CASE STUDY

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Mechanical power, energy cost and performance comparison between two ultra-cycling world records: a case study

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Abstract

Introduction. **Ultra-cycling is a complex sport and a variation of individual characteristics.** Aim of Study. **This study aimed to analyze the mechanical power, energy cost, and performance (estimated time of arrival – ETA) between the old (OWR) and new (NWR) 24-hour road cycling world record.** Material and Methods. **An experienced ultra-cyclist broke the world record (WR) for the second time in 24-hour road cycling. Split times (intervals of 6 h) were used to evaluate the racing performance (0-6 h; >6-12 h; >12-18 h; >18-24 h), to compare the performance between OWR and NWR regarding power to overcome the drag (Pd), power for rolling resistance (PRR), total mechanical power (PTOT), energy cost (Ec) and ETA. One-way ANOVA was used to compare OWR and NWR. Effect size was presented using Cohen's *d*.** Results. **The 6-hour split times allowed to compare the WRs and statistically significant changes ($p < 0.05$) were found for all the assessed variables [Pd (W), PRR (W), PTOT (W), Ec (J/m), Ec (J/Lap), Ec (Kcal/Lap), and ETA (s)]. The comparisons for the variations intra-WR showed significant differences ($p < 0.05$) for all variables between split times. For the OWR, no statistically significant differences were noted between 6-12 h and 12-18 h for PRR, Ec (J/Lap and Kcal/Lap) and ETA. For the NWR, no statistically significant differences were found for the split time between 6-12 h and 12-18 h for Pd, PRR, PTOT, Ec and ETA.** Conclusions. **The cyclist's ability to deliver more mechanical power and energy cost in setting the NWR allowed him to break the 1000 km in 24 h record and establish an NWR. The variable with higher effect was Pd in both WRs and the lower effect was observed in Ec for the OWR and PRR for the NWR.**

KEYWORDS: ultra-cycling, case study, mechanical power, ultra-endurance, exercise.

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Introduction

As a professional or recreational activity [1], cycling is one of the most popular sports in the world. Most research in cycling aims to understand the factors associated with performance [2, 3]. Among those factors, the role of biomechanics has been highlighted in cyclists' performance [4]. Different equipment, materials, designs, body positions, and training programs have been assessed by different methodologies [5-8].

Additionally, the interaction between biomechanics and physiology allows the exploration of participants' performance by presenting some specificities as far as race characteristics [9-10] are concerned.

Ultra-cycling has recently attracted the attention of the cycling fraternity [2]. Its popularity has been increasing over time and studies have emerged in the last few years [11, 12]. Part of this emerging field of study was developed to analyze the performance of participants in competitions, aiming to explain world records (WRs). A recent study was published about Christoph Strasser's world record – breaking the 1000 km in 24 hours nonstop cycling record [2]. Considering the complexity of sports performance, a plethora of factors may justify the achievement of WRs. Racing strategies, individual options, bicycles, racing positions, the weather, pacing, exercise intensity and motivation are among some of the assessed factors [8, 13, 14]. However, in time-based sports, winning (time) depends on mean maximal velocity (Equation 1).

$$v = d / t \quad (1)$$

In Equation 1, v, d and t are velocity, distance, and time, respectively. Thus, it is possible to estimate the winning time (performance: estimated time of arrival – ETA) (Equation 2).

$$ETA = v / d \quad (2)$$

Velocity is obtained by the cyclist's ability to deliver the required amount of mechanical power (PTOT) to overcome the resistance [15]. PTOT results from the power to overcome drag, power of bearing friction, power for rolling resistance, changes in potential energy, changes in kinetic energy and mechanical efficiency. Finally, the cyclist's energy cost (Ec) will be dependent on the kinetic and lost energy for a given velocity or pace. Additionally, Ec depends on the level of resistance (Equation 3), where the drag and rolling resistance are the most important resistive forces [16].

$$Ec = (CR.m.g + 0.5.p.A.C_d.v^2) / n \quad (3)$$

Where CR is rolling resistance coefficient, m is mass, g is gravity, p is air density, A is area, C_d is coefficient of drag, v – velocity and n – mechanical efficiency. So, the cyclist's mechanical power should be enough to overcome the resistive forces and accelerate (Equation 4) [17].

