Elite Triathlete Profiles in Draft-Legal Triathlons

Subjects: Sport Sciences

Contributor: Alba Cuba-Dorado

Triathlon is a sport that combines three disciplines: swimming, cycling, and running. These are carried out consecutively and in this order.

triathlon performance sports performance endurance sport elite triathlon olympic triathlon

1. Introduction

Scientific analysis of triathlon performance initially focused on long distance triathlon until the late 1990s, when it entered in the Olympic program. This led to an increase in short distance research, especially conducted by a group of French researchers, considered the pioneers [1]. Since then, many researchers have tried to point out triathletes' characteristics by focusing on their physiological and anthropometric aspects or race strategies. However, many of these investigations did not focus on elite triathletes, including, in many cases, amateurs or high-performance aspirants.

2. Elite Triathle Competitive Age

Various studies analyzed the age of triathletes participating in top-level competitions. Villaroel et al. [2] concluded that the optimal age range to obtain a male top 10 rank at the WTS level is between 26 and 32 years old, suggesting that experience is a very important factor for Olympic Games performance, since they observed a higher age average in these races. In this line, Malcata et al. [3] and Werneck et al. [4] indicated that the age of maximum performance for males and females was 28 ± 2 and 27 ± 4 years, respectively, while Knechtle et al. [5] reported ages of 27.1 ± 4.9 for males and 26.6 ± 4.4 years for females. Based on these studies, researchers can conclude that the age of maximum performance in triathlon is around 27 years in both females and males.

Werneck et al. [4] delved deeper into the study of age in triathlons, observing that most Olympic triathletes, especially male, were born in the first quarter of the year (32% in the first quarter, 30% in the second, 21% in the third, and 17% in the fourth). Similarly, these authors revealed that 80% of male triathlete medalists in Olympic Games were born within the first quarter of the year, while females who were born in the first quarter obtained the same number of medals as those born in the second quarter.

Based on the above, it seems that approximately 30 is the age at which performance is optimized. Nevertheless, in recent years, young triathletes at around 20 years of age have been achieving excellent results at the highest-level races, and hence the importance of updating the understand of this aspect.

3. Elite Triathlete Anthropometric Profile

It seems that there are no anthropometric characteristics directly related to success. Most studies that analyzed the anthropometric characteristics of elite triathletes focused mainly on height, weight and adipose level, either expressed in fat percentage or sum of folds (see **Table 1**). Although these values are usually present in most studies, it is difficult to find lean mass data. Authors that analyzed this factor in elite triathletes indicated significant relationships of some anthropometric parameters, such as low-fat percentage and long body segments (arms for swimming and legs for cycling and running) [6][7][8][9]. In particular, large dimensions of hands (length: 19.7 ± 0.7 male and 18.2 ± 1.0 female) and feet (shoe size 43.3 ± 2.8 male and 38.3 ± 1.6 female) [10] can especially influence swimming.

The average in women's height over the years has remained around 167 cm; however, a decrease in weight can be observed from the beginning of the century (~60 kg) to present (~55 kg). This decrease is partly due to the decrease in fat percentage around mean values of 19.27% ± 1.94% [9][11][12][13]. In males, the average height has always been close to 180 cm, while weight has remained around 70 kg. Recently, the fat percentage has reduced below 10%, at around 8.77% ± 1.62% [4][9][11][12][13][14][15][16][17][18][19][20][21][22] (see **Table 1**).

Table 1. Mean ± SD values for the anthropometric profile of elite triathletes.

Authors	N	Age (Years)	Weight (kg)	Height (cm)	Σ Folds (mm)	Fat (%)
González-Parra et al. [13]	2 ♀	23.0 ± 4.2	54.5 ± 3.3	168.5 ± 9.2	-	16.6 ± 0.7
Schabort et al. [12]	5 ♀	25 ± 7	59.3 ± 5.8	167 ± 4.2	-	19.5 ± 2.4
Canda et al. [9]	26 ♀	25.6 ± 4.3	53.8 ± 3.8	163.2 ± 5.4	67.7 ± 17.6 (8)	19.8 ± 3.1
Millet and Bentley [11]	9 ♀	27.9 ± 5.0	60.3 ± 6.6	167.2 ± 5.4	-	21.2 ± 2.9
Ackland et al. [7]	19 ♀	29.0 ± 3.0	59.3 ± 4.7	168.3 ± 4.4	62.8 ± 13.4 (8)	-
Laurenson et al. [23]	10 ♀	27.1 ± 3.5	56.4 ± 6.1	167.0 ± 6.8	25.9 ± 9.4 (4)	-
Werneck et al. [4]	56 ♀	27.7 ± 4.1	54.2 ± 4.5	167 ± 6	-	-
Olaya and Cejuela [20]	4 ♂	22.5 ± 1.9	71.4 ± 4.2	184 ± 41	34.4 ± 1.8 (6)	6.5 ± 0.5
Koury et al. [19]	10 ♂	29 ± 10	69 ± 4	174 ± 5	-	7 ± 2
Zapico et al. [22]	9 ♂	26 ± 2	67.8 ± 2.1	177 ± 20	42.8 ± 3.9 (6)	7.3 ± 0.4

