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ORIGINAL ARTICLE

Performance, hydration status, urinary biomarkers, and cardiovascular response during a repeated short-distance swimrun race

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ABSTRACT

Objective: This study aimed to evaluate the performance, hydration status, urinary biomarkers, and heart rate during a repeated short distance swimrun composed of four continuous rounds of swimming and running. Method: This was a descriptive, observational, and repeated-measures study. The sample was convenience-based, comprising 20 adult recreational athletes. The swimrun consisted of laps, completing 1200 m of swimming followed by 6 km of running (i.e., 4 × [300 m swim + 1.5 km run]). Urinary variables were assessed with reagent strips before and immediately after the event, and heart rate was monitored continuously and expressed in absolute terms and as a percentage of age-predicted maximal heart rate. Effect sizes are reported with 95% confidence intervals (CI). Results: A significant increase in urinary protein and a significant decrease in urinary pH were observed, both with large effect sizes (protein: p = .014, r = .85; pH: p = .014, r = −.85). Women showed consistently higher heart rates, especially in 2nd and 3rd lap (g = −0.86), though these differences were not statistically significant (p > .05); in swimming, women showed significantly higher heart rates in the 2nd and 3rd laps (g = −1.62 and −1.14; p = .010 and .046) and higher relative intensity throughout (80.6 vs 69.2 % HRmax in swimming and 93.2 vs 85.6 % HRmax in running). Strong inter-lap HR correlations were found, especially between run 2nd and 3rd laps (r = .87) and run 1st and 2nd laps (r = .82). Age and weight showed moderate negative correlations with heart rate. Conclusions: Overall, repeated short distance swimrun challenges elicit measurable yet moderate physiological stress in recreational athletes, with implications for hydration strategies, performance pacing, and individual monitoring during multisport events. Given the small convenience sample, and particularly the subgroup of seven women, the sex-related comparisons should be regarded as exploratory and hypothesis-generating rather than confirmatory.
Keywords: sports medicine; renal stress; exercise physiology; multisport; endurance; recreational athletes; swimrun; urinalysis.

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INTRODUCTION

Swimrun is a sport that originated in Sweden in 2006, characterized by repeated alternating courses that athletes complete between running and swimming, often exposed to environmental variations, with running in wetsuits at average temperatures of 25 °C (Geromont et al., 2021) and 16 °C when swimming (Geromont et al., 2021). This sport has been gaining popularity among the population, leading to an exponential increase in the number of competitions and the level of competitiveness, making its growth greater than that of triathlons in the 2000s (Culp, 2020).

Although the athletic level in swimrun has improved over the years, scientific research remains scarce (Ferrari et al., 2016; Lepers et al., 2018). The review by Geromont et al. (2021) indicates that the physiological demands of the sport remain unclear and that, in turn, team performance can be characterized as comprising both external and internal factors. The first external factor is the environment: i) air and water temperature; ii) wind and wave direction; iii) speed/power; iv) type of terrain; v) sun exposure; vi) total distance covered; vii) ratio between running and swimming distances. The other external factor is the composition of the team, notably: i) choice of teammates; ii) materials used (type of wetsuit, thickness of wetsuit, footwear, buoy; tether, hand paddles).

On the other hand, internal factors are subdivided into training and team dynamics. In terms of training, the following abilities stand out: i) cardiovascular fitness, nutritional intake and habits, experience in open water and hiking, adaptability to heat and cold water, adaptation to thermal shock. Meanwhile, for team dynamics, the main characteristics are: i) synchronicity in speed and work performed; ii) race strategy and preparation (Geromont et al., 2021). The dynamics of the sport involve overcoming several segments in running and swimming. This leads to ultra-endurance races, among which the ÖtillÖ world championship stands out with 10 km of swimming and 65 km of running (ÖtillÖ Swimrun, 2019) or shorter races with 2 km of swimming and 9 km of running (Torpedo Swimrun, 2019). Swimrun races are characterized by the fact that athletes must compete with all their equipment throughout the event (running with a cap and wetsuit and swimming with shoes) (Geromont et al., 2021).

The first studies on Swimrun sought to compare physical training programs with combined physical and mental fitness training in semi-professional Swimrun athletes, finding that mental training promotes motivational internal dialogue that minimizes perceived effort and improves performance (Ferrari et al., 2016). Meanwhile, Lepers et al. (2018) conducted a four-year observational study to analyse race times and participation, finding that men's teams improved their time by 17 min/year, mixed teams by 40 min/year, and women's teams by 59 min/year. This leads to the conclusion that multiple variables must be analysed in the performance of athletes who practice Swimrun.

Although swimrun is a multi-sport event combining swimming and running that has gained popularity as an accessible endurance challenge for recreational athletes (Geromont et al., 2021; Lepers et al., 2018), the acute physiological responses elicited by repeated short-distance formats remain poorly understood. In endurance sports, exercise-related effects include exhaustion, cramps (Nichols, 2014), hyponatremia, hyperthermia, hypothermia, dehydration, and fatigue (Klingert et al., 2022; Racinais et al., 2015; Schwellnus et al., 2011). These alternating variations to which athletes must adapt make Swimrun a sport that requires further research to elucidate the effects of its practice. In this regard, research has examined how physiological responses change when the body is exposed to cold and heat (Castellani & Young, 2016; Wendt et al., 2007).

Physical exercise induces greater vasodilation, increasing sweat loss and cardiac output (Wendt et al., 2007). In contrast, exposure to cold reduces blood flow via vasoconstriction, with a substantial increase in metabolic rate to generate heat (Castellani & Young, 2016). These effects produced by alternating cold and heat -cold-heat is known as thermoregulatory fatigue (Castellani et al., 2010), possibly causing an attenuated response when the athlete is exposed to cold after a race, creating problems for the athlete's safety and lower performance due to exposure to colder core temperatures (Castellani & Tipton, 2015).

