Scientific approach to the 1-h cycling world record: a case study

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Padilla, Sabino, Iñigo Mujika, Francisco Angulo, and Juan Jose Goiriena. Scientific approach to the 1-h cycling world record: a case study. *J Appl Physiol* 89: 1522–1527, 2000.—The purpose of this study was to describe the physiological and aerodynamic characteristics and the preparation for a successful attempt to break the 1-h cycling world record. An elite professional road cyclist (30 yr, 188 cm, 81 kg) performed an incremental laboratory test to assess maximal power output ($\dot{W}_{max}$) and power output ($\dot{W}_{OBLA}$), estimated speed (V_{OBLA}), and heart rate (HR_{OBLA}) at the onset of blood lactate accumulation (OBLA). He also completed an incremental velodrome (cycling track) test (VT1), during which $V_{OBLAVT1}$ and $HR_{OBLAVT1}$ were measured and $\dot{W}_{OBLAVT1}$ was estimated. $\dot{W}_{max}$ was 572 W, $\dot{W}_{OBLA}$ 505 W, V_{OBLA} 52.88 km/h, and HR_{OBLA} 183 beats/min. $V_{OBLAVT1}$, $HR_{OBLAVT1}$, and $\dot{W}_{OBLAVT1}$ were 52.7 km/h, 180 beats/min, and 500.6 W, respectively. Drag coefficient and shape coefficient, measured in a wind tunnel, were 0.244 and 0.65 m^2, respectively. The cyclist set a world record of 53,040 m, with an estimated average power output of 509.5 W. Based on direct laboratory data of the power vs. oxygen uptake relationship for this cyclist, this is slightly higher than the 497.25 W corresponding to his oxygen uptake at OBLA (5.65 l/min). In conclusion, *1*) the 1-h cycling world record is the result of the interaction between physiological and aerodynamic characteristics; and *2*) performance in this event can be predicted using mathematical models that integrate the principal performance-determining variables.

power output; onset of blood lactate accumulation; steady state; aerodynamics; performance; modeling

THE ONE-HOUR CYCLING WORLD RECORD is a quite unique event, as it is the only cycling event that has been performed under standard conditions until the last decade. By definition, the 1-h cycling record represents the longest distance an unaccompanied cyclist can cover in a velodrome (cycling track) during a 60-min effort. From a historical viewpoint, it is worth noticing that both track cyclists (e.g., Ritter in 1968, Boardman in 1993 and 1996, Obree in 1994) and road cyclists (e.g., Coppi in 1942, Anquetil in 1962, Merckx in 1972, Moser in 1984) have been able to break this world record. From a metabolic viewpoint, this event can be considered as the definitive aerobic endurance cycling test, because the cyclist performs in steady-state conditions at the highest possible percentage of his maximal oxygen uptake ($\dot{V}_{O_2 max}$), just as he would during any other endurance event of similar duration (10, 11, 36). During cycling, the mechanical power output generated by the cyclist is used to overcome, on the one hand, aerodynamic resistance, which represents >90% of the total resistance the cyclist encounters in his forward movement at speeds above 30 km/h (25), and rolling resistance on the other hand (12, 24).

Consequently, the 1-h cycling record requires an optimum compromise between the cyclist's physiological capacities (basically the metabolic variables $\dot{V}_{O_2 max}$ and percentage of $\dot{V}_{O_2 max}$) and the demands of the task, which are reflected by aerodynamic and rolling resistances, highly dependent on anthropometric [i.e., body mass and frontal area (FA)] and environmental (e.g., air density and temperature) variables (12, 35, 46). The speed of the cyclist is thus the result of this compromise. Mathematical models developed by several authors (12, 23, 36, 39) that integrate the different variables determining the speed of motion of the cyclist indicate that aerodynamic resistance is the most performance-determining variable at speeds above 50 km/h (24).

The aim of this study was to describe the physiological and aerodynamic characteristics, as well as the preparation followed by an elite road cyclist, leading to a successful attempt to break the 1-h cycling world record.