$$a = (PF - RF) / m \quad (4)$$

Where a is acceleration, PF is propulsive forces and RF is resistive forces. Most studies focus the analysis on the WR in pacing [12, 18]. So far, only one study assessed the new Christoph Strasser's WR, breaking the barrier of 1000 km in 24 hours [2]. The study provided information about mean mechanical power, drag and efficiency. Pacing and intensity variables were assessed by split times of 6 hours. However, the authors failed to justify the biomechanical reasons for the cyclist to break the WR, especially the resistance and mechanical power variations during the race. Upon that, the aim of this study was to analyze the mechanical power, energy cost and performance (ETA) between the old (OWR) and new (NWR) WRs by analytical procedures. This study will allow us to understand the cyclist's biomechanical profile and when the performance (ETA) allowed to break the WR.

Material and Methods

The athlete

Our subject is a male professional ultra-cyclist. In 2015, the participant set a WR [12] and another WR in 2017 [18]. Within 365 days prior to the first WR, he invested 1,093 h of training with training stress score (TSS) of 44,300. At that time he was 1.86 m tall and weighed 78 kg. He increased training to 1,101 h with TSS of 44,345 in the 365 days preceding the second WR. In comparison with the initial WR, the subject prepared for the second one with higher intensity interval training and lower intensity basic training.

The events

The first WR was stablished on March 20, 2015 at the Tempelhof Airport in Berlin, Germany. The participant completed laps of 11.7 km around the airport; each lap was shaped like an '8' with a start and finish area. The course was 50 m above the sea level. The mean temperature was 3 degrees Celsius. The cyclist took ten breaks to use the toilet and change his clothes. On the second day at 1:00 pm, he suffered a flat tire and wore a different outfit during time trials [2, 12].

The cyclist attempted to beat the record in 24-hour road cycling once more in 2021. He completed 136 circuits over a 7.58 km route at the Zeltweg Air Base from July 16, 5:00 p.m., to July 17, 5:00 p.m., setting a total distance of 1026.2 km at an average cycling speed of 42.8 km/h. The course is located at 670 m above sea level, the weather was cloudy, the temperature stayed constant at 15 degrees Celsius, and it rained intermittently for 9 h as he was trying to complete the race. It was necessary to take a 2-minute stop to change the bike and clothes [2].

Procedures

Aerodynamics
It is possible to estimate the drag for the cyclist based on velocity, the weather and the participant's anthropometrics [2]. The drag equation (4) is presented below.

$$Fd = 0.5pAC_d v^2 \quad (4)$$

The procedures to calculate the drag for the OWR and NWR were set in a previous research [2].
The cyclist anthropometrics allowed to assess A and C_d by the equations 5 and 6, respectively [16, 19].

$$A = 0.0293h^{0.725}m^{0.425} + 0.0604 \quad (5)$$

$$C_d = 4.45m^{-0.45} \quad (6)$$

Where h is the subject's height and m is body mass.

Mechanical power
The cyclist's total mechanical power (PTOT: Equation 7) was given by the sum of power to overcome drag (Pd) and power for rolling resistance (PRR), as used in previously published research [8, 19].

$$PTOT = Pd + PRR \quad (7)$$

Where Pd results from the multiplication of Fd by speed (Equation 8) and PRR results from the multiplication of rolling resistance (Equation 9) by speed (10).

$$Pd = Fd.v \quad (8)$$

$$PR = CR.m.g \quad (9)$$

$$PRR = RR.v \quad (10)$$

The energy cost (Ec) was calculated by Equation 3 based on the values reported in a previous research [2].

Statistical analysis
Descriptive information was presented in mean ± standard deviation (SD). The normality of the distribution was confirmed via the Kolmogorov–Smirnov test and by inspection of the histograms and Q-Q plots. Intervals of 6 hours were used to assess the race time (0-6 h; >6-12 h; >12-18 h; >18-24 h) and the comparisons between the old and new WRs (ANOVA; and eta squared: η^2) regarding Pd, PRR, PTOT, Ec and ETA. The split times were compared with the Bonferroni post hoc test. The effect size was presented with Cohen's d, where the interpretation was considered as without effect if $d < 0.2$, moderate effect if $0.2 \leq d \leq 0.8$ and large effect if $d > 0.8$ [20, 21]. For the η^2, the values of 0.01, 0.06, and above 0.14 were considered small, medium, and large, respectively [21]. The significance level was defined as 5% for graphical and statistical analyses. The statistical analyses were made with IBM SPSS Statistics for Windows (Version 27.0., IBM Corp., Armonk, NY, USA).