Other studies have shown that acclimatization to heat improves physical performance during heat exposure (Schmit et al., 2018), and that cold immersion improves performance in cold environments (De Paula et al., 2018). However, it has been concluded that the adaptive process is greater when cold water immersion occurs statically (Roberts et al., 2015). Failure to replenish fluids (hypohydration) during high-demand sports can compromise athletes' health and reduce athletic performance (McDermott et al., 2017). Maintaining adequate hydration levels supports sustained athletic performance, improved metabolic heat dissipation (Casa et al., 2010; MacLeod & Sunderland, 2012), stable mood (Ganio et al., 2011), and improved recovery (Armstrong, 2021; Vanderlei et al., 2015). Intense exercise with heat exposure can induce acute kidney injury, underscoring the need to study changes in kidney biomarkers in endurance athletes (McDermott et al., 2018). Urinary markers have also been used to assess hydration status, demonstrating that urine specific gravity and urinary osmolality vary with hydration status (Lee et al., 2017). It is important to understand how the body responds to this type of exercise, particularly with respect to hydration status, cardiovascular stress, and renal stress, as reflected in urinary biomarkers.

The selection of urinary protein, urinary pH and urine-based hydration indicators as primary outcomes is grounded in the specific physiological demands imposed by the repeated alternation between swimming and running. During the swimming segments, the horizontal body position and partial immersion increase central blood volume and cardiac filling pressures, and modify renal perfusion and diuresis (Epstein, 1992), whereas the subsequent running segments impose an upright posture, a greater thermal load and a redistribution of blood flow towards the skin and the active musculature. This alternating haemodynamic pattern reduces renal plasma flow and modifies the filtration fraction, which increases the filtered load of low-molecular-weight proteins and may transiently exceed tubular reabsorption capacity, producing the mixed glomerular-tubular proteinuria classically described after exercise (Clerico et al., 1990; Poortmans, 1984; Suzuki & Ikawa, 1991). In parallel, the accumulation of hydrogen ions during high-intensity intermittent efforts is buffered in part through renal acid excretion, a process that is expressed as a change in urinary pH (Poortmans, 1984). Finally, urine specific gravity and urine solids provide a practical, field-applicable estimation of hydration status, which may be compromised by the combination of exertional sweat losses and immersion-induced diuresis (Lee et al., 2017). Taken together, these three domains, renal filtration stress, acid-base regulation and body water balance, constitute a coherent and non-invasive framework with which to characterise the acute internal load of a swimrun event, and they can be obtained in the field without interfering with competition.

To our knowledge, no study has analysed changes in urinary indicators and heart rate, or their potential interactions with performance, in adult recreational athletes. Therefore, the objective of the study was to describe changes in urinary parameters and heart rate dynamics, and to examine their potential associations with performance parameters, in adult recreational athletes. On the basis of the rationale outlined above, three a priori hypotheses were formulated: (i) the repeated short-distance format would elicit a transient increase in urinary protein and a fall in urinary pH, consistent with a moderate and reversible renal and acid-base challenge, but without changes in the urinary indicators that would suggest structural renal or urinary tract compromise; (ii) hydration status, estimated from urine specific gravity and urine solids, would remain within euhydration ranges, given the short total duration of the event and the temperate ambient conditions; and (iii) heart rate would remain high and stable across the four laps, with comparable relative cardiovascular demands in men and women.

METHODS

Study design

This was a descriptive, observational, and repeated-measures study (O'Donoghue, 2010). The swimrun consisted of laps, completing 1200 m of swimming followed by 6 km of running (i.e., 4 × [300 m swim + 1.5 km run]). All segments were completed without rest. The swimming stages were conducted in a 25-meter pool, and the running stages were completed on a flat asphalt circuit. The race was conducted at a temperature of 20°C and 85% humidity from 8:00 to 9:30 a.m. The protocol was deliberately conducted under standardised conditions (indoor 25-m pool and flat asphalt circuit) in order to isolate the physiological effect of the repeated swimming-running alternation from the environmental, thermal and technical variability inherent to open-water swimrun competition; the consequences of this methodological decision for the ecological validity of the findings are addressed in the Discussion and in the Limitations section. Fluid intake during the event was neither imposed nor restricted, and participants were instructed to follow their habitual pre-competition routine.

Participants

A convenience sample of 20 recreational adult athletes (n = 7♀, 13♂) voluntarily participated in the study. Inclusion criteria included being healthy, physically active, and capable of completing the entire swimrun protocol. All participants provided written informed consent before enrolment. The study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki (World Medical Association, 2024) and was approved by the institutional ethics committee of the University of Extremadura (22/2019). In order to contextualise the physiological responses observed, the training background of the participants was documented, including years of systematic endurance training, weekly training volume ($h \cdot week^{-1}$ and $km \cdot week^{-1}$ of swimming and of running), previous experience in swimrun or other multisport events, and habitual participation in endurance competitions; these data were collected for contextual purposes. Menstrual cycle phase, use of hormonal contraceptives and other indicators of hormonal status were not recorded. Because ovarian hormones may influence thermoregulation, plasma volume, fluid-regulatory responses and cardiovascular behaviour during exercise, this is explicitly acknowledged as a potential source of variability within the female subgroup and is considered when interpreting the sex-related findings (Elliott-Sale et al., 2021).

Materials and procedures

Before the swimrun, participants self-reported their age and biological sex. Body mass was measured using a Tanita BC-730F scale (Tokyo, Japan) with 0.1 kg precision. Height was measured using a portable stadiometer (Seca 213, Hamburg, Germany) with 0.1 cm precision. Height was measured using a portable stadiometer Seca, 213 (Hamburg, Germany), and body mass index (BMI) was later calculated. Urine samples were collected before and immediately after the swimrun event. The urine analysis was performed using Roche Combur-Test® UX (Basel, Switzerland) and Combur-Test® M strips (Basel, Switzerland), which allow semi-quantitative assessment of multiple parameters, including pH, leukocytes (LEU), nitrites (NIT), proteins (PRO), glucose (GLU), ketones (KET), urobilinogen (UBG), bilirubin (BIL), haemoglobin/blood (Hb). Urine specific gravity (USG) and urine solids were also analysed to estimate hydration status. Visual reading and scoring of the colorimetric results were done by trained researchers following the manufacturer's guidelines. To minimise observer-related variability, all pre- and post-race strips were scored by the same trained researcher throughout the study, under identical artificial lighting, at the reaction time specified by the manufacturer for each reagent pad and against the reference colour chart supplied by the manufacturer; each result was subsequently checked by a second trained researcher, and the few discrepancies were resolved by consensus. It should be noted that reagent-strip urinalysis provides screening-level, semi-quantitative information and does not offer the analytical sensitivity or precision of laboratory-based biochemical assays (Simerville et al., 2005).