METHODS

Subject. The subject attempting the 1-h cycling world record was a 30-yr-old elite professional road cyclist. At the time the study was performed, the subject had been involved in competitive cycling for 18 yr, and he had cycled ~24,000 km in the season, adding up training and competition distances. However, his velodrome cycling experience was only ~10 h throughout his entire career. The subject received verbal and written explanation of the purpose, procedures,
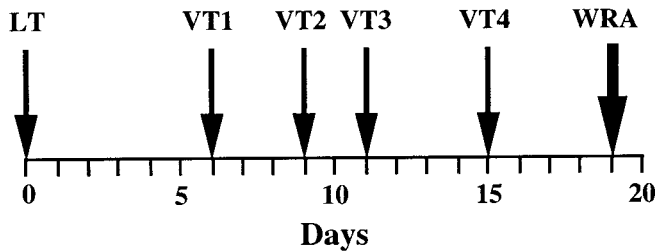
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Fig. 1. Overview of the cyclist's preparation for the 1-h cycling world record. LT, laboratory test; VT1, VT2, VT3, and VT4, velodrome tests 1, 2, 3, and 4, respectively; WRA, world record attempt.

and potential risks of the study before giving written, informed consent to participate. All experimental procedures were approved by the Ethics Committee of the Universidad del País Vasco.

Anthropometric variables. The cyclist's body surface area (BSA, in m^2) was estimated from body mass and height, using the equation of Du Bois and Du Bois (13)

$$BSA = 0.007184 \times BM^{0.425} \times H^{0.725}$$

in which BM is the cyclist's body mass (in kg) and H is his height (in cm).

The frontal area (FA) of the cyclist and his bicycle was estimated as follows (4, 45): photographs of the cyclist in riding position and of a reference rectangle of known area are taken. The contour of the ensemble cyclist-bicycle and that of the rectangle are then cut out and weighed. The subject's FA is estimated by comparing the masses of the pictures of the ensemble cyclist-bicycle and that of the reference area.

Laboratory testing. Nineteen days before his world record attempt (Fig. 1), the subject performed an incremental maximal laboratory test on a mechanically braked cycle ergometer (Monark 818 E, Varberg, Sweden), which was adapted with a racing saddle, drop handlebars, and clip-in pedals. Initial workload was set at 110 W and was increased by 35 W every 4 min, with 1-min recovery intervals between workloads. Keeping cadence with a metronome, pedal rate was kept constant at 75 rpm through the entire test. Testing continued until the subject could no longer maintain the required pedal rate. Heart rate (HR) was recorded every 5 s throughout the test (Sport Tester PE 3000, Polar Electro Oy, Kempele, Finland). Blood samples were obtained to determine blood lactate concentration ([Lac]) immediately after each workload was completed. [Lac] values attained during the last workload were considered to be maximal (37).

Maximal power output ($\dot{W}_{max}$) was determined as the highest workload the cyclist maintained for a complete 4-min period. Following the recommendation of the manufacturer, 9% was added to this value in the final computation of $\dot{W}_{max}$, due to the friction in the transmission system of Monark cycle ergometers (1).

The exercise intensity corresponding to the onset of blood lactate accumulation (OBLA) was identified on the [Lac]-power output curve by straight-line interpolation between the two closest points as the power output eliciting a [Lac] of 4 mmol/l (41). Power output and HR values at OBLA ($\dot{W}_{OBLA}$ and HR_{OBLA}, respectively) were determined by straight-line interpolation.

Oxygen uptake ($\dot{V}o_2$) was not measured in this laboratory test to avoid any possible interference of gas-analyzing equipment with the subject's cycling performance. However, previous laboratory tests using an identical protocol elicited a $\dot{V}o_{2\,max}$ of 6.4 l/min, a $\dot{V}o_2$ at OBLA of 5.65 l/min, and a mean true efficiency (28) of 26%.