Results

Descriptive analysis
The drag varied between 10.14 N and 21.89 N for the two races. Lower drag values were observed in the OWR (10.14-18.40 N) in comparison to the NWR (11.87-21.89N). Also, Pd was lower in the OWR (86.09-211.78 W) in comparison to the NWR (108.17-258.54 W). Figure 1 depicts the drag (bottom panel) and Pd

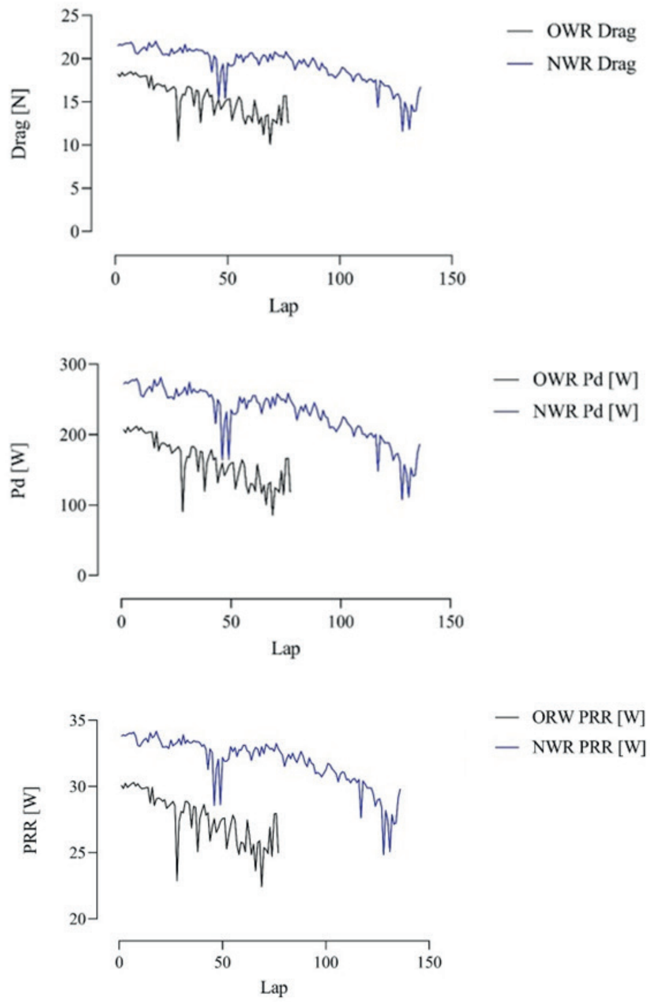

Figure 1. Drag (top panel) and power to overcome drag (Pd) variations (middle panel) and power for rolling resistance (PRR; bottom panel) for the old (OWR) and new world record (NWR)