Urine strip test parameters provide either qualitative results, indicating the presence or absence of a substance (e.g., nitrites, leukocytes), or semiquantitative results, based on colorimetric changes that approximate concentration levels (e.g., protein, glucose, blood). Parameters like pH and specific gravity are typically reported as quantitative values. Swimming and running completion times were recorded for each of the four laps using a manual stopwatch worn by each athlete. Each stage time (swim and run) and total lap time were stored for later analysis. Heart rate (HR) was continuously monitored throughout the event using Garmin Forerunner 245 smartwatches (Taipei, Taiwan) with chest-strap heart rate monitors. Segment-specific heart rate data (swim and run) for each lap were extracted from the Garmin Connect platform post-event and averaged for analysis. In addition to absolute values, heart rate was expressed as a percentage of age-predicted maximal heart rate, estimated with the equation 208 − 0.7 × age (Tanaka et al., 2001), to allow a more meaningful comparison between sexes and with previous endurance-sport literature. Maximal heart rate was not determined by direct testing, and the limitations of this estimation are acknowledged.

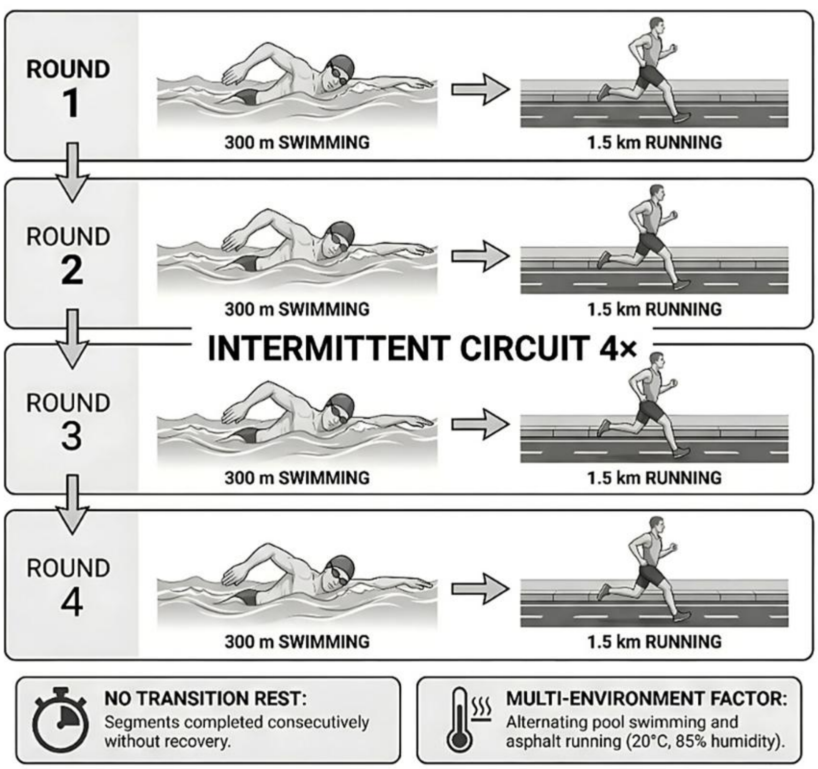

Figure 1. Repeated short-distance Swimrun protocol.

Statistical analysis

Descriptive statistics (mean ± SD) were calculated for all urinary biomarkers before and after the Swimrun. Normality was assessed using the Shapiro-Wilk test. Depending on data distribution, paired t-tests or

Wilcoxon signed-rank tests were used for pre–post comparisons. To analyse performance and heart rate changes across laps, repeated measures ANOVA or the Friedman test was applied, with Bonferroni or Wilcoxon post hoc tests as needed. Independent t-tests or Mann–Whitney U tests were used to assess sex differences. Correlations between heart rate, performance, and anthropometric variables (age, weight, height) were examined using Pearson or Spearman coefficients. Effect sizes followed Cohen's guidelines.

All analyses were performed using SPSS Statistics software for Windows (Version 26.0; IBM Corp, Armonk, NY, USA). Given the exploratory nature of the study, the interpretation of the results was based primarily on the magnitude and the precision of the effects rather than on statistical significance alone (Hopkins et al., 2009). Accordingly, exact effect-size values are reported throughout, together with 95% confidence intervals (CI) for pre-post mean differences, for standardised effect sizes and for correlation coefficients.

Standardised mean differences were computed as Cohen's d and corrected with Hedges' g because of the small sample size, whereas effect sizes for non-parametric comparisons were expressed as the rank-biserial correlation r; thresholds of .20, .50 and .80 (d and g) and of .10, .30 and .50 (r) were used to define small, moderate and large effects, respectively. Individual pre-post responses for each urinary biomarker and individual heart-rate trajectories across laps are presented as supplementary material to illustrate inter-individual variability.

In addition, exploratory multiple linear regression models were fitted, with the post-race change in urinary protein and in urinary pH as dependent variables and age, body mass and total race time as candidate predictors; because of the sample size, no more than two predictors were entered simultaneously in any model, and these analyses are interpreted as hypothesis-generating rather than confirmatory. No correction for multiple comparisons was applied, in line with the exploratory design, so the p-values reported should be read as descriptive. Statistical significance was set at $p < .05$.

RESULTS

The descriptive characteristics of the sample, including age, height, body mass, body mass index and predicted maximal heart rate, are presented in Table 1 for the whole group and separately for men and women.

Table 1. Descriptive characteristics of the participants for the whole sample and by sex.

Variable	Total (n = 20)	Men (n = 13)	Women (n = 7)	Mean difference [95% CI]	*p*	Hedges' g [95% CI]
Age (years)	27.6 ± 12.0 (18–52)	25.5 ± 11.4	30.7 ± 13.1	−5.2 [−17.6, 7.2]	.355[a]	−0.41 [−1.36, 0.55]
Height (cm)	169.8 ± 8.8 (155–183)	174.5 ± 5.9	162.4 ± 7.8	12.0 [5.2, 18.9]	.002	1.72 [0.62, 2.82]
Body mass (kg)	69.0 ± 5.4 (58–80)	70.8 ± 4.7	66.1 ± 5.6	4.7 [−0.5, 9.9]	.074	0.88 [−0.11, 1.87]
BMI ($kg \cdot m^{-2}$)	24.0 ± 2.3 (21.1–29.2)	23.3 ± 1.5	25.2 ± 3.0	−1.9 [−4.1, 0.3]	.088	−0.84 [−1.82, 0.15]
Predicted HRmax (bpm)	188.7 ± 8.4 (171.6–195.4)	190.1 ± 8.0	186.5 ± 9.2	3.6 [−5.1, 12.3]	.355[a]	0.41 [−0.55, 1.36]

Note. Values are mean ± standard deviation (range) for the whole sample and mean ± standard deviation for each sex. Mean difference and Hedges' g are expressed as men minus women; positive values indicate higher values in men. BMI = body mass index; CI = confidence interval; HRmax = maximal heart rate, estimated as 208 − 0.7 × age (Tanaka et al., 2001). [a] Mann–Whitney U test (variable not normally distributed, Shapiro–Wilk p < .05); all other comparisons by independent-samples t test.

