Brief Report

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Brief Report

Proteinuria and Significant Dehydration in a Short-Steep Triathlon: Preliminary Report

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Abstract: Endurance triathlons impose substantial physiological stress, yet effects of short-course formats remain relatively unexplored. In this preliminary study, we assessed proteinuria and hydration levels in 27 well-trained triathletes (41.9 [7.4] years) who completed a sprint triathlon consisting of a 1500-m swim, 26-km cycle, and 8-km run. Urine samples were collected before and after the race. The results showed an increase in cases of post-race proteinuria from four to nine (p=0.03). Also, one case of urobilinuria and ketoacidosis was observed after the race. Pre-race glucosuria, which was present in nine cases, decreased to three cases post-race. Although hematuria cases decreased from six to two (p=0.13), pre-race leukocyturia (found in two cases) resolved post-race. There was a significant increase in urine specific gravity (from 1.018 to 1.023, p=0.03), indicating dehydration. In conclusion, short-course triathlons were found to induce post-race proteinuria, urobilinuria, and dehydration without exacerbating pre-race glucosuria, hematuria, or leukocyturia. These preliminary findings contribute to our understanding of medical guidelines for sprint triathlons, an area of endurance sports that has received limited research attention. Further investigation, both mechanistic and longitudinal, is warranted in this regard.

Keywords: physical endurance; renal function; exercise-induce dehydration; athlete health; urinary biomarkers; physiological stress

1. Introduction

Endurance sports, such as triathlons, impose considerable physiological stress on athletes, demanding exceptional cardiovascular fitness, muscle strength, flexibility, and mental stamina to complete [1]. Among these, the triathlon, consisting of sequential swimming, cycling, and running legs, is renowned as one of the most physically demanding single-day endurance events [2]. While the physiological demands of long-course triathlons like the Ironman have been extensively investigated [3], there is a relative dearth of knowledge regarding the effects of shorter, high-intensity

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triathlons that encompass the same sequence of disciplines. These shorter races, categorized as sprint or Olympic distance triathlons, feature shorter distances but greater exercise intensity, enabling athletes to maintain higher speeds across all legs [4].

One notable concern associated with prolonged and strenuous activities is exercise-induced proteinuria, characterized by the transient elevation of abnormal protein levels in urine following physical exertion [5]. Although typically reversible, recurrent instances may indicate underlying kidney damage or dysfunction [6]. The mechanisms driving transient proteinuria remain somewhat elusive, but it is likely linked to increased kidney blood flow and altered glomerular permeability induced by physical exercise [7]. Previous studies have reported proteinuria in a significant proportion of Olympic and Ironman triathletes after competition [8]. However, the effects of short, steep triathlon formats on this phenomenon have not been explored.

Adding to this complexity is the heightened risk of dehydration during triathlon events, which can extend for several hours, particularly in warm outdoor conditions. Substantial fluid loss can compromise endurance capacity, temperature regulation, and cardiovascular function [9]. Dehydration may also exacerbate temporary proteinuria by increasing blood viscosity, promoting renal vasoconstriction, and altering glomerular permeability [10]. This preliminary study aimed to evaluate proteinuria and hydration status in athletes participating in a short-course triathlon. We hypothesized that greater dehydration would correlate with higher post-race proteinuria levels. The findings from this study have the potential to enhance medical guidelines for this rapidly growing, yet understudied, format of endurance sport.

2. Materials and Methods

2.1. Study Design

This was repeated-measures observational study. Data were collected both before and after a competitive hilly triathlon that started with a 1500-m swim in a temperate 25-m indoor pool, followed by a 26-km cycling leg with a total ascend of 1100 m, and concluded with an 8-km run featuring a total ascend of 180 m. The triathlon took place under specific environmental conditions, with temperatures ranging from 23-25°C and relative humidity between 60-75%. Throughout the triathlon, participants and distance were continuously monitored using smartwatches. Additionally, urine components were assessed before and after the event.

2.2. Participants

Twenty-seven well-trained triathletes participated in the study, comprising 20 men and 7 women with a mean age of 41.9 (7.4) years, body mass of 70.1 (13.7) kg, stature of 1.7 (8.8) m, and a VO_{2max} of 57.6 (6.4) ml/kg/min. These participants were recruited from a pool of highly experienced ultra-endurance triathletes, boasting an average of 12.4 (5.2) years of experience in the field. Inclusion criteria required participants to undergo rigorous training, involving 5-6 weekly sessions lasting between 300 to 400 min/week. Additionally, male participants were expected to achieve a season best of under 20 minutes in a 5-km run, while female participants were required to attain a season best of under 25 minutes in the same running distance.