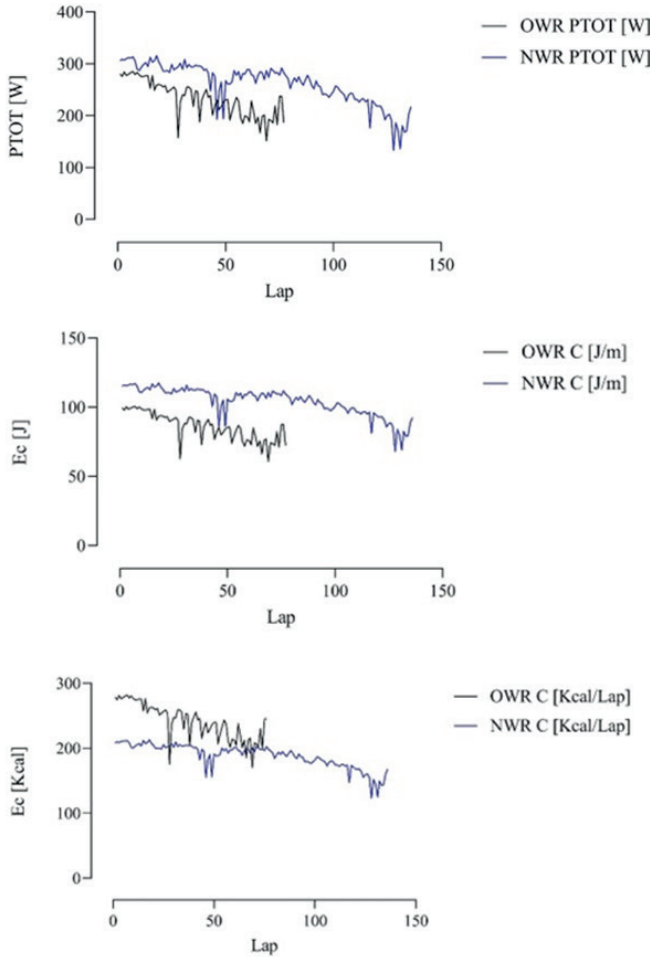

Figure 2. Total mechanical power (PTOT; top panel), energy cost (Ec) variations in J/m (middle panel), Kcal/m (bottom panel) for the old (OWR) and new (NWR) world record

variations (middle panel) for the OWR and NWR. The estimated rolling resistance was 2.64 N for the OWR and 2.67 N for the NWR. PRR varied between 22.44 and 30.29 W, whereas for the NWR, it varied between 24.85 and 33.22 W. The bottom panel in Figure 1 depicts the PRR variations for the OWR and NWR.

PTOT was higher in the NWR (133.02-291.76 W) in comparison to the OWR (151.53-285.06 W). In Figure 2, the top panel represents the PTOT variations for the OWR and NWR. The energy cost (Ec) per meter and lap was higher in the NWR (68.13-111.77 J/m) in comparison to the OWR (60.84-100.53 J/m) and the same was observed when the Kcal/m/lap variable was analyzed. Figure 2 represents the energy cost in J/m (middle panel) and Kcal/m (bottom panel) for the OWR and NWR.

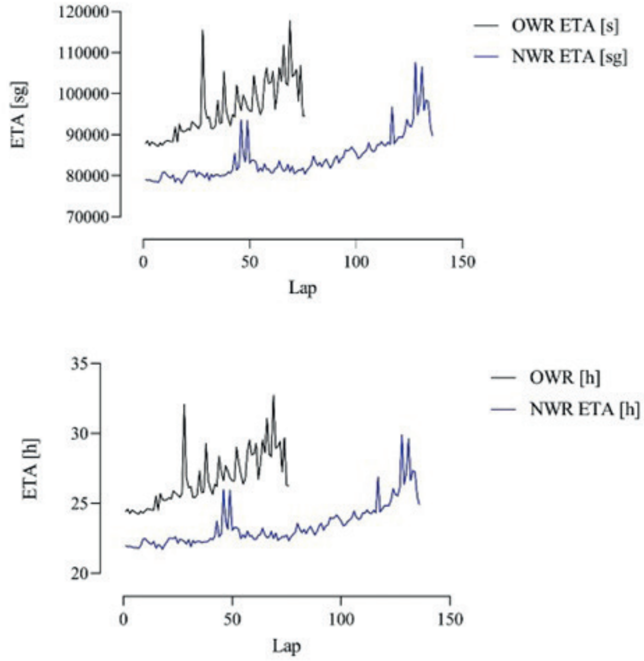

Figure 3. Variations of the estimated time of arrival (ETA) for the old (OWR) and new (NWR) world record in seconds (top panel) and hours (bottom panel)

The ETAs were higher for the OWR (80446.93-107559.01 s) in comparison to the NWR (87209.30-117724 sg), where a better performance was obtained by the cyclist. Figure 3 presents the variations of ETA for each WR.

Comparisons between WRs

Table 1 presents the comparisons between the OWR and NWR per split time (0-6 h; 6-12 h; 12-18 h; 18-24 h). Significant differences ($p \leq 0.001$) were noted between WRs for all the assessed variables.

Table 2 assessed the group variations for split times using one-way ANOVA for the OWR and NWR. Again, all variables presented significant differences with large effect ($p < 0.001$; $\eta^2 > 0.140$).