Authors	N	Age (Years)	Weight (kg)	Height (cm)	Σ Folds (mm)	Fat (%)
Gonzalez-Haro et al. [17]	6 ♂	25.3 ± 4.2	69.9 ± 4.6	175.2 ± 4.5	38.9 ± 5.7 (6)	7.6 ± 0.6
González-Parra et al. [13]	4 ♂	23.3 ± 2.9	66.7 ± 6.5	167.8 ± 4.4	-	7.8 ± 0.5
Díaz et al. [16]	5 ♂	24.8 ± 5.6	71.9 ± 6.8	172 ± 3	-	8.3 ±0.4
Díaz et al. [15]	6 ♂	24.8 ± 5.6	71.9 ± 6.8	180.2 ± 8.6	-	8.3 ± 0.4
	6 ♂	24 ± 5.6	71.2 ± 8.7	180.0 ± 8.8	-	8.5 ± 0.6
Schabort et al. [12]	5 ♂	23 ± 4	72.1 ± 4.7	181 ± 1.6	-	9.7 ± 2.4
Canda et al. [9]	65 ♂	26.0 ± 4.3	68.5 ± 5.0	178.0 ± 5.2	48.4 ± 9.4 (8)	9.9 ± 2.2
Chollet et al. [14]	6 ♂	24.7 ± 1.3	69.3 ± 1.9	177.5 ± 2.0	-	10.1 ± 0.8
Millet and Bentley [11]	9 ♂	24.8 ± 2.6	70.2 ± 5.2	177.9 ± 4.8	-	10.4 ± 2.1
Hoffmann et al. [18]	11 ♂	23.4 ± 2.8	74.5 ± 4.3	187.0 ± 2.90	-	10.7 ± 1.4
Park et al. [21]	8 ♂	23.5 ± 3.6	66.0 ± 5.1	174.4 ± 4.9	-	11.8 ± 0.5
Ackland et al. [7]	19 ♂	26.3 ± 4.4	72.6 ± 6.0	180.1 ± 5.9	48.3 ± 10.2 (8)	-
Hue [24]	8 ♂	24.8 ± 2.1	71.4 ± 7.3	180.5 ± 9.3	22.3 ± 0.5 (4)	-
Werneck et al. [4]	55 ♂	28.3 ± 4.2	67.6 ± 5.3	180 ± 6	-	-

♀ (females); ♂ (males); Σ Folds (number of folds).

triathletes versity of or low-fat levels can facilitate performance in any of the disciplines.

4. Elite Triathlete Physiological Profile

Among the main factors that influence triathlon performance, physiological parameters are the commonly most explored. Many authors directly relate successful performance to different physiological parameters, most of them giving great importance to maximum oxygen consumption (VO_2max) relative to weight and the percentage of VO_2max that triathletes can maintain (ventilatory threshold intensity) [25][26]. These are considered as the primary indicators of triathlon performance success, hence their large-scale study.

Other parameters such as movement efficiency, VO_2 kinetics or anaerobic capacity have been scarcely studied, and therefore it is difficult to state their influence on elite female and male triathlon performance.

4.1. Maximum Oxygen Consumption (VO_2max) and Ventilatory Threshold (TV2)

The VO_2max is one of the most commonly studied parameters in triathletes, both absolute and relative to weight; however, greater importance is given to the latter [6][25][27]. The cardiac adaptations produced by endurance training such as increases in stroke volume, due to the enlargement in size and mass of the left ventricle, causes an increase in VO_2max [26]. Most authors that have reported VO_2max values for cycling and running disciplines obtained them in laboratory settings using cycle ergometers and treadmills, respectively. These ergometers used for obtaining VO_2 data are widely used in both triathlon training and research.