Table 2. Pre–post analysis of urinary biomarkers and hydration status.

Biomarker	Pre	Post	W	*p*	Effect size [95% CI]
pH	5.83 ± 0.92	5.17 ± 0.38	4.0	.014	−0.85 [−1.00, −0.45]
Leukocytes	0.17 ± 0.51	0.06 ± 0.24	1.5	.750	−0.50 [−1.00, 1.00]
Nitrites	0.00 ± 0.00	0.06 ± 0.24	0.0	1.000	n.e.
Protein	0.22 ± 0.55	0.89 ± 1.13	4.0	.014	0.85 [0.46, 1.00]
Glucose	0.06 ± 0.24	0.33 ± 0.97	2.0	.375	0.60 [−1.00, 1.00]
Ketones	0.11 ± 0.47	0.00 ± 0.00	0.0	1.000	n.e.
Urobilinogen	0.00 ± 0.00	0.00 ± 0.00	—	—	n.a.
Bilirubin	0.11 ± 0.32	0.00 ± 0.00	0.0	.500	n.e.
Erythrocytes	0.00 ± 0.00	0.11 ± 0.47	0.0	1.000	n.e.
Haemoglobin	0.06 ± 0.24	0.22 ± 0.94	1.0	1.000	n.e.
Hydration marker	**Pre**	**Post**	**t**	***p***	**Effect size [95% CI]**
Urine specific gravity	1.0149 ± 0.0094	1.0199 ± 0.0239	0.81	.429	0.18 [−0.28, 0.65]
Urine solids (g·L⁻¹)	3.68 ± 2.47	3.19 ± 2.16	−1.11	.282	−0.25 [−0.72, 0.22]

Note. Values are mean ± standard deviation of the semi-quantitative reagent-strip categories (n = 20). Ordinal biomarkers were compared with the exact Wilcoxon signed-rank test (null differences excluded); W is the sum of the positive signed ranks. Effect size for these variables is the matched-pairs rank-biserial correlation r, with a 95% bootstrap percentile CI (20,000 resamples); positive values indicate an increase from pre to post. Hydration markers were compared with paired-samples t tests, and the effect size is Hedges' g for repeated measures. CI = confidence interval; n.e. = not estimable (fewer than three non-null differences); n.a. = not applicable (no variation in either measurement).

Table 3. Evolution of performance, heart rate and relative intensity during the event by sex.

Variable	Leg	Lap	Men (n = 13)	Women (n = 7)	*p*	Hedges' g [95% CI]
Time (min)	Run	1	8.90 ± 2.26	8.07 ± 2.23	.456	0.35 [−0.60, 1.31]
		2	9.04 ± 2.28	8.70 ± 2.27	.763	0.14 [−0.81, 1.09]
		3	8.13 ± 1.31	8.72 ± 1.97	.501	−0.35 [−1.31, 0.60]
		4	7.40 ± 0.76	7.34 ± 0.52	.852	0.08 [−0.87, 1.03]
	Swim	1	8.76 ± 2.21	6.49 ± 2.11	.047	1.00 [−0.01, 2.00]
		2	11.76 ± 5.50	6.95 ± 2.13	.021	1.01 [0.01, 2.01]
		3	6.95 ± 4.91	7.11 ± 2.40	.928	−0.04 [−0.98, 0.91]
		4	5.52 ± 0.08	5.88 ± 0.55	.137	−0.99 [−1.99, 0.01]
Heart rate (bpm)	Run	1	159.64 ± 16.32	171.89 ± 10.14	.067	−0.81 [−1.80, 0.17]
		2	162.09 ± 18.38	176.77 ± 11.69	.055	−0.86 [−1.85, 0.13]
		3	163.27 ± 16.13	176.29 ± 10.73	.057	−0.86 [−1.85, 0.12]
		4	165.09 ± 19.41	170.00 ± 6.71	.455	−0.29 [−1.25, 0.66]
	Swim	1	109.64 ± 13.07	128.57 ± 28.39	.138	−0.89 [−1.88, 0.10]
		2	134.42 ± 14.05	163.00 ± 20.59	.010	−1.62 [−2.71, −0.53]
		3	139.88 ± 14.61	160.57 ± 20.90	.046	−1.14 [−2.16, −0.12]
		4	141.96 ± 14.16	150.51 ± 15.31	.257	−0.56 [−1.52, 0.41]
Relative intensity (% HRmax)	Run	1	84.0 ± 8.1	92.2 ± 4.3	.013	−1.13 [−2.14, −0.11]
		2	85.3 ± 9.4	94.8 ± 4.0	.010	−1.16 [−2.18, −0.14]
		3	85.9 ± 8.1	94.5 ± 3.5	.008	−1.21 [−2.24, −0.19]
		4	87.0 ± 10.6	91.3 ± 4.7	.255	−0.47 [−1.43, 0.49]
	Swim	1	57.6 ± 5.5	68.7 ± 13.2	.070	−1.15 [−2.17, −0.13]
		2	70.7 ± 6.2	87.2 ± 8.6	.001	−2.19 [−3.38, −1.00]
		3	73.8 ± 9.2	85.9 ± 8.0	.010	−1.31 [−2.35, −0.27]
		4	74.8 ± 8.3	80.7 ± 7.2	.131	−0.71 [−1.69, 0.26]

Note. Values are mean ± standard deviation. Men n = 13, women n = 7. Comparisons between sexes were made with Welch's independent-samples t test, which does not assume equal variances and is appropriate for unequal group sizes. Effect size is Hedges' g, expressed as men minus women, so positive values indicate longer times or higher heart rates in men. Relative intensity is the heart rate of each segment expressed as a percentage of age-predicted maximal heart rate, estimated as 208 − 0.7 × age (Tanaka et al., 2001). CI = confidence interval.