Velodrome testing. The subject performed four velodrome tests before his world record attempt (Fig. 1). The first test (VT1) was an incremental maximal test performed in an indoor 285-m track situated at sea level. Testing consisted of 2,850-m (10-lap) workloads, interspersed with 1-min recovery periods. At each workload, the subject progressively reached the target speed during the first 2 laps, then maintained it during the remaining 8 laps. Initial speed was 31.2 km/h, and it was increased by 2.6 km/h after each workload until exhaustion. The cyclist selected his preferred gear ratio at each riding speed. VT1 was performed using a time trial road racing bicycle (Pinarello, Treviso, Italy). The weight of the bicycle was 9.0 kg; the diameter of the front and rear wheels was 0.7 m. The front wheel had 19 flat spokes, and the back wheel had four carbon fiber spokes. The tubeless tires (Vittoria, Bergamo, Italy) were inflated at a pressure of 6.0 kg/cm^2. The gear ratio ranged from 55×18 to 55×11 and the pedal rate from 70 to 112 rpm.

The subsequent velodrome tests (VT2, VT3, and VT4) were performed in the same indoor 250-m track where the world record was to be attempted, also at sea level. VT2 consisted of five repetitions of 5,250 m (21 laps), interspersed with 6-min recovery periods. VT3 consisted of four repetitions of 9,000 m (36 laps), with 8 min recovery between repetitions. During VT4, the subject performed two repetitions of 16,000 m (64 laps), recovering for 10 min between repetitions. During VT2, VT3, and VT4, the cyclist rode the bicycle and wore the aerodynamically designed suit (85% Coolmax, 15% elastane, Nalini Sport, Vicenza, Italy) and helmet (Ruddy Project, Treviso, Italy) with which he would attempt the world record. The total weight of the bicycle was 7.280 kg. Front and rear disk wheels (Campagnolo, Vicenza, Italy) were made of Kevlar, the diameters being 66 cm for the former and 71.2 cm for the latter. The front and rear tubeless tires were 19 and 20 mm wide, respectively; they were made of silk and inflated at a pressure of 6.0 kg/cm^2 (Vittoria, Bergamo, Italy). The crank arm's length was 180 mm.

During all velodrome tests, the subject's bicycle was equipped with a handlebar microcomputer for speed, pedal rate, and HR monitoring (Polar Cyclovantage, Polar Electro Oy). In VT1, steady-state HR values were determined as the mean value of the last min of each workload. In VT2, VT3, and VT4, average HR and speed attained during the last 3, 4 and 6 min of each repetition, respectively, were computed. Blood samples were obtained after each workload or repetition for [Lac] determination.

After VT1, speed and HR values at OBLA ($V_{OBLAVT1}$ and $HR_{OBLAVT1}$, respectively) were determined by straight-line interpolation on the [Lac]-speed curve.

Wind tunnel testing. Wind tunnel testing (Augusta Helicopter, Milano, Italy) was carried out to determine the drag coefficient (C_x), which has been proposed as a measure of aerodynamic efficiency. It has also been suggested that the size of an object is of major importance for aerodynamic efficiency, as it determines the FA of moving objects (15, 22). These two variables are integrated in the following equation

$$C_x = FA \times C_d$$

in which C_x and FA are in m^2, and C_d is the shape coefficient (in m^2).

Testing was performed at a speed of 50 km/h, with an air temperature of 20.4°C, an air pressure of 1,000 mbar, and an air density of 1.186151 kg/m^3. The precision of the force measurement system in terms of speed is on the order of 0.05 km/h for each point of drag (1 point corresponding to a C_x of 0.001 m^2). From the measurement point of view, this corresponds to a drag force of 12 g at 50 km/h.

Table 1. *Speed, heart rate, and blood lactate concentration values during the different velodrome tests performed by the subject*

Velodrome Test	Speed, km/h	HR, beats/min	[Lac], mmol/l
VT2			
Repetition 1	53.3 ± 0.5	180 ± 1	6.1
Repetition 2	53.0 ± 0.5	183 ± 1	5.1
Repetition 3	53.2 ± 0.6	189 ± 1	5.3
Repetition 4	53.3 ± 0.5	191 ± 2	6.7
Repetition 5	53.6 ± 0.7	196 ± 1	7.7
VT3			
Repetition 1	53.1 ± 0.3	182 ± 3	7.5
Repetition 2	53.0 ± 0.5	186 ± 1	5.4
Repetition 3	53.4 ± 0.5	184 ± 2	3.0
Repetition 4	54.2 ± 0.5	194 ± 1	5.3
VT4			
Repetition 1	53.0 ± 0.3	182 ± 2	4.5
Repetition 2	53.0 ± 0.3	186 ± 1	4.5