Female elite triathletes' VO_2max mean values are around 67.3 ± 23.79 $mL \cdot kg^{-1} \cdot min^{-1}$, both in treadmill and cycle ergometer tests [11][12][13][23][28]. However, very few females' data have been reported, so these values should be considered with caution. Regarding males, values usually exceed 70 $mL \cdot kg^{-1} \cdot min^{-1}$, with mean values of 72.90 ± 3.96 $mL \cdot kg^{-1} \cdot min^{-1}$ [11][12][13][15][16][17][18][20][22][24][28][29][30][31][32][33] (see **Table 2**).

Table 2. Mean ± SD values of VO_2max reported for elite triathletes.

Authors	Laboratory Test	N	Age (Years)	Weight (kg)	VO_2max ($mL \cdot kg^{-1} \cdot min^{-1}$)	VO_2max ($L \cdot min^{-1}$)
Bernard et al. [28]	Cycle ergometer	3 ♀	26.9 ± 4.7 *	55 ± 2.6	67.3 ± 0.7	-
Schabort et al. [12]	Cycle ergometer	5 ♀	25 ± 7	59.3 ± 5.8	61.3 ± 4.6	3.6 ± 0.4
Millet and Bentley [11]	Cycle ergometer	9 ♀	27.9 ± 5.0	60.3 ± 6.6	61.0 ± 5.0	3.7 ± 0.4
Le Meur et al. [33]	Cycle ergometer	6 ♀	27 ± 4	57 ± 5	60.9 ± 7.0	-
Díaz et al. [15]	Cycle ergometer	6 ♂	24 ± 5.6	71.2 ± 8.7	77.8 ± 3.6	-
	Cycle ergometer	6 ♂	24.8 ± 5.6	71.9 ± 6.8	77.4 ± 4.6	-
Díaz et al. [16]	Cycle ergometer	5 ♂	24.8 ± 5.6	71.9 ± 6.8	77.6 ± 5.1	4.9 ± 0.2
Hue et al. [31]	Cycle ergometer	6 ♂	21.8 ± 2.4	69.9 ± 7.3	75.9 ± 5.2	5.3 ± 0.4
Hue et al. [30]	Cycle ergometer	5 ♂	25.4 ± 0.8	72.2 ± 3.4	75.7 ± 2.3	-
Millet and Bentley [11]	Cycle ergometer	9 ♂	24.8 ± 2.6	70.2 ± 5.2	74.3 ± 4.4	5.2 ± 0.3
Zapico et al. [22]	Cycle ergometer	9 ♂	26 ± 2	67.8 ± 2.1	72.9 ± 2.0	4.9 ± 0.2
Le Meur et al. [33]	Cycle ergometer	6 ♂	30 ± 6	67 ± 5	71.7 ± 5.4	-

Authors	Laboratory Test	N	Age (Years)	Weight (kg)	VO_2max (mL·kg^{-1}·min^{-1})	VO_2max (L·min^{-1})
Hue [24]	Cycle ergometer	8 ♂	24.7 ± 2.1	71.4 ± 7.3	70.5 ± 6.5	-
Schabort et al. [12]	Cycle ergometer	5 ♂	23 ± 4	72.1 ± 4.7	69.9 ± 4.5	5.0 ± 0.4
Bernard et al. [28]	Cycle ergometer	5 ♂	26.9 ± 4.7 *	67 ± 5	69.8 ± 5.3	
Gonzalez-Haro et al. [17]	Cycle ergometer	6 ♂	25.3 ± 4.2	69.9 ± 4.6	64.7 ± 5.7	4.6 ± 0.3
Hue et al. [32]	Cycle ergometer	5 ♂	25.7 ± 1	71.6 ± 3.3	64.4 ± 1.2	-
González-Parra et al. [13]	Treadmill	2 ♀	23.0 ± 4.2	54.5 ± 3.3	74.0 ± 0.1	-
Laurenson et al. [23]	Treadmill	10 ♀	27.1 ± 3.5	56.4 ± 6.1	65.6 ± 6.0	-
Schabort et al. [12]	Treadmill	5 ♀	25 ± 7	59.3 ± 5.8	63.2 ± 3.6	3.7 ± 0.3
Hue et al. [31]	Treadmill	6 ♂	21.8 ± 2.4	69.9 ± 7.3	78.5 ± 3.6	5.5 ± 0.3
Hue et al. [30]	Treadmill	5 ♂	25.4 ± 0.8	72.2 ± 3.4	76.3 ± 3.2	-
González-Parra et al. [13]	Treadmill	4 ♂	23.3 ± 2.9	66.7 ± 6.5	76.0 ± 6.9	-
Schabort et al. [12]	Treadmill	5 ♂	23 ± 4	72.1 ± 4.7	74.7 ± 5.3	5.3 ± 0.5
Olaya-Cuartero and Cejuela [20]	Treadmill	4 ♂	22.5 ± 1.9	71.4 ± 4.2	72.8 ± 2.2	-
Hoffmann et al. [18]	Treadmill	11 ♂	23.4 ± 2.8	74.5 ± 4.3	72.0 ± 4.3	5.5 ± 0.3
Hue [24]	Treadmill	8 ♂	24.7 ± 2.1	71.4 ± 7.3	71.8 ± 7.6	-
Baldari et al. [29]	Treadmill	8 ♂	21 ± 1	73 ± 4	69.7 ± 4.7	-
Hue et al. [32]	Treadmill	5 ♂	25.7 ± 1	71.6 ± 3.3	69.5 ± 1 [32]	-