Table 3 allowed to assess the between-groups comparisons (per split time) for each variable for the OWR and NWR, respectively. No statistically significant differences were found between 6-12 h and 12-18 h for PRR, Ec [J/m], Ec [J/Lap], Ec [Kcal/Lap] and ETA [s] for the OWR. For the NWR, no statistically significant differences were found between 6-12 h and 12-18 h for Pd [W], PRR [W], PTOT [W], Ec [J/m], Ec [J/Lap], Ec [Kcal/Lap], ETA [s].

Table 1. Comparisons of power to overcome drag, power for rolling resistance, total mechanical power, energy cost, and estimated time of arrival between the old (OWR) and new (NWR) world record per split time

Split time	0-6 h				6-12 h			
Variable	*t*	*p*	*d*	95% CI *d*	*t*	*p*	*d*	95% CI *d*
Pd [W]	–22.495	<0.001	–5.030	[–6.669; –3.379]	–9.165	<0.001	–2.049	[–2.822; –1.259]
PRR [W]	–27.096	<0.001	–6.059	[–8.013; –4.094]	–10.123	<0.001	–2.264	[–3.093; –1.417]
PTOT [W]	–9.400	<0.001	–2.102	[–2.888; –1.298]	–3.820	0.001	–0.854	[–1.361; –0.332]
Ec [J/m]	–20.520	<0.001	–4.589	[–6.094; –3.071]	–8.290	<0.001	–1.854	[–2.576; –1.114]
Ec [J/Lap]	30.881	<0.001	6.905	[4.680; 9.053]	10.214	<0.001	2.284	[1.432; 3.119]
Ec [Kcal/Lap]	30.881	<0.001	6.905	[4.680; 9.053]	10.214	<0.001	2.284	[1.432; 3.119]
ETA [s]	22.881	<0.001	5.116	[3.440; 6.782]	7.975	<0.001	1.783	[1.061; 2.487]
Split time	12-18h				18-24h			
Pd [W]	–20.916	<0.001	–4.930	[–6.629; –3.219]	–12.251	<0.001	–2.811	[–3.818; –1.787]
PRR [W]	–21.597	<0.001	–5.090	[–6.841; –3.328]	–13.483	<0.001	–3.093	[–4.183; –1.988]
PTOT [W]	–11.764	<0.001	–2.773	[–3.797; –1.732]	–4.913	<0.001	–1.127	[–1.697; –0.538]
Ec [J/m]	–18.866	<0.001	–4.447	[–5.991; –2.889]	–11.258	<0.001	–2.583	[–3.524; –1.625]
Ec [J/Lap]	10.137	<0.001	2.389	[1.460; 3.300]	4.227	<0.001	0.970	[0.412; 1.509]
Ec [Kcal/Lap]	10.137	<0.001	2.389	[1.460; 3.300]	8.469	<0.001	1.996	[1.177; 2.796]
ETA [s]	109.286	<0.001	25.759	[16.710; 34.051]	10.544	<0.001	2.485	[1.528; 3.424]

Note: Pd – power to overcome the drag, PRR – power for rolling resistance, PTOT – total mechanical power, Ec – energy cost (J/m; J/Lap; Kcal/Lap), ETA – estimated time of arrival, *t* – test value between OWR and NWR, *p* – significance level, *d* – Cohen's d effect size, 95% CI *d* – confidence interval at 95% for Cohen's *d*

Table 2. Between-groups variance for power to overcome drag, power for rolling resistance, total mechanical power, energy cost, and estimated time of arrival by WR

WR	Variable	*F*	*p*	η^2
OWR	Pd [W]	52.897	<0.001	0.685
	PRR [W]	43.673	<0.001	0.642
	PTOT [W]	52.346	<0.001	0.683
	Ec [J/m]	48.194	<0.001	0.664
	Ec [J/Lap]	31.239	<0.001	0.562
	Ec [Kcal/Lap]	46.023	<0.001	0.657
	ETA [s]	33.569	<0.001	0.583
NWR	Pd [W]	26.346	<0.001	0.520
	PRR [W]	22.704	<0.001	0.483
	PTOT [W]	26.176	<0.001	0.518
	Ec [J/m]	24.497	<0.001	0.502
	Ec [J/Lap]	24.425	<0.001	0.501
	Ec [Kcal/Lap]	24.425	<0.001	0.501
	ETA [s]	19.359	<0.001	0.443