Speed and heart rate (HR) values are means $\pm$ SD recorded during the final 3, 4, and 6 min, respectively, during velodrome tests VT2, VT3, and VT4. VT2, $5 \times 5,250$ m with 6 min recovery; VT3, $5 \times 9,000$ m with 8 min recovery; VT4, $2 \times 16,000$ m with 10 min recovery. [Lac], blood lactate concentration.

Estimation of cycling power output. Power output during cycling was estimated by means of the following equation (31)

$$\dot{W}_T = FA \times C_d \times (\rho/2) \times V^3 + (C_R \times M \times g \times V)$$

in which $\dot{W}_T$ is power output (in W), FA is in m^2, C_d is in m^2, ρ is air density (1.225 kg/m^3 at sea level), V is the speed of movement (in m/s), C_R is the rolling resistance coefficient [0.0025 (30, 32)], M is the mass of the cyclist and his bicycle (in kg), and g is gravity (9.81 m/s^2).

Blood lactate. During both laboratory and velodrome testing protocols, capillary blood samples (25 μl) were withdrawn from a previously hyperemized earlobe (Finalgon, Laboratorios FHER, Barcelona, Spain) during the first seconds of recovery after each workload or repetition. As well, blood samples were obtained 3 and 5 min after the world record attempt (3). [Lac] was immediately determined by using an electroenzymatic method with an automatic analyzer (YSI 1500 Sport, Yellow Springs Instruments, Yellow Springs, OH), which was calibrated with standard solutions of known [Lac] (0, 5, and 15 mmol/l) as recommended by the manufacturer.

RESULTS

Anthropometric variables. The cyclist's height and body mass were 188 cm and 81 kg, respectively. His estimated BSA was 2.0713 m^2, and the FA of the cyclist and his bicycle was 0.3755 m^2.

Laboratory data. The subject's laboratory $\dot{W}_{max}$ was 572 W, whereas his $\dot{W}_{OBLA}$ attained 505 W. His HR_{max} and HR_{OBLA} were 195 and 183 beats/min, respectively. Speed corresponding to the OBLA exercise intensity during the laboratory test (V_{OBLA}), estimated from $\dot{W}_{OBLA}$, was 52.88 km/h. Maximal [Lac] in this test was 7.4 mmol/l.

Velodrome data. During VT1, the subject was able to perform nine workloads, attaining a final steady-state speed of 54.6 km/h, with a peak HR of 190 beats/min. $V_{OBLAVT1}$ and $HR_{OBLAVT1}$ were, respectively, 52.7 km/h and 180 beats/min. Power output at OBLA during VT1 ($\dot{W}_{OBLAVT1}$), estimated from $V_{OBLAVT1}$, was 500.6 W. Peak [Lac] at the end of VT1 was 8.5 mmol/l.

Table 1 shows average speed and HR values of the final 3, 4, and 6 min of each repetition performed by the subject during VT2, VT3, and VT4, respectively, as well as [Lac] values after each repetition.

Wind tunnel data. Considering the above-mentioned FA value of 0.3755 m^2, the subject's C_x measured in the wind tunnel was 0.244 m^2, and his C_d was 0.65 m^2.

World record attempt data. The successful world record attempt took place 4 days after VT4 (Fig. 1) at 3:00 PM, in a 250-m velodrome situated at sea level. Ambient temperature was 20°C, and relative humidity was 75%. The cyclist covered 53.040 km, 327 m more than the previous world record. The speed maintained by the cyclist lap by lap is shown in Fig. 2. Average mechanical power output estimated from the average record speed was 509.53 W. The gear ratio used by the cyclist during the record ride was 59×14 (8.77 m), and the average pedal rate was 101 rpm. At 3 and 5 min after the completion of the world record, [Lac] was 5.2 and 5.1 mmol/l, respectively.

