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COMPARISON OF AEROBIC CAPACITY AND SOMATIC CHARACTERISTICS BETWEEN COMPETITIVE YOUTH MOUNTAIN BIKERS AND ROAD CYCLISTS

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Abstract

Objective: To compare the anthropometric characteristics of mountain bicycle riders (MTB) and road cyclists and identify the somatic variables that affect aerobic capacity.

Methods: 100 males aged 16–18 years involved in professional mountain (*n* = 25) and road (*n* = 75) cycling for 2–5 years were recruited. Initial measurements of arterial blood pressure, body height, body mass, and body composition were taken. Aerobic capacity was measured in terms of respiratory function and work done (*W*) during a graded exercise test on a cycle ergometer. Analysis was performed on seven somatic variables (including body composition), maximal oxygen uptake, *W*, and body mass index. Basic statistical methods were employed, including Student's *t*-test for independent samples and cluster analysis.

Results: Cluster analysis found that *W* was the last variable that merged with the other analyzed parameters, suggesting that it can be regarded as a universal indicator of physical fitness among cyclists. The MTB performed significantly less *W* and featured lower values of body water percentage, fat-free mass, body mass, and body height. This group also had lower absolute values of oxygen consumption and was characterized by having less body fat than the road cyclists.

Conclusions: When compared with road cyclists, MTB riders have lower body height and body mass and less fat mass and fat-free mass, giving them an advantage in uphill climbing. The criteria for selecting competitive cyclists should include not only various somatic variables but also the amount of work done in a graded exercise test and maximal oxygen uptake values.

Key words: *bicycling, anthropometry, somatotype, selection criteria*

Introduction

Cycling is a sport in which competitive results are influenced by many physiological, anthropometric, biochemical, biomechanical, aerodynamic, psychological, environmental, and technical factors [1-11].

Furthermore, each form of cycling elicits different physical adaptations in the body [12]. The nature of road cycling requires athletes who have high aerobic capacity and the ability to produce and maintain peak power output throughout the duration of an entire race [13]. Road cyclists frequently need to perform high-intensity effort over long periods of time, reaching levels of 90% maximal oxygen uptake ($\dot{V}O_2max$), well above the anaerobic threshold [3]. In races such as the Tour de France and the Vuelta a España, riders spend approximately 93 minutes (flat sections) and 123 minutes (mountain stages) above 70% $\dot{V}O_2max$ [14]. Thus, the body's adaptation to road cycling includes increased aerobic capacity (by increased oxygen consumption, improved oxygen transport, and more efficient use of oxygen by the body) and increased lean body mass in order to produce more power [12].

In turn, mountain biking (MTB) requires athletes to maintain high work intensity for most of a race [15] but where both aerobic and anaerobic capacity play a role in determining competitiveness. As a result, the varied intensity (frequent hill climbs and accelerations) in a MTB race leads to better developed muscle and blood buffering capacities, indicative of the specific adaptation of the body to such physical effort. The duration of effort during a MTB race (approx. two hours) and its high intensity promote changes in the cardiovascular and respiratory systems, also improving oxygen transport from the lungs to the working muscles. Other changes include body composition, such as decreases in both body mass and fat mass [12].

Maximal oxygen uptake is traditionally considered to be the best determinant of aerobic capacity [16-17]. Research on measuring $\dot{V}O_2max$ began almost 100 years ago [18-19]. Within a few years, it was proven that top endurance athletes are characterized by high maximal oxygen uptake levels [20-23]. It is important to reiterate that this measure describes the body's efficiency in delivering oxygen to mitochondria and should not be confused with measuring the efficiency of cellular respiration [6]. A high level of $\dot{V}O_2max$ has been described by numerous researchers as necessary to achieve high performance in cycling [3,5,9,24], although the ability to maintain high-intensity effort (≥ 90% max) for extended lengths of time may have a larger impact on sporting results [25-27].

Maximal oxygen uptake has been reasoned to be an individual trait that is largely inherited [28], although the genes responsible for this characteristic are still unknown. However, there is evidence that oxygen uptake decreases with age. In studies by Peiffera et al. [10], a group of road cyclists were divided into three age groups (35–45, 45–54 years, and ≥ 55 years old), finding that mean $\dot{V}O_2max$ decreased with age (60.7 ± 5.1 ml min^{-1} kg^{-1} in the 34–45 age group, 54.2 ± 6.6 ml min^{-1} kg^{-1} in the 45–54 age group, and 45.9 ± 4.6 ml min^{-1} kg^{-1} in the ≥ 55 age group).