Note: WR – world record, OWR – old world record, NWR – new world record, Pd – power to overcome drag, PRR – power for rolling resistance, PTOT – total mechanical power, Ec – energy cost (J/m; J/Lap; Kcal/Lap), ETA – estimated time of arrival, *F* – variance between OWR and NWR, *p* – significance level; η^2 – eta squared

Table 3. OWR split time comparisons for power to overcome drag, power for rolling resistance, total mechanical power, energy cost, and estimated time of arrival for the OWR and NWR

WR		OWR					NWR			
Variable	*h*	*h*	Mean Δ	*t*	*p*	*d*	Mean Δ	*t*	*p*	*d*
Pd [W]	0-6	6-12	33.763	5.800	<0.001	1.834	10.246	2.278	<0.001	1.269
		12-18	50.884	8.508	<0.001	2.764	39.276	8.500	<0.001	1.729
		18-24	71.683	12.155	<0.001	3.894	21.387	4.694	<0.001	4.405
	6-12	12-18	17.122	2.863	0.033	0.930	29.029	6.282	0.349	0.460
		18-24	37.920	6.430	<0.001	2.060	11.141	2.445	<0.001	3.136
	12-18	18-24	20.798	3.435	0.006	1.130	–17.888	–3.824	<0.001	2.676
PRR [W]	0-6	6-12	1.837	5.000	<0.001	1.581	0.431	1.972	<0.001	1.070
		12-18	2.792	7.399	<0.001	2.404	1.768	7.883	<0.001	1.447
		18-24	4.136	11.115	<0.001	3.561	0.914	4.134	<0.001	4.050
	6-12	12-18	0.955	2.532	0.081	0.823	1.338	5.963	0.719	0.377
		18-24	2.299	6.179	<0.001	1.980	0.484	2.187	<0.001	2.980
	12-18	18-24	1.344	3.517	0.005	1.157	–0.854	–3.760	<0.001	2.603
PTOT [W]	0-6	6-12	35.597	5.754	<0.001	1.820	10.677	2.264	<0.001	1.259
		12-18	53.674	8.444	<0.001	2.744	41.044	8.472	<0.001	1.715
		18-24	75.815	12.096	<0.001	3.875	22.302	4.668	<0.001	4.389
	6-12	12-18	18.076	2.844	0.035	0.924	30.367	6.268	0.362	0.456
		18-24	40.217	6.417	<0.001	2.056	11.625	2.433	<0.001	3.129
	12-18	18-24	22.141	3.441	0.006	1.132	–18.742	–3.821	<0.001	2.673
Ec [J/m]	0-6	6-12	9.968	5.393	<0.001	1.706	2.592	2.123	<0.001	1.170
		12-18	15.100	7.952	<0.001	2.583	10.275	8.192	<0.001	1.589
		18-24	21.795	11.640	<0.001	3.729	5.457	4.412	<0.001	4.236
	6-12	12-18	5.131	2.702	0.051	0.878	7.684	6.126	0.506	0.419
		18-24	11.827	6.316	<0.001	2.024	2.865	2.316	<0.001	3.066
	12-18	18-24	6.696	3.483	0.005	1.146	–4.819	–3.795	<0.001	2.647
Ec [J/Lap]	0-6	6-12	116936.145	3.967	0.001	1.254	19647.690	2.122	<0.001	1.170
		12-18	177120.078	5.848	<0.001	1.900	77830.963	8.181	<0.001	1.589
		18-24	282750.506	9.468	<0.001	3.033	41359.912	4.409	<0.001	4.236
	6-12	12-18	60183.932	1.987	0.304	0.646	58183.272	6.116	0.503	0.419
		18-24	165814.361	5.552	<0.001	1.779	21712.222	2.314	<0.001	3.067
	12-18	18-24	105630.428	3.445	0.006	1.133	–36471.050	–3.787	<0.001	2.647
Ec [Kcal/Lap]	0-6	6-12	27.948	5.367	<0.001	1.697	4.696	2.122	<0.001	1.170
		12-18	42.333	7.913	<0.001	2.571	18.602	8.181	<0.001	1.589
		18-24	60.587	11.325	<0.001	3.680	9.885	4.409	<0.001	4.236
	6-12	12-18	14.384	2.689	0.053	0.874	13.906	6.116	0.503	0.419