Prior to participating in the study, athletes received comprehensive information detailing the potential risks and discomforts associated with the testing procedures. They provided their informed consent, and the research adhered to the guidelines outlined in the Declaration of Helsinki (2013). Furthermore, the study underwent a thorough review and received approval from an Institutional Review Board (Reg. Code UNA-2019).

2.3. Outcomes

2.3.1. Anthropometry

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Body mass measurements were obtained using a digital scale (Elite Tanita-Ironman® Series BC554, Illinois, United States of America) with a sensitivity of 0.1 kg. Stature measurements were taken to the nearest 0.1 cm using a stadiometer (SECA 213, Hamburg, Germany).

2.3.2. Physical Performance

Maximum oxygen consumption (VO_{2max}) was assessed with a gas analyzer device (VO 2000, MedGraphics®) and the BreezeSuite® software. The VO_{2max} testing was conducted on a treadmill (T5, Lifefitness, Illinois, United States of America) following an incremental intensity protocol developed by Martin & Coe [11]. The protocol consisted of a 3-minute warm-up, followed by a gradual increase in speed (1 km/h) every three minutes until the participants reached volitional fatigue. The gas analyzer had an accuracy of within ±3% for absolute volume measurements [12]. Speed, distance, and time were monitored using a smartwatch (Forunner 745, Garmin, Kansas, United States of America). Participants completed the laps between disciplines and transitions independently, with distances verified by event judges at the conclusion.

2.3.3. Urine Collection and Analysis

Prior to and following the triathlon, urine samples were collected on-site using sterile 30 mL polypropylene containers (Nipro Medical Corp., Osaka, Japan). Subsequently, these samples underwent analysis employing highly sensitive and accurate dipsticks specifically designed for urine screening (Combur10Test M, Roche, Mannheim, Germany) [5,13]. The analysis was conducted immediately after collection by two independent microbiologists who compared the results against the color scale provided by the manufacturer. In case of discrepancies between the two observers, a third researcher's opinion was sought to reach a consensus. None of the participants reported any urination difficulties or discomfort.

The urine samples were screened for several parameters, including leucocytes, erythrocytes, bilirubin, ketones, nitrites, protein, glucose, and urobilinogen. Trace amounts were considered negative, while scores greater than one was recorded. The interpretation of the urine test results was as follows: a score above one indicated leucocytes counts greater than 10 cells/μL, erythrocytes count greater than 5 cells/μL, bilirubin levels higher than one, ketones higher than one, positive nitrites, protein levels exceeding 30 mg/dL, glucose levels higher than 50 mg/dL, and urobilinogen levels higher than 1 mg/dL.

2.3.4. Hydration status

To assess the hydration status of the participants, urine specific gravity (USG) was determined. This measurement involved an evaluation of urine solids, with USG values confirmed utilizing a handheld digital refractometer (Palm AbbeTM, Misco, Solon, Ohio, United States of America) [14]. Prior to usage, the refractometer underwent appropriate cleaning and calibration. The classification of hydration status based on USG values was categorized as follows: well-hydrated (USG < 1.01), minimal dehydration (USG = 1.01–1.02), significant dehydration (USG = 1.02–1.03), and severe dehydration (USG > 1.03) [15]. Employing these methods, valuable insights into the hydration levels of the participants throughout the study were obtained.

2.4. Statistical analysis

The data were presented as mean and standard deviation (SD) or frequencies for relevant distributions. A significance level of 0.05 was predetermined, and the critical value was calculated based on the sample size and alpha level. Statistical analysis of the data collected was conducted using IBM SPSS® (IBM Corp., Armonk, New York, United States of America). The association between pre- and post-event urine component outcomes was assessed using a Chi-squared test for within-subjects (McNemar's Test). Additionally, the Wilcoxon (Z) parametric test was employed to explore the differences in the number of cases of specific urinary conditions (pre vs. post).

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Furthermore, a paired t-test was selected to analyze potential variations in USG, with normal distribution confirmed using the Shapiro-Wilk Test.

3. Results

The triathletes completed the swimming section at an average pace of 2:00 min/100m, the cycling section at an average pace of 15.43 km/h, and the subsequent running section at a pace of 5:38 min/km.

Table 1 presents the number of cases per urine component based on the results and assessment time-point. The findings indicate the presence of glucosuria (n= 9) and proteinuria before the start of the event (n= 4). Moreover, following the event, there was a 133% increase (five new cases) in proteinuria cases. Additionally, one case of urobilinuria and ketoacidosis was reported.