Urinary protein increased significantly from pre to post (p = .014, r = .85 [.46, 1.00]), whereas urinary pH decreased significantly (p = .014, r = −.85 [−1.00, −.45]); both effects were large. Other biomarkers, such as glucose and haemoglobin, showed small, non-significant changes. Most remaining parameters (e.g., nitrites, ketones, urobilinogen, erythrocytes) showed no meaningful variation (Table 2). None of the indicators associated with urinary tract or structural renal compromise (nitrites, leukocytes, blood/haemoglobin, bilirubin and urobilinogen) showed statistically significant changes. The exact effect-size values and their 95% CI for all pre-post comparisons are reported in Table 2, and the individual pre-post responses of each participant are displayed in the supplementary material. For the biomarkers with fewer than three non-null differences the effect size was not estimable, and no inference is drawn from them.

Regarding hydration markers, urine specific gravity and urine solids did not change significantly (p > .05), with small effect sizes (Hedges' g = 0.18 and −0.25, respectively). Women showed consistently higher heart rates, especially in 2nd and 3rd lap (g = −0.86 for both), although these differences did not reach statistical significance. In swimming, the difference was large and statistically significant in the second and third laps (g = −1.62 and −1.14; p = .010 and .046), and large but non-significant in the first lap (g = −0.89), with higher values in females (Table 3).

Strong inter-lap HR correlations were found, especially between run 2nd and 3rd laps (r = .87) and run 1st and 2nd laps (r = .82). Age and weight showed moderate negative correlations with heart rate (e.g., age and 1st lap heart rate: r = –.48; weight and 1st lap heart rate: r = –.53), suggesting lower cardiovascular responses in older or heavier participants (Figure 2).

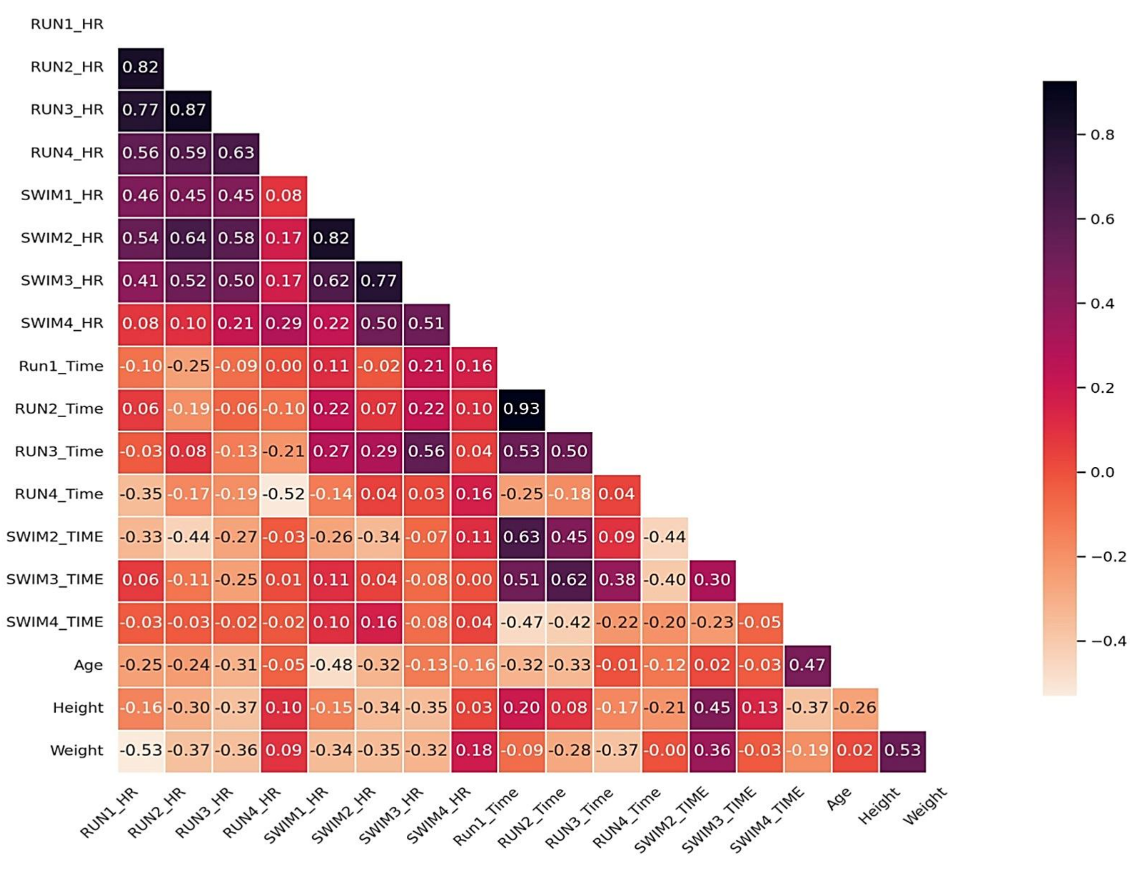

Figure 2. Correlations between heart rate, performance, and anthropometric variables.

When heart rate was expressed relative to age-predicted maximal heart rate, the mean relative intensity was 73.6 ± 8.1 % HRmax during the swimming segments and 88.5 ± 7.4 % HRmax during the running segments (Table 3). Relative intensity was consistently higher in women than in men, both in swimming (80.6 ± 6.6 vs 69.2 ± 5.5 % HRmax; $p = .003$; g = 1.84 [0.72, 2.96]) and in running (93.2 ± 2.9 vs 85.6 ± 8.0 % HRmax; $p = .012$; g = 1.11 [0.10, 2.12]), and the difference reached statistical significance in the second and third swimming laps and in the first three running laps. The running segments therefore elicited an intensity close to the maximum, whereas the swimming segments were performed at a clearly submaximal relative intensity.

In the exploratory regression models, age, body mass and total race time jointly explained a negligible and non-significant proportion of the variance in the post-race change in urinary protein ($R^2 = .015$, adjusted $R^2 = −.196$; $F(3, 14) = 0.07$; $p = .974$) and in the change in urinary pH ($R^2 = .105$, adjusted $R^2 = −.087$; $F(3, 14) = 0.55$; $p = .659$). No individual predictor approached significance in either model (all $p > .30$). These analyses therefore do not support an association between the anthropometric or performance variables measured and the magnitude of the urinary response; given the sample size and the number of predictors, they are reported as exploratory and require confirmation in larger cohorts.