		18-24	32.639	6.101	<0.001	1.982	5.189	2.314	<0.001	3.067
	12-18	18-24	18.255	3.326	0.008	1.109	–8.717	–3.787	<0.001	2.647
ETA [s]	0-6	6-12	–6114.149	–4.244	<0.001	1.342	–1023.234	–1.686	0.002	0.876
		12-18	–9310.851	–6.291	<0.001	2.044	–4530.515	–7.266	<0.001	1.171
		18-24	–14463.052	–9.772	<0.001	3.175	–2211.291	–3.597	<0.001	3.642
	6-12	12-18	–3196.702	–2.160	0.205	0.702	–3507.281	–5.625	1	0.295
		18-24	–8348.903	–5.641	<0.001	1.833	–1188.057	–1.932	<0.001	2.766
	12-18	18-24	–5152.201	–3.393	0.007	1.131	2319.224	3.674	<0.001	2.471

Note: WR – world record, OWR – old world record, NWR – new world record, Pd – power to overcome drag, PRR – power for rolling resistance, PTOT – total mechanical power, Ec – energy cost (J/m; J/Lap; Kcal/Lap), ETA – estimated time of arrival, *t* – test value between OWR and NWR, *p* – significance level, *d* – Cohen's *d* effect size

Discussion

The aim of this study was to analyze and compare by analytical procedures the mechanical power, energy cost and performance (ETA) between the OWR and the NWR. This study will allow us to understand whether mathematical equations allow the prediction of a cyclist's ability to break a WR. Statistically significant differences were found between the OWR and the NWR. The variable with higher effect was Pd in both WRs, suggesting the importance of aerodynamics in these races.

In the present research, the cyclist had higher drag, Pd, power to overcome the rolling resistance, PTOT and Ec. As expected, the ETA was higher for the OWR, where the cyclist was not able to break the 1000 km in 24 hours. Pd, PRR and PT are speed dependent [3, 8]; therefore, as a consequence of higher mean velocity in the NWR, the cyclist's resistance was also higher [2]. Regarding the ETA, it is possible to understand when the cyclist was not capable to break the winning time in the OWR. However, in the NWR, only in the last 30 laps and between lap 46 and 51, the cyclist was above the winning time. Thus, it may be possible to argue that the previous experience of the cyclist allowed to redefine the racing strategy [2, 12, 18]. In a previous paper [2], the authors highlighted that the cyclist adopted higher velocity throughout the entire racing process as opposed to the previous record-breaking. Higher pace, mean velocity and intensity (heart rate) helped the cyclist to break the WR.

Previous research assessed the WRs by split times (6-hour intervals) [2]. In the present case study, 6-hour split times allowed to compare the WRs. Statistically significant changes were found for all the assessed variables [Pd (W), PRR (W), PTOT (W), Ec (J/m), Ec (J/Lap), Ec (Kcal/Lap) and ETA (s)]. Again, this allowed to argue that the cyclist adopted a higher intensity strategy since the beginning of the race. Pd in the NWR varied between 108.17 and 258.54 W. Pd is speed dependent and the drag variations were between 10.14 and 21.89 N. These drag values were below the ones presented in literature regarding different cyclist positions (near 20 N at 11.11 m/s) [8, 17, 22]. PRR between 22.44 and 30.29 W and it is in agreement with a previous study at similar speed (11.11 m/s: PRR = 24.82 W) [17]. PTOT varied between 133.02 and 291.76 W. The literature reported that for 11 m/s elite cyclist delivery was near 224.97 and 271.05 W [17]. In laboratory experiments a peak power output of 355 W at 52.3 km/h was reported [23]. Also, another study reported that near 11.41 m/s, six cyclists delivered between 190 W and 392 W [24]. Thus, the mechanical power delivered by the participant of this case study agrees with the values reported in the literature. In the current research, Ec varied between 68.13 and 111.77 J/m. When comparing the use of two different helmets, an elite cyclist may have Ec of 106.89 and 23.19 J/m at 11.11 m/s [17]. Similar estimations were provided based on the cyclist position [8], where the energy cost may be (at 11 m/s) between 200 and 250 J/m, above the values of the present study.