triathlon

$_2$ values at

VT2 intensity close to VO_2max will allow triathletes to maintain high-intensity exercise for a longer time, which will increase the possibility of obtaining a better performance [6][25][26][27]. A compilation of triathletes' VO_2 values at VT2 intensity is summarized in **Table 3**. It is worth noting the scarce presence of data on elite female triathletes, with only one study reporting values over 80% of VO_2max [11]. In males, the mean value is 84.41% ± 2.72% [11][16][17][20]

[22][27]. VO_2max (maximum oxygen consumption); ♀ (females); ♂ (males); * (mean age of overall sample: female + male).

although great variation can be observed, with values ranging between 81% and 87% of VO_2max (see **Table 3**).

Table 3. Mean ± SD values of VO_2 at VT2 of elite triathletes.

Authors	Laboratory Test	N	Age (Years)	Weight (kg)	VT2 (mL·kg^{-1}·min^{-1})	VT2 (%VO_2max)
Millet and Bentley [11]	Cycle ergometer	9 ♀	27.9 ± 5.0	60.3 ± 6.6	-	80.5 ± 7.9
Zapico et al. [22]	Cycle ergometer	9 ♂	26 ± 2	67.8 ± 2.1	-	86.2 ± 1.6
Millet and Bentley [11]	Cycle ergometer	9 ♂	24.8 ± 2.6	70.2 ± 5.2	-	83.9 ± 4.5
Gonzalez-Haro et al. [17]	Cycle ergometer	6 ♂	25.3 ± 4.2	69.9 ± 4.6	-	83 ± 5
Díaz et al. [16]	Cycle ergometer	5 ♂	24.8 ± 5.6	71.9 ± 6.8	-	81.0 ± 4.4
Olaya and Cejuela [20]	Treadmill	4 ♂	22.5 ± 1.9	71.4 ± 4.2	64 ± 2.94	87.94 ± 1.59
Baldari et al. [29] [26]	Treadmill	8 ♂	21 ± 1	73 ± 4	52.9 ± 4	-

VT2 (ventilatory threshold 2); ♀ (females); ♂ (males).

...ement in ...ol training ...on and in laboratory. The reserve HR value is the best indicator for triathlon performance, but few studies report this parameter, instead focusing on HRmax (see **Table 4**).

Table 4. Mean ± SD values of HRmax of elite triathletes.

Authors	Laboratory Test	N	Age (Years)	Weight (kg)	HRmax (bpm)
Bernard et al. [28]	Cycle ergometer	3 ♀	26.9 ± 4.7 *	55 ± 2.6	185.7 ± 13.1
Millet y Bentley [11]	Cycle ergometer	9 ♀	27.9 ± 5.0	60.3 ± 6.6	184.3 ± 7.1
Millet y Bentley [11]	Cycle ergometer	9 ♂	24.8 ± 2.6	70.2 ± 5.2	187.6 ± 8.9
Díaz et al. [15]	Cycle ergometer	6 ♂	24 ± 5.6	71.2 ± 8.7	186 ± 3
	Cycle ergometer	6 ♂	24.8 ± 5.6	71.9 ± 6.8	184 ± 4
Zapico et al. [22]	Cycle ergometer	9 ♂	26 ± 2	67.8 ± 2.1	183 ± 5
Bernard et al. [28]	Cycle ergometer	5 ♂	26.9 ± 4.7 *	67 ± 5	180.8 ± 5.4
Hue et al. [32]	Cycle ergometer	5 ♂	25.7 ± 1	71.6 ± 3.3	177 ± 3