Furthermore, there is mixed consensus on the impact of training on increasing $\dot{V}O_2max$. It is certain that during the early phase of training in young road cyclists, marked by continuous training at moderate and low intensities, the body's adaptation to natural stressors is manifested by an increase in maximal oxygen uptake [29]. However, at later training phases when in adulthood, this measure may plateau and no longer increase. Some of literature on the subject pointed to only a slight increase in $\dot{V}O_2max$ when training and competing during the cycling season [30-33], while other studies did not confirm any statistically significant changes in professional cyclists in response to different forms of training [27,34,35]. Hence, it has been suggested that $\dot{V}O_2max$ should not be used as a factor in analyzing training effectiveness but instead is better suited in the selection of cyclists by choosing those better predisposed towards achieving high performance in cycling or in predicting cyclists' future physical development [36].

The use of $\dot{V}O_2max$ as a selection criterion in the recruitment of cyclists and as a measure of aerobic capacity is indisputable. However, it seems appropriate to supplement its use with additional suitable anthropometric variables, such as body mass, body height, body composition, trunk frontal area, and body size. Body mass is considered to be an important variable, as cyclists work against gravity (particularly in MTB races, where riders often need to ascend steep climbs). As body mass increases, so does trunk frontal area and body size, in effect increasing both aerodynamic drag and rolling resistance and thus increasing the physiological cost of cycling [6,7,13]. The available literature finds that mountain bikers are characterized by being lighter and shorter and feature less percent body fat than road cyclists. Body composition is also considered an important factor that differentiates competitive cyclists. Mean body fat percentage has been cited by the previously mentioned authors to be less than 6.2% in MTB riders and 8–22% for road cyclists who compete at the highest sporting level. However, among cyclists at lower competitive levels, body fat percentage was found to range from 11% to 13.1% of body mass for both MTB and road cyclists. This suggests that there exists a relationship between this parameter and competition level.

In addition researchers also analyzed bone mineral density (BMD). It was found that BMD is higher in untrained individuals compared with trained individuals (1.234 ± 0.09 g $[cm^2]^{-1}$ and 1.187 ± 0.09 g $[cm^2]^{-1}$, respectively), although the differences were statistically non-significant [37]. Other studies on groups of highly trained cyclists found higher BMD in MTB riders than in road cyclists or physically-active individuals. Higher BMD in MTB riders was explained by increased osteogenic activity, in part explained by the forces experienced when riding over uneven terrain characteristic of MTB races [38].

Considering the above, it seems further examination is needed on the anthropometric characteristics of road and MTB cyclists and to compare them on the basis of various basic physiological parameters so as to identify which somatic variables may have a significant impact on competitive success in professional cycling. Therefore, the aim of this study was to compare the anthropometric characteristics of competitive MTB bikers and road cyclists and identify the somatic variables that affect aerobic capacity.

We expected that MTB bikers have lower body height and body mass and less fat mass in relation to the road cyclists. We also expected that the amount of work done in the graded exercise and body composition should be included in criteria for selecting competitive cyclists.

Methods

Participants

The study group consisted of junior and youth competitive cyclists involved in road (n = 75) and MTB (n = 25) cycling. Subjects were recruited included criteria: 1) athletes who had a minimum of two years competitive experience and maximal oxygen uptake values higher than 3.5 l min^{-1}, 2) had 16-18 year old and share similar fitness levels, competitive experience, and physical activity levels. Before participating in the study, the athlete or his guardian (if underage) provided a signed informed consent form that contained the study's purpose and adopted procedures.

The basic anthropometric characteristics of the participants are presented in Table 1. These variables were taken at rest and included taking measures of:

– arterial blood pressure, measured in order to exclude those participants whose blood pressure was >160/100 mm Hg (treated as a pass/fail),

Table 1. *Basic anthropometric characteristics of the sample population*

	Road cyclists					MTB riders				
	Age (years)	Body mass (kg)	Body height (cm)	$\dot{V}O_2max$ ($l \cdot min^{-1}$)	$\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	Age (years)	Body mass (kg)	Body height (cm)	$\dot{V}O_2max$ ($l \cdot min^{-1}$)	$\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)
Min	16.0	57.4	168.0	3.62	54.3	16.0	55.8	168.0	3.50	53.5
Max	18.0	84.3	190.0	5.45	90.2	18.0	80.8	190.0	5.43	84.0
$\bar{x}$	17.8	68.1	178.6	4.41	65.19	16.8	64.8	175.6	4.26	66.0
SD	0.81	5.65	5.05	0.40	5.9	0.82	5.79	6.07	0.49	7.53

– body height (h), using an anthropometer produced by GPM (Switzerland),
– body mass (m), performed on a WPT 200 medical scale manufactured by Radwag (Poland),
– body composition, measured with a 6100/XL analyzer by Futrex (England).