When comparing the intra-WR variations, significant differences were found for all variables between split times. For the OWR, no statistically significant differences were noted between 6-12 h and 12-18 h for PRR, Ec (J/Lap and Kcal/Lap) and ETA. This suggested that the speed target and biomechanical demands were similar for this part of the race [2, 12, 18]. Regarding the NWR, no statistically significant differences were found for the split time between 6-12 h and 12-18 h for Pd, PRR, PTOT, Ec and ETA. Again, this may suggest that the racing strategy for the OWR and NWR were similar [2, 12, 18]. However, the cyclist had (statistically) significantly improved his performance over time, allowing him to deliver more power, to be able to overcome more resistance (Pd, PRR and PTOT), and tolerate more intensity (higher Ec) contributing to breaking the WR and the 1000 km milestone.

The data on performance variation during the NWR showed a more even pacing than in the OWR. In both WRs, the performance declined during the race, i.e., a positive pacing was adopted; however, the decline was less pronounced in the NWR than in the OWR. A pacing strategy depends on several factors such as the kind of locomotion, the round of competition and the criteria for competitive success [25]. Our finding was in agreement with research on 24-hour road cycling that showed a gradual decline of speed across the race [12]. Although it has been suggested that even pacing would be optimal for events lasting more than 2 minutes [26], such a pacing strategy cannot be applied in ultra-cycling due to its long duration that makes the decline of performance inevitable. Also, it was interesting to observe a final spurt, i.e., higher speed in the final lap compared to laps close to the end. This outcome was similar to previous research on ultra-cycling [18], indicating that – despite the prolonged duration of this event – the cyclist had the ability to increase his performance in the end. This is easy to explained by the cyclist's pacing regulation. The tele-anticipation model proposed by Ulmer [27] may explain why the cyclist made a final spurt. During the race, the cyclist might have adopted a "safe" threshold to break the WR and complete the event without failure [28, 29]. That may have contributed for the athlete to increase the velocity in the final part. Also, with the possibility to break the WR the cyclist's motivation might have also contributed to adjustments in the intensity and pacing [28, 29].

This study allows to gather important information about the WRs that the participant of this case study established. It is important to note that some limitations must be highlighted: (i) the participant did not declare anything regarding the racing strategy; (ii) the analysis was carried out based on mechanical estimations; (iii) it is not possible to directly attribute the effects of the cyclist's training because it was not possible to assess training monitoring data; (iv) it was impossible to get laboratory tests to support the athlete's performance (VO_2max, lactate, etc.). However, this study is the first case report to present a deep understanding of the mechanical (i.e., resistance and mechanical power) and physiological (energy cost) demands and performance (ETA) between WRs. This article may contribute to coaches and cyclists defining strategies in long-distance races. Also, further studies should consider comparing experimental measures with analytical procedures, allowing to estimate the cycling performance based on individual characteristics.

Conclusions

In conclusion, when comparing the WRs, the cyclist improved his capacity to overcome the mechanical and physiological demands at higher velocity (in the NWR). The cyclist seemed to maintain his racing strategy, where the speed, mechanical power and energy cost did not differ between 6-12 h and 12-18 h. This means that the cyclist increased the intensity for the first 6 hours and decreased it in the last six. The cyclist's ability to deliver more mechanical power and energy cost in the NWR allowed him to break the 1000 km in 24 hours record and establish an NWR. This research paper contributes to cyclists and coaches managing the demands during a long-distance event, by adjust pacing and intensity. Based on this research, coaches and cyclists may use the biomechanical profile of a world record cyclist as a reference for training prescription and racing strategy. Based on effect size, the most important variables for each WR were Pd followed by PTOT, Ec [J/m], Ec [Kcal/Lap], PRR [W] and Ec [J/Lap] for the OWR; Pd, PTOT, Ec [J/m], Ec [J/Lap; Kcal/Lap] and PRR for the NWR.

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Conflict of Interest

The authors declare no conflict of interest.

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