Table 1. Distribution of urine components by outcome and measurement time-point.

Variable	Outcome	Pre		Post	
		n	%	*n*	%
Bilirubin	Negative	27	100	27	100
Urobilinogen	Negative	27	100	26	96.30
	70mg/dL	0	0.00	1	3.70
Ketones	Negative	27	100	26	96.30
	1+	0	0	1	3.70
Glucose	Normal	13	48.10	24	88.90
	50 mg/dL	9	51.90	3	11.10
Protein	Negative	23	85.20	18	66.70
	30mg/dL	2	7.40	3	11.10
	100mg/dL	2	7.40	5	18.50
	500mg/dL	0	0.00	1	3.70
Erythrocytes	Negative	21	77.80	25	92.60
	5-10 cells/µL	6	22.20	1	3.70
	250 cells/µL	0	0.00	1	3.70
Nitrites	Negative	26	96.30	26	96.30
	Positive	1	3.70	1	3.70
Leucocytes	Negative	25	92.60	27	100
	10-25 cells/µL	2	7.40	0	0.00

Table 2 presents the number of positive cases of urobilinuria, ketoacidosis, glucosuria, proteinuria, hematuria, leukocyturia, and urine nitrates. Pre-post associations were observed in cases of urobilinuria, ketoacidosis, and urine nitrates, with each health condition having only one case. Additionally, there was a statistically significant change in the number proteinuria cases (Z= 29.60, p= 0.03). The results of the paired t-test indicated a significant increase in USG when comparing pre vs post values (1.018 ± 0.009 vs 1.023 ± 0.005; t= 2.26, p= 0.03).

Table 2. Association between cases above normal/negative values by evaluation time-point.

Variable	Pre		Post		Z (Wilcoxon)	p-value	X^2	p-value	McNemar´s Test Value
	n	%	n	%					
Bilirubin (≥1+)	0	0.00	0	0.00	0.00	1	-	-	-
Urobilinogen (≥ 8mg/dL)	0	0.00	1	3.70	0.00	1	22.00	<0.01	1
Ketones (>1+)	0	0.00	1	3.70	1	0.32	22.00	<0.01	1
Glucose (≥50 mg/dL)	9	51.90	3	11.10	2.12	0.03	0.95	0.33	0.07
Protein (>30 mg/dL)	4	14.80	8	29.60	1.16	2.49	1.20	0.28	0.39

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Erythrocytes (≥5 Cells/μL)	6	22.20	2	7.40	1.41	0.16	0.83	0.83	0.29
Nitrites (Positive)	1	3.70	1	3.70	0.00	1	22	<0.01	1
Leucocytes (≥10 Cells/μL)	2	7.40	0	0.00	1.41	1.16	-	-	-

4. Discussion

The aim of this preliminary study was to assess proteinuria and hydration status in athletes participating in a short-distance triathlon. Several noteworthy findings emerged from the study, including instances of proteinuria, urobilinuria, and significant dehydration induced by participation in the short-distance triathlon.

The increase in the number of proteinuria cases post-race aligns with previous research demonstrating elevated proteinuria rates among Olympic and Ironman triathletes [5,8]. While the frequency of cases observed in our study is lower than that reported in previous studies of ultramarathon athletes [16], the mechanisms underlying exercise-induced proteinuria likely involve heightened renal blood flow and altered glomerular permeability resulting from extreme physical exertion [7]. One notable case of post-race urobilinuria was reported, indicating potential acute kidney injury that warrants further medical investigation [10]. Previous research has reported significant associations between biochemical markers of acute kidney injury and continuous downhill running training in hot environments (33°C). Endurance training or competitions in hot conditions have been shown to increase plasma interleukin-6 levels and biomarkers of kidney injury, suggesting that this type of training, combined with heat exposure, may trigger counterproductive physiological responses to health [10,17].

Regarding the presented case of urobilinuria and ketoacidosis, further studies are necessary to elucidate potential mechanisms involving accelerated red blood cells destruction or alterations in bilirubin metabolism by this type of competition. However, it is essential not to discount the possibility of hepatic or hemolytic issues, as well as challenges in muscular heat dissipation, in this athlete [18]. Ketoacidosis, while more common in triathletes or endurance athletes due to their reliance on fat as an energy source when insulin levels decrease, should be noted for its potential health hazards. Nevertheless, ketogenic diets garnered attention as nutritional strategies to enhance performance in endurance sports like triathlons in recent years. These diets focus on increasing oxidative metabolism for energy production, potentially improving endurance and performance in prolonged activities. However, it is crucial to emphasize that while ketogenic diets may offer benefits for some athletes, they also carry risks and side effects if not appropriately followed or tailored to individual needs and conditions. Therefore, athletes considering implementing a ketogenic diet should seek professional guidance and supervision to ensure it is adjusted correctly to their goals and nutritional requirements, thus mitigating potential health complications [19].