The Futrex body composition analyzer uses the near infra-red (NIR) interactance method and was placed on the middle of the biceps brachii of the dominant upper limb. The subject was in sit position and the dominant upper limb was lay on the table. To mark middle of the biceps brachii was used measure included from producer. It was used to calculate the Quetelet weight/height index (BMI), body fat percentage (Fat %), fat mass (Fat kg) and fat-free mass (FFM kg) expressed in kilograms, total body water content expressed in liters (Water L), and body water percentage (Water %).

The second phase of the study consisted of performing a graded exercise test on a Excalibur Sport cycle ergometer (Lode, The Netherlands). The participants were asked to refrain from any heavy physical activity at least 2 days before the day of the test and to refrain from eating 3–4 h prior the test. The graded exercise test began with each participant adjusting the ergometer's saddle and handlebars to suit their own individual preference. The cycle ergometer was calibrated before testing by special computer software. The test began at an initial load of 50 W and increased every 3 min by an additional 50 W. The participants were instructed to maintain a pedaling frequency of at least 60 revolutions min^{-1}. The test was performed until exhaustion or until increased load did not increase oxygen consumption, after which it was continued without any load for another 5 min. The cycle ergometer was monitored by a computer program that also registered instantaneous power, time, and speed and used these values to calculate the total work done during the test.

Respiratory parameters to calculate $\dot{V}O_2max$ were measured by a face mask connected to a Quark b^2 gas analyzer (Cosmed, Italy). This apparatus was calibrated before each test using atmospheric air and reference gases. The values of all analyzed parameters were examined breath-by-breath. Respiratory parameters were registered 2 min before beginning the test and continued for 5 min after completion (after reaching exhaustion).

Statistical analysis

Statistical analysis began with the Shapiro-Wilk test to evaluate for normal distribution. Afterwards, basic statistical methods were used to calculate the arithmetic means, standard deviations, and minimum and maximum values. An additional step included applying Student's *t* test for independent samples to calculate the significant differences between the means of the analyzed parameters between the road and mountain cyclists.

Furthermore, cluster analysis was applied so as to group the test parameters and indicate the differences between the road and mountain cyclists. This method is used to classify variables into subsets (clusters) that relate to one another more similarly than to variables located in other clusters. In effect, the greater the Euclidean distance (abscissa) created by a cluster, the greater impact this parameter has on the other variables.

All statistical analysis was performed using standard statistical software, Statsoft Statistica 10.0 (USA).

Results

Cluster analysis (Fig. 1–2) found that the amount of work done in the graded exercise test was the last or one of the last parameters linking the remaining parameters, suggesting that it can be regarded as a universal indicator of physical fitness in cyclists. In both groups, cluster analysis grouped the test parameters and somatic variables into three clusters. The first cluster included body mass, fat-free mass, body water percentage, body water content in liters, and maximal oxygen uptake calculated per kg of body mass. The second cluster grouped BMI, maximal oxygen uptake, body fat percentage, and the amount of body fat expressed in kg. In turn, the third cluster included the amount of work done during the graded exercise test and body height. However, for road cyclists, the amount of work done during the graded exercise test