DISCUSSION

The aim of this study was to evaluate athletic performance, hydration status, urinary biomarkers, and heart rate during a repeated short-distance swimrun race. A total of 20 athletes of both sexes were evaluated, and urine samples were collected before and after the race. During the competition, race time and continuous heart-rate monitoring were recorded. In this regard, few studies have reported on the demands that swimrun athletes may be subjected to (Geromont et al., 2021) and to our knowledge, this is one of the first studies to attempt to understand the level of physiological stress in competition by jointly evaluating urinary biomarkers, hydration status, and cardiovascular response.

Biomarkers and hydration status

The findings of the present study indicate that the repeated short-distance swimrun format can induce a moderate level of physiological stress. In this regard, most urinary biomarkers did not show significant changes associated with kidney damage; only changes in urinary pH and protein concentration were observed, indicating moderate acute physiological stress. Classic studies conducted more than 30 years ago have reported that exercise induces protein excretion in urine due to alterations in renal filtration processes (Suzuki & Ikawa, 1991), including in endurance sports such as cycling, among healthy untrained athletes (Clerico et al., 1990). Currently, this phenomenon continues to be reported similarly in ultra-endurance sports.

The study by Wołyniec et al. (2020) analysed the factors that influence post-exercise proteinuria in a marathon, observing that the albumin/creatinine ratio increased significantly from 6.41 to 21.96 mg/g at 42 km and from 5.37 to 49.64 mg/g at distances >40 km ($p < .05$), concluding that this response is mainly associated with the duration of the race rather than the intensity of the exercise. These findings are partially consistent with the results of the present study, as there is an increase in urinary protein concentration, but to a lesser extent, demonstrating that intermittent efforts generate acute renal stress without reaching exponential values such as those observed in long-duration tests, so the total duration of exercise is a determining factor in post-exercise renal physiological responses.

From a clinical standpoint, the magnitude of these changes deserves a cautious interpretation. Transient post-exercise proteinuria is a well-characterised functional phenomenon that typically appears within minutes of finishing exercise, peaks during the first 30 min of recovery and resolves spontaneously within 24-48 h, without histological or long-term functional consequences in healthy individuals (Clerico et al., 1990; Poortmans, 1984). Provided that the post-race values remained within the lower semi-quantitative categories of the reagent strip (Table 2), the response observed here is compatible with this benign, exercise-induced pattern rather than with a clinically meaningful renal challenge; this interpretation is reinforced by the absence of concomitant changes in blood/haemoglobin, leukocytes or nitrites, which would be expected if glomerular or tubular integrity had been compromised. It must be stressed, however, that no recovery sample was obtained, so the reversibility of these changes could not be documented and no inference regarding acute kidney injury can be drawn from the present data. The concurrent decrease in urinary pH, that is, a more acidic urine after the event, is consistent with the renal excretion of hydrogen ions that contributes to acid-base homeostasis after high-intensity intermittent exercise, although urinary pH is also influenced by diet, time of day and hydration status, and the resolution of the reagent pad (0.5-1.0 pH units) constrains the precision of this measurement. In addition, the protein pad detects mainly albumin and is insensitive to the low-molecular-weight proteins that characterise tubular involvement, so the renal response may have been only partially captured (Simerville et al., 2005). Taken together, these findings should be read as indicators of a moderate and presumably transient physiological stress, rather than evidence of renal impairment.

With respect to hydration status, the results did not show significant differences in urine specific gravity (p = .429) or urinary solids (p = .282), both with small effect sizes after the race, indicating that this format did not compromise water balance in terms of acute effects on athletes. In a study by Cutrufello et al. (2016) evaluating the hydration status of marathon runners, pre-exercise urine specific gravity values (1.009 ± 0.007) and post-exercise (1.018 ± 0.009) specific gravity values with a statistically significant difference (p < .001). In this regard, these results are inconsistent with our findings, possibly because marathon runners are exposed to longer durations than in the short swimrun format. Compared with previous studies, our results indicate that participants remained within the optimal range of euhydration. These initial findings and approaches to repeated short-distance swimrun courses are not associated with dehydration; however, further research is needed to expand the evidence.

Cardiovascular performance and response

Some studies have highlighted the importance of evaluating performance and physiological response between sexes in endurance sports such as swimming and triathlon, as this allows for an understanding of the differences and similarities in certain segments of the competition based on distinct physiological responses, such as relative heart rate and the contribution of the aerobic system (Thompson et al., 2000; Vleck et al., 2008). More recent research by Le Meur et al. (2009) recorded times and heart rates during a triathlon World Cup, enabling analysis of gender differences. The results of this study presented several relevant components: 1) swimming and running speeds were similar for both sexes (p < .05); 2) in men, speed showed a decreasing pattern over the course of the race; 3) women only showed reductions in speed on specific uphill and downhill sections (p < .05). Compared with our findings, the recorded times showed stable, sustained performance across laps, although the fastest times were recorded on the last lap. This apparent negative pacing must, however, be interpreted with caution, because the dataset was imputed and the fourth-lap splits are identical for two thirds of the sample; the pattern may therefore be an artefact of imputation rather than a genuine effort-management strategy.

The study by Le Meur et al. (2009) reports increase in the duration of the final execution stage; however, these findings do not align with our results. Another study by Leite et al. (2025) used data from the 2024 Paris Olympic Games triathlon competition. In this case, they recorded statistically significant differences between men and women (p < .001), with men performing better, clarifying that the greatest differences were in cycling, while in the running event, the results were more homogeneous, with men achieving 29.8% and women

29.5% of the total performance, which is consistent with our results, considering that there are no differences between the sexes in the swimming and running disciplines.

The cardiovascular response, monitored by heart rate, has been investigated by Le Meur et al. (2009), who reported similar responses in both sexes, with values of 92 ± 2 % and 92 ± 3% of maximum heart rate. In this regard, they report intensities greater than 90% based on maximum heart rates. The authors concluded that the athletes presented comparable results in swimming-running both in terms of times (performance) and heart rates (physiological). In the present study the relative cardiovascular demand differed markedly between the two modes of locomotion: the running segments elicited 88.5 ± 7.4 % of age-predicted maximal heart rate, a value close to the maximum and comparable to the triathlon literature, whereas the swimming segments reached only 73.6 ± 8.1 %, well below the values reported for open-water triathlon swimming. This gap is plausibly explained by the pool setting, the absence of a mass start and of open-water navigation, and the known attenuation of heart rate during horizontal, partially immersed exercise. Other background information on endurance tests combining up to three disciplines also reports relative heart rates of 89.8% ± 3.7% of maximum in swimming and 90.7% ± 5.1% in running (Aoyagi et al., 2021). In our results, women worked at a significantly higher relative intensity than men in the second and third swimming laps and in the first three running laps, with large, standardised differences, whereas the remaining segments showed moderate-to-large but non-significant differences. Overall, the running component of this swimrun format shows characteristics comparable to those of traditional endurance sports, whereas the pool-based swimming component does not.

