.001$).

In terms of stroke index, the percentage variations were also greater in the conventional group ($p < 0.001$), regardless of the distance covered. As observed for stroke length, there was a significant effect for distance ($p < 0.001$ in both groups), with the 25-100 delta being significantly greater than the others, and no differences between 25-50 and 50-100.

Discussion

The present study aimed to compare the kinematic behavior of front crawl during maximal tests over 25 m, 50 m, and 100 m in para swimmers (with physical-motor disabilities) and conventional swimmers (without disabilities).

Raw values of the parameters across the different distances (25 m, 50 m, and 100 m)

The results (Table 2) for the VEL showed a significant distance effect, indicating that velocity decreases as distance increases. This finding was expected and corroborates the study by Barbosa et al. (2010),



which showed that the decrease in velocity is progressive with increasing effort (distance covered), due to changes in stroke kinematic parameters and fatigue accumulation.

A significant group effect was also observed, confirming that velocity differed between groups, with higher values in conventional swimmers than in para swimmers. This result was expected, since the specific functional limitations of para swimmers may compromise their propulsive capacity, directly impacting performance across the different analyzed distances (Feitosa et al., 2022; Santos et al., 2020).

Similarly, SL decreased with increasing distance in the conventional group. According to Maglischo (2013), this behavior can be explained by the fact that longer distances (25 m–100 m) require greater energy expenditure, promote muscular fatigue, and may consequently lead to a reduction in SL. However, the para swimmers group did not exhibit the same behavior. One possible explanation is that disabled swimmers may have strategically adopted a higher SR in the shorter-distance events, resulting in a modest stroke length at these distances. As the race distance increased, the reduction in SR allowed the maintenance of stroke length. Indeed, Feitosa et al. (2022) indicated that performance variation in swimmers with disabilities is sometimes determined predominantly by SR rather than SL.

In fact, SR decreased in both groups as distance increased, corroborating the literature (Costa et al., 2023). According to Costa et al. (2023), over distances, swimmers are often unable to maintain velocity due to increased muscular fatigue, which reduces power production and alters kinematics, leading to reductions in SR (Stirn et al., 2011). Indeed, the high accumulation of lactate resulting from the anaerobic system may influence kinematic parameters. The rapid response of fast-twitch muscle fibers, which exhibit a range of metabolic profiles and robust power-generating capacities, may explain the progressive decrease in SR across the 25, 50, and 100 m events (Ruiz-Navarro et al., 2025).

Regarding the stroke index (SI), the group $\times$ distance interaction showed that both groups exhibited a progressive reduction in SI with increasing distance, with consistently lower values in the para swimmer group, which may be attributed to the functional limitations' characteristic of this population. The reduction in SI with increasing distance corroborates the findings of López-Plaza et al. (2024) and highlights the importance of stroke length (SL) in maintaining both velocity and SI.

The physiology involved in short-distance events contributes to a better understanding of these mechanisms, as the accumulation of metabolites, such as Pi and H⁺, may impair contractile function by reducing force-producing capacity and interfering with intracellular Ca²⁺ sensitivity, thereby contributing to a reduction in muscle contractile capacity and, consequently, impairing force production during maximal efforts. In parallel, as exercise duration increases, the glycolytic and oxidative contributions become increasingly relevant to ATP resynthesis, while the reduced availability of phosphocreatine resulting from swimming above critical speeds limits the ability to sustain high power production rates (Sundberg & Fitts, 2019).

Variation of the parameters across the distances (25 m, 50 m, and 100 m)

Regarding the variation in kinematic parameters across distances (Table 3), increasing distance was associated with progressive changes in the analyzed parameters. Velocity showed a similar reduction between 25–50 m and 50–100 m in both groups, but with a greater total decrease over the 25–100 m distance, especially in para swimmers, indicating a greater need for intensity adjustments to maintain effort (Santos et al., 2020; Costa et al., 2023). These changes may be explained by the transition between energy systems, neuromuscular fatigue, and biomechanical adjustments throughout the race. Furthermore, the significant interaction between group and distance for velocity ($p = 0.006$) suggests a greater magnitude of decline in para swimmers, possibly due to the need for compensatory strategies to overcome limitations in the propulsive segments (Junior et al., 2018; Fletcher et al., 2021; Feitosa et al., 2022).