DISCUSSION

As can be seen in Table 2, the anthropometric characteristics of the cyclist (188 cm, 81 kg) were different from those of Merckx (184 cm, 72 kg) and Moser (182 cm, 76 kg), who broke the world record in the past, but even more different from recent world record holders like Rominger (175 cm, 65 kg) and Boardman (177 cm, 69 kg). The morphotype of the latter two cyclists confers them relatively small FA values of 0.3220 and 0.3342 m^2, respectively. These result in very low C_x values, which could explain to a great extent the elevated record speeds attained by these cyclists, i.e., 55.291 km/h by Rominger and 56.375 km/h by Board-
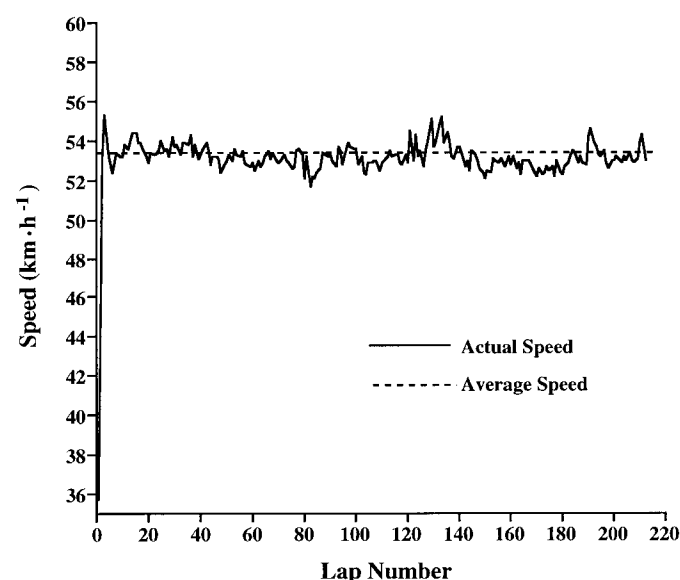

Fig. 2. Actual (lap-by-lap) and average speed of the cyclist during the 1-h cycling world record performance.

Table 2. *Characteristics of recent 1-h cycling world record holders*

Cyclist	Record, km/h	Date, mo/day/yr	Height, cm	Mass, kg	BSA, m^2	FA, m^2	C_d, m^2	C_X, m^2	Power, W
Merckx	49.432	10/25/72	184	72	1.940	0.3491	0.75	0.2618	380
Moser	51.151	01/21/84	182	76	1.969	0.3544	0.70	0.2481	400
Obree	52.713	04/27/94	182	71	1.912	0.3441	0.50	0.1720	359
Indurain	53.040	09/02/94	188	81	2.076	0.3755	0.65	0.2441	510
Rominger	55.291	11/05/94	175	65	1.791	0.3220	0.60	0.1932	456
Boardman	56.375	09/06/96	177	69	1.857	0.3342	0.55	0.1838	462

BSA, body surface area, estimated using the equation of Du Bois and Du Bois (13); FA, frontal area, considering it as a constant 18% fraction of BSA (12, 36, 46); C_d, shape coefficient, estimated from values of the literature for different riding positions and equipment (4, 5, 10, 22, 32, 33, 36); C_x, drag coefficient, measured for Moser (9) and Indurain, and estimated from FA and C_d for the rest of the cyclists; Power, mechanical power output during the record ride, estimated with the model of Menard (31).

man. Indeed, aerodynamic efficiency is a performance-determining variable at speeds above 50 km/h (15, 25). The FA value of the subject in this study (0.3755 m^2) represents 18.1% of his BSA, which agrees with previous reports that consider FA to be a constant fraction of BSA (12). The present values are also in keeping with those observed by Swain et al. (45) for riders with similar physical characteristics (0.378 m^2 and 17.8% of BSA), but slightly lower than values reported by Capelli et al. [0.393 m^2 and 20% (4) and 0.42 m^2 and 22% (5)] and Sjøgaard et al. [25% of BSA (43)].