The sex-related observations require a balanced reading. The moderate-to-large, standardised differences in heart rate reported here were derived from a subgroup of only seven women, so the corresponding confidence intervals are necessarily wide and remain compatible with both trivial and substantial effects. Under these conditions standardised effect sizes are known to be unstable and positively biased; equally, where differences did not reach statistical significance this cannot be interpreted as evidence of equivalence (Hopkins et al., 2009). These observations should therefore be regarded as exploratory and hypothesis-generating rather than confirmatory, and they are best interpreted alongside the relative intensities expressed as a percentage of age-predicted maximal heart rate, which allow a more meaningful comparison between sexes and with previous endurance-sport literature (Aoyagi et al., 2021; Le Meur et al., 2009). It should also be noted that menstrual cycle phase and hormonal contraceptive use, which may modulate thermoregulatory, cardiovascular and fluid-regulatory responses, were not controlled (Elliott-Sale et al., 2021), which adds a further source of unexplained variability to the female subgroup.

Beyond comparisons with triathlon and marathon running, the repeated alternation between swimming and running may pose a physiological challenge qualitatively distinct from that of conventional endurance events. Each transition entails a rapid change from a horizontal, partially immersed, upper-body-dominant mode of locomotion to an upright, weight-bearing, lower-body-dominant one. Head-out immersion produces a central translocation of blood volume with increased cardiac filling pressures and immersion diuresis, a state that is abruptly reversed on leaving the water, when orthostatic stress and the redistribution of blood flow towards the skin and the locomotor muscles predominate (Epstein, 1992). Superimposed on this are a thermoregulatory transition between a cooler aquatic environment and a warmer terrestrial one (Castellani & Young, 2016), the shift from the mechanically constrained breathing pattern of swimming to unrestricted ventilation during running, and the neuromuscular reorganisation required to change the dominant muscle groups. In triathlon, the transition between disciplines has been shown to modify the metabolic and mechanical efficiency of the subsequent segment (Bentley et al., 2002); in swimrun this phenomenon is not isolated but repeated, and it therefore constitutes a defining feature of the discipline. Conceptualising swimrun as a model of repeated multimodal transition, rather than as a mere sequence of swimming and running bouts, may help to explain why the cardiovascular demand observed here remained close to maximal despite the short duration of each segment, and it offers a testable framework with which to position swimrun as a distinct model within endurance sport.

A further consideration concerns the ecological validity of the protocol. The event was held in a 25-m indoor pool and on a flat asphalt circuit, whereas authentic swimrun competitions take place in open water and over varied, often technical terrain. Several features of real competition were therefore absent: cold-water immersion and the associated cardiorespiratory and thermoregulatory stress, waves, currents and reduced visibility, navigation demands, the continuous use of a wetsuit and of specific equipment, uneven or slippery running surfaces, elevation changes, and the paired team format that characterises most swimrun races. Each of these factors would be expected to increase cardiovascular strain, to alter pacing and to modify both thermoregulatory and fluid-balance responses; repeated entries into cold open water, in particular, add a cold-shock and immersion-diuresis component that was largely absent from the present pool-based protocol (Castellani & Tipton, 2015; Epstein, 1992). The stability of hydration status and the moderate renal response reported here should therefore be regarded as a conservative, best-case scenario, and their extrapolation to open-water swimrun competition is not warranted. Conversely, the degree of standardisation achieved made it possible to examine the effect of the repeated swimming-running alternation with minimal environmental confounding, which represents a necessary first step before field-based studies in authentic race settings.

Finally, in recent years, scientific evidence has enabled multivariate analyses to correlate multiple performance variables, including correlation matrices, with the aim of gaining a comprehensive understanding of sport (d'Hondt et al., 2024; Newans et al., 2022), which is particularly relevant in endurance sports. This analysis showed that, in the present results, heart rates and execution times were negatively correlated: segments of higher intensity, in which the cardiovascular response increases, were associated with shorter execution times (performance). A recent meta-analysis investigated how heart rate variables correlated with improvements in physiological markers and found that time spent working at high heart rates correlates with aerobic performance (Clemente et al., 2025), a finding supported by Castagna et al. (2011), who also report performance improvements when training time is between heart rate >90% and speed.

Practical applications

Within the limits imposed by a small, exploratory sample, several practical implications can be derived for coaches, sport scientists and race organisers. First, in short-format swimrun events held under temperate conditions, hydration does not appear to be a limiting factor, so aggressive fluid-replacement strategies seem unnecessary; ensuring pre-competition euhydration, verified with simple field tools such as urine specific gravity or urine colour, combined with drinking ad libitum, appears sufficient (Armstrong, 2021; McDermott et al., 2017). Second, because the cardiovascular demand remained close to maximal throughout the event despite the short duration of each segment, training prescription should include repeated swim-run transitions performed at high intensity rather than isolated continuous work in each discipline, and pacing advice should emphasise controlling the opening laps, given that the fastest split was recorded in the final lap and that a stable heart-rate profile was compatible with maintained performance. Third, the transient increase in urinary protein and the accompanying fall in urinary pH suggest that reagent-strip urinalysis may serve as a low-cost screening tool for post-race athlete monitoring: a persistent alteration in a follow-up sample obtained 24-48 h after competition, or the appearance of blood, leukocytes or nitrites, would warrant medical evaluation, whereas an isolated and self-limiting increase should not be interpreted as pathological. Fourth, because older and heavier participants showed attenuated heart rate responses, individual monitoring based on internal load is preferable to group-based external targets in the heterogeneous conditions typical of recreational events. Finally, organisers of short-format events under similar environmental conditions may reasonably prioritise safety supervision during the aquatic segments and the transitions, where the highest relative intensities and the largest haemodynamic changes are concentrated, and incorporate a brief pre-race screening of athletes reporting recent illness, febrile episodes or renal antecedents.