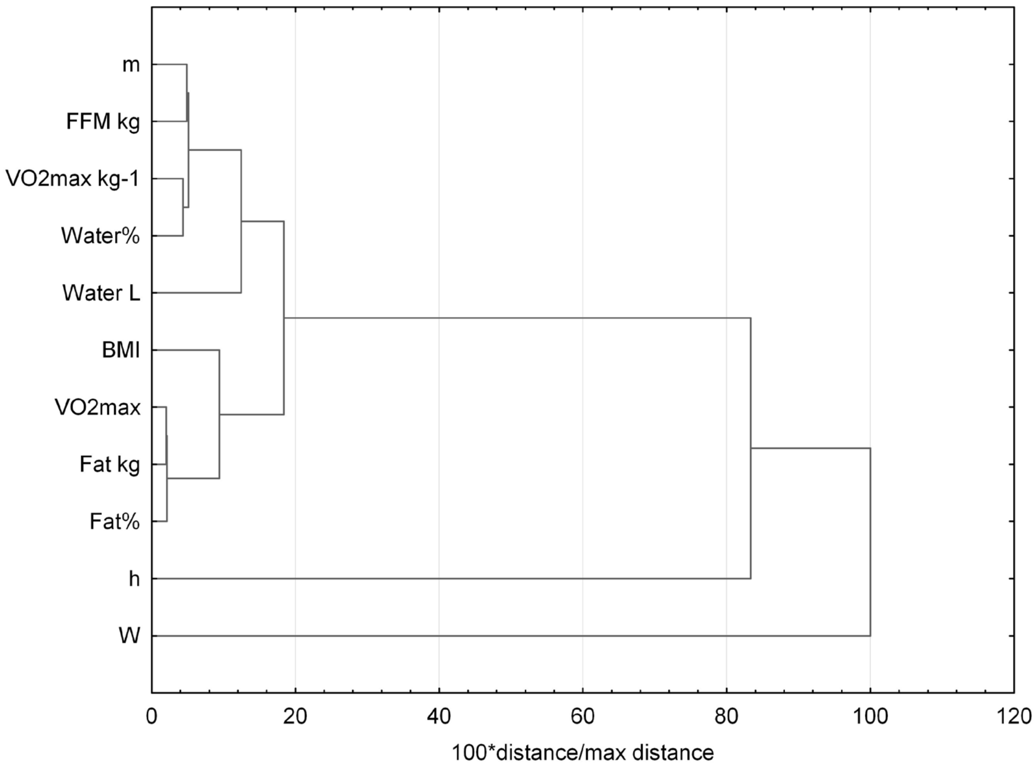

Figure 1. *Cluster analysis of the analyzed parameters in road cyclists, represented by a single-link dendrogram using the squared Euclidean distance*

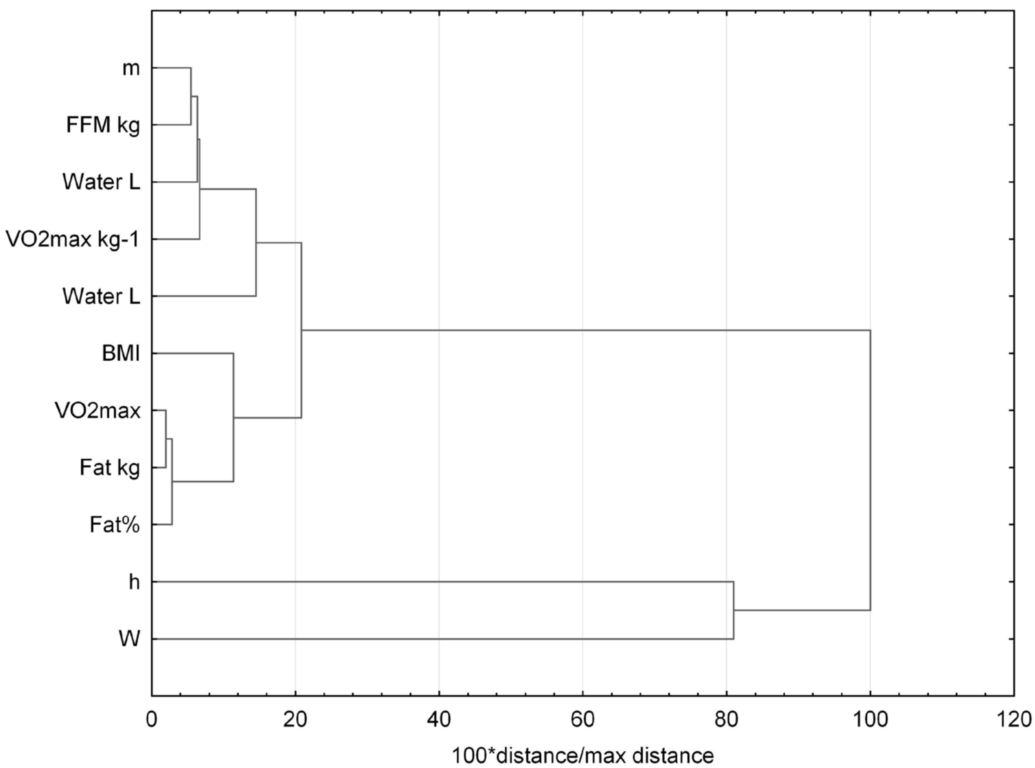

Figure 2. *Cluster analysis of the analyzed parameters in mountain bikers, represented by a single-link dendrogram using the squared Euclidean distance*

lay at a greater Euclidean distance and merged as the last of the analyzed parameters, while in the group of mountain bikers the amount of work done merged at an equal Euclidean distance with body height and then with the remaining clusters.