The validity of the OBLA intensity determined during an incremental test as a predictor of the maximal steady-state intensity sustainable during prolonged exercise for all individuals has been questioned. Several authors have reported steady-state conditions at exercise intensities eliciting blood lactate values different from the fixed 4 mmol/l value corresponding to OBLA (14, 44). However, this exercise intensity was chosen because it has also been reported that it is the highest possible steady-state work intensity that can be maintained for a prolonged period of time and has therefore been considered an excellent endurance index (41, 42, 44, 47). This fully agrees with the metabolic description of the 1-h cycling record given in the introduction. Therefore, and given that V_{OBLA} estimated from laboratory power measurements (52.88 km/h) and $V_{OBLAVT1}$ (52.7 km/h) were very close to the world record set by Obree (52.713 km), it was decided that the subject could make a world record attempt. The slight difference between V_{OBLA} and $V_{OBLAVT1}$ could be due to the different methodology used in both progressive protocols (estimation vs. measurement, and constant time vs. constant distance) and/or the intrasubject variability (18). In addition to the above, the subject's OBLA intensity was 88.2% of his maximal aerobic power, similar to the 87.7% (27) and 87.9% (42) values previously reported for endurance runners or the 88.7% (7) and 89.7% (8) values reported during steady-state prolonged cycling for elite cyclists.

These observations led us to 1) set a target record speed of 53.0 km/h, which was determined by taking into consideration the standing record on the one hand and the cyclist's V_{OBLA} and $V_{OBLAVT1}$ on the other hand; and 2) perform several velodrome tests to evaluate whether the subject could maintain such a speed under steady-state conditions. This was done by measuring speed, HR, and [Lac] during VT2, VT3, and VT4. As can be seen in Table 1, the first repetition of VT2 and VT3 elicited higher HR and [Lac] values than those expected from the incremental tests and those measured during subsequent repetitions. This could be attributed to the speed, which was higher than V_{OBLA} and $V_{OBLAVT1}$, and to the "early lactate" phenomenon (6, 40), given that the duration of the repetitions was relatively short (between 6 and 10 min) and the target riding speed was attained in 15–17 s. As a matter of fact, these elevated HR and [Lac] values were not observed during the first repetition of VT4, performed at a speed closer to V_{OBLA} and $V_{OBLAVT1}$ (53.0 km/h) and of longer duration (18 min). In addition, a drift in HR and [Lac] values can be observed during VT2, most probably due to an increase in speed between repetitions 2 and *5* and to the fact that, only during VT2, the subject started each repetition from a still position. This could have induced an accumulated oxygen deficit over the five repetitions (30). Thereafter, the target speed during VT3 and VT4 was attained drafting behind a motorcycle, and the HR and [Lac] drift was thus avoided (Table 1). Only in the fourth repetition of VT3 were these values increased, as a result of a significantly higher riding speed (54.2 km/h). Despite this increased speed, neither HR nor [Lac] reached the values attained during the last repetition of VT2. This seemed to confirm the negative influence of initiating the effort from a still position.

During both repetitions of VT4, speed was kept constant, and HR and [Lac] values were stable and very close to the values predicted from laboratory measurements. Nevertheless, there was a slight cardiovascular drift between *repetitions 1* and *2*, which has also been observed by other authors for exercise intensities similar to that maintained by the subject (19, 21, 34). In the present case, this drift could have been induced by a slight hyperthermia (16) because the tests were performed in an indoor velodrome, at an ambient temperature of 22°C and relative humidity of 70%, and/or a by state of mild dehydration because the subject had been exercising for ~50 min (17). In any case, the observed drift was not due to nondetected speed increments, because the measurement system used during the tests

is quite reliable (26) and manual timing was simultaneously performed.