Limitations and future research

This research is among the first to examine the physiological and cardiovascular demands and performance in swimrun, although it is important to note the study's limitations. The first is that the sample size is small, which means that the data cannot be generalized or extrapolated to the entire population that practices discipline. Similarly, the format used was designed for repeated short distances; therefore, the results presented should not be interpreted in relation to longer formats or different environmental conditions. Secondly, the study focuses on acute effects, whereas it is necessary to investigate chronic effects by observing differences over longer periods with greater intervention. Finally, the assessment of hydration status was based solely on urinary biomarkers, without a broader battery of tests to monitor changes in body mass and assess the effects of water ingestion. Several additional limitations should be acknowledged. The urinary variables were assessed with semi-quantitative reagent strips read visually by a single non-blinded evaluator, without formal quantification of intra- and inter-rater reliability and without confirmatory laboratory analyses; this approach provides screening-level information only and cannot detect the low-molecular-weight tubular proteins or the specific injury markers required to characterise renal stress precisely (Simerville et al., 2005). No recovery sample was obtained, so the reversibility of the observed changes could not be documented. Maximal heart rate was estimated from age rather than measured directly, which introduces error into the relative intensities reported (Tanaka et al., 2001). The female subgroup comprised only seven participants, and menstrual cycle phase and hormonal contraceptive use were not recorded (Elliott-Sale et al., 2021); consequently, all sex-related comparisons are exploratory and hypothesis-generating. Body-mass change, sweat rate, fluid intake, core temperature, and perceived exertion were not quantified, thereby limiting interpretation of hydration and thermoregulatory status. Finally, the controlled pool-and-circuit setting discussed above limits the ecological validity of the findings, and no correction for multiple comparisons was applied, so the p-values reported should be considered descriptive.

Future research should extend these preliminary observations in several directions. The renal response would be characterised far more precisely by combining serum and urinary markers of glomerular filtration and tubular injury, such as cystatin C, neutrophil gelatinase-associated lipocalin (NGAL), kidney injury molecule-1 (KIM-1) and the albumin/creatinine ratio, with repeated sampling at 2, 24 and 48 h post-competition in order to document the time course and the reversibility of the changes (Lee et al., 2017; McDermott et al., 2018). Hydration should be assessed continuously and multidimensionally, combining pre- and post-race body-mass change corrected for fluid intake and urine output with plasma or urine osmolality (Armstrong, 2021). The thermoregulatory component of the discipline warrants particular attention, ideally through continuous monitoring of core and skin temperatures during repeated entries into cold open water (Castellani & Tipton, 2015). The inclusion of perceived exertion and wearable-derived metrics, such as heart rate variability, stroke rate, running cadence, and locomotor load, and their integration into multivariate models would allow the internal and external loads of each segment and each transition to be quantified (Newans et al., 2022). Finally, studies should be conducted in authentic competitive settings, with larger and better-characterised samples that permit adequately powered analyses by sex, with longer race formats, and with team-based designs that reflect the paired structure of most swimrun competitions.

CONCLUSIONS

This study provides new insights into the acute physiological responses elicited by repeated short distance swimrun formats in recreational athletes. The results revealed a significant increase in urinary protein and a significant decrease in urinary pH post-exercise, suggesting renal and acid-base stress despite the event's short duration. However, no substantial changes were observed in other urinary biomarkers, such as ketones, nitrites, or haemoglobin, indicating that the exercise did not trigger marked renal or metabolic disruption. As hypothesised, these changes occurred in the absence of alterations in the indicators suggestive of structural renal or urinary tract compromise; nevertheless, since the analyses relied on semi-quantitative reagent strips and no recovery sample was obtained, the findings describe a moderate and presumably transient physiological stress rather than renal impairment.

Hydration status, as assessed through urine specific gravity and urine solids, remained relatively stable, suggesting that participants maintained adequate hydration despite moderate cardiovascular strain. Heart rate data showed consistent within-individual patterns across laps and higher values in women, particularly during swimming stages, although sex-based differences were not statistically significant.

Negative correlations between heart rate and age or body weight suggest attenuated cardiovascular responses in older or heavier individuals. These findings highlight the potential roles of body composition and age in modulating perceived exercise intensity and physiological load. Overall, repeated short-distance swimrun challenges elicit measurable yet moderate physiological stress in recreational athletes, with implications for hydration strategies, performance pacing, and individual monitoring during multisport events. These conclusions derive from a small convenience sample evaluated under standardised pool-and-circuit conditions; the sex-related comparisons, based on seven women, must be regarded as exploratory and hypothesis-generating, and extrapolation to open-water swimrun competition requires confirmation in authentic race settings.

AUTHOR CONTRIBUTIONS

All authors meet the criteria for authorship in accordance with established ethical guidelines. Contributions are specified according to the CRediT (Contributor Roles Taxonomy) as follows: Conceptualisation: Daniel Rojas-Valverde. Methodology: Daniel Rojas-Valverde, Juan David Paucar-Uribe, Carlos David Gomez-Carmona, Aldo Vasquez-Bonilla. Formal analysis: Daniel Rojas-Valverde, Boryi A. Becerra-Patiño, Dionela Cáseres-Mighty, Valery Ramírez-Delgado. Investigation: Daniel Rojas-Valverde, Juan David Paucar-Uribe, Boryi A. Becerra-Patiño, Dionela Cáseres-Mighty, Valery Ramírez-Delgado. Data curation: Dionela Cáseres-Mighty, Valery Ramírez-Delgado. Writing – original draft: Daniel Rojas-Valverde. Writing – review & editing: Daniel Rojas-Valverde, Juan David Paucar-Uribe, Boryi A. Becerra-Patiño, Carlos David Gomez-Carmona, Aldo Vasquez-Bonilla. Supervision: Carlos David Gomez-Carmona, Aldo Vasquez-Bonilla.

All authors have critically reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all the subjects involved in this study.

DATA AVAILABILITY STATEMENT

The data is not publicly available because it contains information that could compromise the privacy of research participants.

AI USE DISCLOSURE

In accordance with current publishing ethics and transparency recommendations, artificial intelligence (AI) tools were used solely to assist with translation and language editing, with the aim of improving clarity and readability. No AI tools were used in the generation of scientific content, including the study design, data collection, analysis, interpretation of results, or the formulation of conclusions. The authors retain full responsibility for the content of the manuscript and confirm its originality, integrity, and accuracy.

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