Authors	Laboratory Test	N	Age (Years)	Weight (kg)	HRmax (bpm)
González-Haro et al. [17]	Cycle ergometer	6 ♂	25.3 ± 4.2	69.9 ± 4.6	176 ± 14
Hue et al. [31]	Cycle ergometer	6 ♂	21.8 ± 2.4	69.9 ± 7.3	174 ± 3
Díaz et al. [16]	Cycle ergometer	5 ♂	24.8 ± 5.6	71.9 ± 6.8	172 ± 3
Laurenson et al. [23]	Treadmill	10 ♀	27.1 ± 3.5	56.4 ± 6.1	186.6 ± 4.9
Olaya and Cejuela [20]	Treadmill	4 ♂	22.5 ± 1.9	71.4 ± 4.2	191 ± 9.3
Hue et al. [31]	Treadmill	6 ♂	21.8 ± 2.4	69.9 ± 7.3	184 ± 5
Hue et al. [32]	Treadmill	5 ♂	25.7 ± 1	71.6 ± 3.3	182 ± 5

HRmax (maximum heart rate); bpm (beats per minute); ♀ (females); ♂ (males); * (mean age from overall sample: female + male).

[28] ment was 165 ± 5, which represents 91% ± 4% of the HRmax of the triathletes analyzed. Whyte et al. [34] defined the characteristics of physiological myocardial hypertrophy presented by potential Olympians and/or members of British squads regarding interventricular wall thickness during diastole (male: 10.4 ± 1.5 mm; female: 9.2 ± 0.9 mm); left ventricular internal diameter during diastole (male: 54.9 ± 3.1 mm; female: 50.2 ± 2.1 mm); ventricular posterior free wall during diastole (male: 9.8 ± 1.5 mm; female: 9.3 ± 0.9 mm); and left ventricular mass (male: 274 ± 64 g; female 207 ± 34 g). These authors considered the abovementioned values as high and associated with the concurrent effect of resistance and endurance necessary for good performance in triathlons.

Only case studies have analyzed HR variability in elite short-distance triathletes. Plews et al. [35] verified the changes produced during a 77-day training period in two elite triathletes (1 female and 1 male). One was diagnosed with overtraining during the study period, presenting a higher coefficient of variation for rMSSD (calculated as the root mean of the standard deviations of the differences between successive cycles, measured in ms), as well as lower values than those of the healthy triathlete and even its own values at the beginning of the season. These data show that the increase in rMSSD is an indicator of good physical shape compared to baseline values out of season, and its variations may be indicative of poor adaptation or overtraining.

5. Conclusions

The main findings of the Cuba-Dorado et al. [36] indicate that there are physiological, biomechanical, neuromuscular, tactical parameters, etc., that could be related to successful triathlon performance in competitions.

Competition Age. It seems that the optimal age for female and male triathlon performance is about 30. However, continuous updates in this regard are essential due to the results achieved in recent years by young triathletes.

Anthropometric profile. The anthropometric profile of elite triathletes does not seem to be defined by height or weight, mainly due to the diversity of profiles. However long segments or low-fat levels can facilitate performance in any of the disciplines.

Physiological profile. Triathletes' main physiological adaptations are typical of an endurance sport. One of the most studied parameters is the VO_2max. Female elite triathletes' relative VO_2max values are around 67.3 ± 23.79 mL·kg^{-1}·min^{-1}, while males usually exceed 70 mL·kg^{-1}·min^{-1}. The VT_2 has also been widely studied in elite triathletes, reporting values over 80% of VO_2max for females and 84.41% ± 2.72% of VO_2max for males. However, being a long-duration sport, it can be observed that in competitions and/or simulations, HR and [La] are quite high. This may indicate that the interaction and differentiated muscular involvement between the swimming, cycling and running segments allows very well-trained triathletes to maintain very high ranges of effort for long periods of time.

Biomechanical and neuromuscular factors. The fact that the swimming takes places in open environments means that there are differentiating aspects to consider regarding to swim in a pool. The cycling segment in elite triathlon is characterized by a variable power with high intensity short-duration peaks. The running segment is influenced by the previous disciplines; however, highly experienced triathletes can adapt themselves to this last segment, despite the high levels of fatigue accumulated, so that it affects them as little as possible.

Tactical Strategy. The increasing importance of shorter distances (i.e., team relay or sprint distance) for the World Triathlon makes triathletes' competition strategy very changeable, which affects the relative importance of each discipline. Therefore, elite triathletes need to have good performance in all disciplines to be able to face any international level race with confidence.

Interaction between disciplines. The main difference between elite and less experienced triathletes is their ability to adapt to running with high levels of fatigue caused by previous cycling in a way that affects the running segment as little as possible.

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