It was found that the MTB bikers produced significantly less work and had lower values of body water percentage, fat-free mass, body mass, and body height than the road cyclists. Furthermore, the mountain bikers featured lower absolute values of oxygen con-

Table 2. *Significant differences between the analyzed parameters in the road and mountain cyclists (statistically significant differences indicated by bold font)*

	MTB	ROAD	*t*
m (kg)	**64.84 ± 5.79**	**68.09 ± 5.65**	**–2.47***
h (cm)	**175.60 ± 6.07**	**178.61 ± 5.05**	**–2.45***
BMI (kg (m^2)$^{-1}$)	21.00 ± 1.55	21.30 ± 1.47	–0.86
W (kJ)	**249.92 ± 50.39**	**302.80 ± 49.51**	**–4,61†**
$\dot{V}O^2$max (l·min^{-1})	4.26 ± 0.49	4.41 ± 0.40	–1.48
$\dot{V}O^2$max·kg^{-1} (ml·min^{-1}·kg^{-1})	66.03 ± 7.53	65.19 ± 5.90	0.57
Fat% (%)	8.66 ± 2.14	8.92 ± 2.43	–0.46
Fat kg (kg)	5.67 ± 1.71	6.16 ± 2.06	–1.08
FFM kg (kg)	**59.16 ± 4.68**	**62.04 ± 4.38**	**–2.81***
Water L (l)	**43.43 ± 3.46**	**45.58 ± 3.23**	**–2.83***
Water% (%)	67.03 ± 1.48	66.87 ± 1.63	0.44

MTB – mountain bikers, ROAD – road cyclists, *t* – indicates Student's *t* test statistic for independent samples; * $P \leq 0.05$, † $P \leq 0.001$

sumption (although higher when calculated per kg of body mass) and were characterized by lower body fat in relation to the road cyclists although this difference was not statistically significant.

Discussion

Selection criteria in choosing road and mountain cyclists for competition

Cluster analysis (Fig. 1–2) indicated that the amount of work done (*W*) during the graded exercise test can be used to estimate the physical fitness of cyclists regardless of what type of cycling they engage in, which is a factor that has been confirmed in previous studies [12]. This underlines the importance of this parameter in being taken into account when determining various applicable selection criteria in choosing road and mountain cyclists for competition.

Besides *W*, the other parameter that significantly affected the remaining parameters and significantly differentiated both groups was body height (Tab. 2). Body height lay at a larger Euclidean distance in the MTB riders when compared with the road cyclists (Fig. 1–2). This can be explained by the influence of aerodynamic drag when riding a bicycle on the energy cost of cycling at high speeds [39,40]. This factor depends primarily on the position of the body when cycling and also includes factors such as body size, trunk frontal area, wind strength and direction, and the use of any specialized equipment [41-44]. Furthermore, tall cyclists are characterized by higher absolute surface drag than shorter ones. However, when calculating absolute surface drag as a unit of body mass, the relative surface drag of tall riders is actually smaller. This explains why larger cyclists achieve better results in events such as track cycling or individual time trials. In turn, shorter and leaner riders are considered to be more predisposed to perform better in MTB competition [6,36,42,45].

As mentioned, cluster analysis grouped the analyzed variables into three groups. The merging of body mass with fat-free mass, total body water content, and $\dot{V}O_2$max·kg^{-1} seems to be quite obvious. Body mass is linked to the amount of fat-free mass, where higher water content in fat-free mass is commonly associated with these variables, while maximal oxygen uptake per kg of body mass depends on, among others, the ability of muscle mass to use oxygen. Therefore, it seems logical for these variables to merge into one cluster.

The second cluster that was formed included: BMI, $\dot{V}O_2$max, Fat kg, and Fat%. Researchers examining the body composition of cyclists have indicated that highly-competitive athletes are characterized by low body fat content [13-15,46-53]. It was also shown that a high level of $\dot{V}O_2$max is necessary to achieve high performance in cycling [3,5,9,24], which may explain the combination of these parameters into one cluster.