On the other hand, some cases of glucosuria, proteinuria, hematuria, leukocyturia, and dehydration were observed before the competition. Interestingly, pre-race glucosuria did not worsen with triathlon exertion; instead, it decreased post-race. This contrasts with previous findings indicating that endurance exercise can exacerbate glucosuria in athletes with diabetes [20]. Skeletal muscle contractions during competition may have stimulated glucose transport and uptake by active muscles. Physical exercise has been shown to increase glucose uptake substantially, depending on its duration and intensity, partly due to the activation of various cellular signaling pathways to ensure energy supply during exercise [21]. In our study, the progressive nature of the cycling and running course may have enhanced glucose uptake at the cellular level, although this aspect has not been specifically documented in the context of triathlons. Furthermore, training in hypoxic environments has been found to stimulate cellular signaling responsible for glucose transport, accompanied by positive changes in some glucoregulatory hormones [22]. Pre-race hematuria and leukocyturia were also resolved after the competition, suggesting that short triathlons may help clear minor urinary

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anomalies. This phenomenon is consistent with findings related to light and moderate physical activity [17].

Finally, participation in the triathlon significantly increased USG, indicating dehydration. This aligns with studies demonstrating a worsening of hydration status in longer triathlons [9]. Dehydration can exacerbate exercise-induced proteinuria by increasing blood viscosity, renal vasoconstriction, and glomerular permeability [10,23]. It is essential to note that dehydration often leads to exercise-associated hyponatremia, where the concentration of sodium in blood, plasma, or serum decreases to abnormally low levels (< 135 mmol/L). This condition can manifest symptoms ranging from mild, such as nausea, muscle cramps, and weakness, to severe, including confusion, seizures, and even coma (exercise-associated hyponatremic encephalopathy) [24]. However, this aspect has received limited attention in the context of short-distance triathlons [25].

3.1. Limitations

This study has certain limitations. These include a relatively small sample size and the absence of a non-exercising control group. Furthermore, the assessment of post-race proteinuria relied on a single urine sample, whereas multiple measurements could offer a more comprehensive picture of peak proteinuria levels. While dipstick urinalysis enabled rapid screening, the utilization of more advanced urine and blood markers such as urine protein-creatinine ratios, cystatin-C, NGAL, KIM-1 could enhance the precision of the analysis regarding conditions as acute kidney injury.

3.2. Practical Recommendations

From a practical perspective, these findings suggest that athletes should engage in post-competition monitoring of urine biomarkers to identify potential instances of proteinuria or dehydration. To mitigate these risks, athletes may benefit from adopting preventative strategies such as maintaining proper hydrating and allowing sufficient kidney recovery between intensive training sessions. Several key considerations should be considered:

- Tailoring fluid and electrolyte supplementation during and after short-distance triathlons to individual athlete's specific requirements, rather than relying on generalized approaches.
- Vigilantly tracking changes in athletes' body composition, particularly among those who experience substantial weight loss following training or competitions, as this can disrupt fluid and sodium balance.
- Athletes who exhibit proteinuria, urobilinuria, and severe dehydration accompanied by symptoms indicative of post-competition hyponatremia should undergo comprehensive clinical evaluation for enhanced biochemical diagnosis and, if necessary, receive appropriate medical attention.
- The establishment of educational initiatives targeting short-distance triathlon athletes, coaches, and sports leaders is crucial. These programs should emphasize safe fluid replacement practices, aiming to prevent both excessive fluid intake and inadequate hydration during training and short-distance triathlon competitions.

5. Conclusions

This preliminary study has revealed that participation in a short, high-intensity triathlon has notable effects on trained athletes, inducing post-race proteinuria, urobilinuria, and significant dehydration. The incidence of proteinuria cases increased significantly from pre- to post-race. Furthermore, one instance of post-race urobilinuria and ketoacidosis surfaced, suggesting potential kidney dysfunction. Conversely, pre-race glucosuria, hematuria, and leukocyturia did not worsen due to triathlon exertion; instead, these conditions either decreased or resolved after the race. These findings underscore the substantial physiological stress imposed on kidney function and hydration status by short-distance triathlons, despite their abbreviated distances. Further research, encompassing mechanistic and longitudinal aspects, is essential to gain a more comprehensive understanding of the health implications associated with this relatively understudied yet increasingly popular sport format.

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