The C_x value determined for the subject in the wind tunnel (0.244 m^2) was similar to that reported by Dal Monte et al. (9) for Moser (0.246 m^2) and that observed by Menard (31) for professional cyclists (0.250 m^2). On the other hand, it was much higher than the values for Obree (0.1720 m^2), Boardman (0.1838 m^2), or Rominger (0.1932 m^2), estimated from their anthropometric characteristics and C_d values during their record rides (Table 2). These estimated values were not very different from those previously attributed (Menard, personal communication, 34) to Obree (0.1800 m^2), Boardman (0.207 m^2), and Rominger (0.2017 m^2). The subject's C_d (0.65 m^2) was in keeping with the values of 0.654 and 0.660 m^2 recently reported for road cyclists (4, 5) and 0.592 m^2 for indoor cyclists (36). All these values were much lower than those of 0.75, 0.80, and 0.83 m^2, respectively described by di Prampero (10), Kyle (22), and Gross et al. (15) for cyclists using nonaerodynamically designed equipment and riding in less aerodynamically efficient positions. Indeed, several authors have reported lowered aerodynamic resistance induced by equipment and position changes that reduce FA and/or C_d and, therefore, C_x (24, 25, 29, 31, 33). Although the subject's C_d could be considered as good, the C_x measured in the wind tunnel was quite high due to his big body size, which determines a much higher FA than that of recent world record holders and contributes to a relatively poor aerodynamic efficiency. In fact, considering FA as a constant 18% fraction of BSA (12), which was the case of the present subject, the estimated FA values of other record holders were much lower (Table 2). All of the above indicate that the subject could only be successful in breaking the world record by riding with a much higher power output and a much higher $\dot{V}_{O_2}$ than his competitors. As a matter of fact, the subject was able to cycle 53.040 km with an estimated average power output of 509.5 W, whereas Rominger and Boardman cycled, respectively, 4.24 and 6.29% further with 11.84 and 10.39% lower power outputs (Table 2). On the basis of direct laboratory data of the power vs. $\dot{V}_{O_2}$ relationship for this cyclist, the power output for a $\dot{V}_{O_2}$ at OBLA of 5.65 l/min is 497.25 W. This is slightly lower than the power output estimated from his record ride.

The model used in this investigation to estimate cycling speed from mechanical power output or vice versa (31) takes the most important variables that determine a cyclist's forward movement into consideration, in agreement with other cycling motion models published in the literature (5, 12, 24, 35, 36). Differences with the power output estimations recently published by Bassett et al. (2) may be related to the fact that important determinants of cycling speed such as FA, C_x, and C_d were precisely measured in this investigation, whereas the above-mentioned authors used estimations and assumptions that imply a greater possibility of error, including that bigger cyclists have a much smaller FA-to-BM ratio and that C_d is similar in all cyclists. This leads to underestimating the power output of bigger cyclists. Indeed, our power output estimations are similar to those of Bassett et al. for smaller cyclists but quite higher for bigger cyclists like the one under investigation.

The 188-m difference in 1 h estimated from V_{OBLA} and $V_{OBLAVT1}$ was very close to the 160-m difference between V_{OBLA} and the actual record distance covered by the cyclist. The interest of analyzing the relationship between laboratory and actual performance measurements has been recently discussed (18). The present results show the existence of a close relationship between those measurements for cycling. When standardized environmental and equipment conditions are maintained, adequate models that integrate all major performance-determining variables are used, and laboratory-based assumptions are verified in the field, cycling laboratory tests can have a high predictive value. Moreover, the performance and metabolic values obtained during the record ride corroborate the validity of OBLA as the intensity at which the subject was in a metabolic steady-state condition during the 1-h event, as indicated by the recovery in [Lac] values measured 3 and 5 min after the ride.

In conclusion, the present results indicated that the 1-h cycling world record is an event in which there is a close interaction between, on the one hand, anthropometric characteristics (which determine C_x) and, on the other, metabolic capacity (evaluated in this study by means of $\dot{W}_{max}$ and percentage of $\dot{W}_{max}$ that can be maintained for a prolonged period of time), the record speed or cycled distance being the result of this interaction. Performance in this event is thus the outcome of and implies the need for scaling a cyclist's physiological capacities, as previously suggested (20, 37, 38, 46). In addition, the present results show the validity of several mathematical models that integrate the main cycling performance-determining variables to predict velodrome cycling performance.

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