Aerobic capacity of road cyclists and MTB bikers

This study found that road cyclists presented higher aerobic capacity, based on maximal oxygen uptake values and the amount of work done in the graded exercise test, than mountain bikers. Additionally, although $\dot{V}O_2$max calculated per kg of body mass did not differ between the groups of road and mountain cyclists (Tab. 2), it was significantly lower when compared with a similar group of cyclists (75.5 ± 3.1 ml kg^{-1} min^{-1}) investigated by Faria et al. [46]. This may be explained by the differences in graded exercise test protocols [54-56], the samples' fitness levels, as well as training history, which were not provided in the above study. However, additional comparison of $\dot{V}O_2$max- with other studies (analyzing young male cyclists in the senior age category) finds that the present study's group of junior cyclists presented only slightly lower values, which can indicate their relatively high aerobic fitness level [14,26,33,41,48-50,57,58]. On the other hand, the present group of junior mountain bikers was characterized by significantly lower $\dot{V}O_2max \cdot kg^{-1}$ values than a group of their senior peers who were competitively successful [2,15,52].

Although it was postulated that a high level of $\dot{V}O_2max$ is necessary to achieve high performance in cycling, this factor by itself does not guarantee competitive success [3,5,9,24]. This has been confirmed in part by the performed cluster analysis, where $\dot{V}O_2max$ in both groups of cyclists merged with the other parameters at similar Euclidean distances, suggesting its weak impact on the other variables/clusters (Fig. 1–2). As a result, it should not be the sole deciding criterion when selecting suitable competitive cycling candidates.

In the present study, the junior and youth road cyclists were heavier and taller than their MTB peers of the same age category (Tab. 2). This variance has also been reported in other studies analyzing the anthropometric characteristics of competitive cyclists in various cycling sub-disciplines [13,49,50]. It is also noteworthy to consider that the surveyed road cyclists were very similar in body size to other studied road cyclists (179.2 ± 1.1 cm and 69.0 ± 8.4 kg, [46]).

At the senior age category, most cyclists already begin specializing in various cycling niches (mountain stages, individual time trials, flat terrain, or all terrain). When taking this into consideration, road cyclists who specialize in mountain stages or all terrain riding can be considered similar to MTB riders in terms of their anthropometric characteristics [2,8,13,49].

Differences in somatic characteristics between mountain bikers and road cyclists

Analysis of the results also found that the group of road cyclists featured slightly higher body fat content, body water, and fat-free mass values than their MTB peers (Tab. 2). This trend has also been noted in other studies, where Fat% among professional road cyclists ranged between 7.9–8.9% [14,47,49,50], while elite MTB riders had 5.1–6.1% [15,50,52,53]. When again compared with their peers, the participants of the present study were quite similar in this regard, where Fat% in Faria et al. [46] was found to be 7.4 ± 2.0% and lean body mass at 63.6 ± 7.5 kg.

Attention does need to be paid to the fact that the comparison of body composition values from different studies may not be conclusive, as various techniques, instruments, and measurement methods are commonly employed. Nonetheless, based on an overview of the available literature, it can be concluded that

Table 3. *Somatic characteristics of mountain bikers and road cyclists performing at different competitive levels and in different bicycling sub-disciplines as recorded in various studies*