The variation in stroke length (Δ SL) also showed progressive changes with increasing distance, with greater variation in the conventional group and smaller oscillations in the para swimmers group. While the pooled values were similar to those reported by Wądrzyk et al. (2022) ($\sim 11\%$), the conventional swimmers in the present study showed greater variation. In contrast, the smaller deltas observed in para swimmers corroborate Feitosa et al. (2022), indicating that, in this population, SL plays a secondary role due to functional limitations, causing velocity and its variation across different distances to depend



predominantly on adjustments in stroke rate (SR), although at a greater metabolic cost (Junior et al., 2018).

Regarding stroke rate variation (Δ SR), variation increased with distance, reflecting technical adjustments and neuromuscular fatigue. The results were close to those observed by Staunton et al. (2025) for conventional swimmers (25% versus 21% in the present study), who identified a reduction in SR between 50 m and 100 m as a strategy to balance velocity and efficiency. The absence of a significant group effect ($p = 0.139$) and a group $\times$ distance interaction ($p = 0.327$) indicates that para swimmers and conventional swimmers exhibited similar SR modulation across distances, reinforcing that distance is the main determinant of these changes (Hogarth et al., 2020).

For stroke index variation (Δ SI), conventional swimmers showed greater variation than para swimmers, with significant effects of group and distance ($p < 0.001$) but no interaction. These findings suggest a similar trend of response to increasing distance between groups (pacing strategies). Previous studies have demonstrated that factors such as muscular strength, SR, and the balance between SR and SL directly influence performance in short-distance events (Ruiz-Navarro et al., 2025).

Some limitations should be considered when interpreting the results. Although the analysis included fundamental kinematic parameters of swimming performance, the isolated evaluation of these variables may not fully reflect swimmers' performance, since physiological, neuromuscular, and anthropometric factors also influence swimming efficiency. Furthermore, the functional heterogeneity of the para swimmers (classes S3–S10), together with between-group differences in age and body dimensions, may limit the generalizability of the findings. The absence of body segments or the presence of movement restrictions, associated with substantial implications for drag production, appear to contribute to a high degree of heterogeneity across most classes of swimmers with disabilities (Feitosa et al., 2022).

Thus, future studies may incorporate neuromuscular and anthropometric assessments to provide a more integrated understanding of the relationship between technical efficiency and swimming distances. In addition, future studies should incorporate physiological assessments, such as blood lactate, VO_2max , and heart rate, to monitor exercise responses and guide training intensity (Feitosa et al., 2024).

From a practical perspective, coaches should monitor stroke rate and stroke length separately when progressing from short to longer maximal efforts, particularly in para swimmers, for whom maintaining stroke length while appropriately reducing stroke rate may help preserve technique as distance increases.

Conclusions

Overall, the results demonstrate that increasing distance (25, 50, and 100 m) promotes progressive changes in the kinematic variables of both conventional and para swimmers, highlighting adaptations related to effort, neuromuscular fatigue, and the biomechanical adjustments required to maintain performance. Velocity decreased with increasing distance, with a more pronounced decline among para swimmers, whereas stroke length showed greater sensitivity to distance changes in conventional swimmers. In contrast, stroke rate may contribute to compensating for the lower stroke length observed in para swimmers, possibly due to functional limitations of the propulsive segments. Nevertheless, SR showed similar behavior across groups at different distances, suggesting that distance is the main determinant of adjustments in this parameter. Meanwhile, stroke index decreased with increasing distance in both groups, though to a greater extent among conventional swimmers, suggesting different patterns of adjustment of stroke length and velocity across distances between the groups. Thus, the findings reinforce the idea that kinematic responses to different distances differ between conventional and para swimmers, highlighting the need for individualized training strategies tailored to the functional characteristics of each group and distance.



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