Authors	Participants	Age (years)	Body mass (kg)	Body height (cm)	Fat (%)
Hoogeveen et al. [47]	Professional ROAD	19–26	69.2 ± 6.8	181.0 ± 6.0	8.3 ± 4.2*
Lucía et al. [48]	Professional ROAD	22–26	70.8 ± 5.2	180.2 ± 2.2	—
Fernández-García et al. [14]	Professional ROAD	24–35	68.6 ± 4.89	177.1 ± 4.1	8.1 ± 1.4*
Lucía et al. [49]	Professional C Professional ITT	25–28 26–28	64.3 ± 2.2 72.3 ± 2.3	176.0 ± 2.0 181.0 ± 1.7	8.9 ± 0.1* 8.6 ± 0.2*
Mujika and Padilla [13]	Professional FT Professional ITT Professional AT Professional UH	24–30 23–33 23–27 21–29	76.0 ± 3.0 71.0 ± 6.0 68.0 ± 3.0 62.0 ± 4.0	186.0 ± 4.0 181.0 ± 6.0 180.0 ± 2.0 175.0 ± 7.0	— — — —
Lee et al. [50]	Professional ROAD Professional MTB	21–34 21–30	74.7 ± 3.8 65.3 ± 6.5	184.0 ± 3.0 178.0 ± 7.0	7.9 ± 1.8 6.1 ± 1
Chennaoui et al. [51]	Professional ROAD	20–24	67.6	176.4	12.2*
Faria et al. [46]	Elite junior ROAD	15–19	69.0 ± 8.4	179.2 ± 1.1	7.0 ± 1.4* 7.4 ± 2.0**
Impellizzeri et al. [52]	Elite MTB	18–22	65.0 ± 6.0	177.0 ± 8.0	5.3 ± 1.6*
Impellizzeri et al. [15]	Elite MTB	17–25	64.9 ± 4.6	174.6 ± 3.4	5.1 ± 1.6*
Costa and De-Oliveira [53]	Elite MTB	23–30	69.1 ± 2.1	174.0 ± 1.2	5.9 ± 0.9*
Bertucci et al. [54]	Amateur ROAD	18–27	71.2 ± 7.7	179.0 ± 5.0	12.3 ± 2.8
Penteado et al. [37]	Amateur ROAD	20–30	70.98 ± 9.2	175.0 ± 6.0	10.97 ± 3.7
Costa et al. [55]	Amateur ROAD	29–45	71.1 ± 10.1	173.0 ± 8.0	13.1 ± 5.7*

MTB – mountain bikers, ROAD – road cyclists, UH – road cyclists specializing in uphill riding, C – road cyclists specializing in mountain climbing, ITT – road cyclists specializing in individual time trials, FT – road cyclists specializing in flat terrain, AT – road cyclists specializing in all terrain riding, Fat – body fat percentage; *estimated by skinfold thickness, **estimated by hydrostatic weighing mountain bikers have significantly lower body mass and body fat levels than their road cycling peers. This may suggest that maximum cycling power, calculated per kg of body mass, may be a better-suited indicator of cycling ability in steep mountain terrain [8, 24,50,52,53]. This notion is supported by studies in which road cyclists specializing in mountain stages presented the highest values of maximal cycling power in relation to body mass [13,33,49]. Road cyclists also, although to a lesser extent, pay attention to body composition, as long as increased muscle mass is able to both maintain minimal relative surface drag and factually increase maximum cycling power during long-term effort on flat terrain. These parameters are generally agreed upon as being the main determinants of sporting success [1-3,5,8-10,13,50,57,59].

Research performed by Impellizzeri et al. [24] found a negative correlation between time gained in a cross-country race and body mass ($r = -0.68$) as well as between their finish place in the same race and body mass ($r = -0.81$). Therefore, when analyzing the total mass of the rider and bicycle, it can be advocated that a reduction in mass is especially significant during races with multiple climbs. A 3 kg reduction in body mass during a 20 km individual time trial (6% grade) was found to shorten finishing time by 75 s, while a reduction in time of 2 min and 50 s was recorded when the same conditions were repeated during a race with a grade twice as steep (12%) [45,60]. As the pace of technology has now reached a point where only modest weight reductions can be made in bicycles, cyclists attempting to gain an edge in today's competitions are almost required to reduce body mass.

Strength, weakness, limitations, practical applications and implications for future research

The strength of the study is a number of a practical purposes. When choosing multi-stage selection criteria in recruiting competitive cyclists, one of the first factors that need to be taken into consideration are the anthropometric characteristics of an athlete. This, above all, can include the rational selection of cyclists in terms of what cycling sub-discipline they are naturally predisposed to perform well in. The next recommended selection criteria would be the amount of work done during a graded exercise test and maximal oxygen uptake values (expressed in both absolute and relative terms), which, after a young athlete reaches full biological maturity, can be used to more precisely identify athletically talented individuals.

The weakness could be that these result embraced only chosen somatic and physiological parameters. Furthermore, future studies need to evaluate which physiological parameters so as to identify which somatic variables may have a significant impact on competitive success in professional cycling.

Conclusions

1. When compared with road cyclists, MTB riders have lower body height and body mass and less fat mass and fat-free mass, giving them an advantage in uphill climbing.
2. The criteria for selecting competitive cyclists should include not only various somatic variables but also the amount of work done in a graded exercise test and maximal oxygen uptake values.

Declaration of interest

The authors report no conflicts of interest.

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