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1 **Physiological and anthropometric characteristics of top-level youth cross-country cyclists**

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1 **Abstract**

2 In the literature there is a lack of data about the development of top level athletes in cross-country
3 mountain biking (XCO). The purpose of this study was to analyze anthropometric and physiological
4 characteristics of some of the best XCO bikers aged between 13 and 16. The study involved 45
5 bikers (26 males and 19 females) belonging to a youth national team. The evaluations, consisting of
6 anthropometric measures, incremental cycling tests (VO_{2max} , PPO, P@RCP), and 30 s Wingate
7 Tests (PMax, PMean), were conducted over a lapse of four years. Our findings showed in bikers,
8 already at young age, a specific athletic profile advantageous for XCO performance. At the age of
9 16, just before entering the junior category and competing at international level, male and female
10 bikers showed physiological values normalized to the body mass comparable to those reported in
11 literature for high level athletes ($VO_{2max}>70$ and >60 ml/kg/min, PPO >6.5 and >5.5 W/kg,
12 respectively in males and females). The production of high power-to-weight ratios and high peaks
13 of anaerobic power attests the presence of highly developed aerobic and anaerobic systems in young
14 XCO cyclists reflecting the high physiological demand of this sport.

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26 **Keywords:** *cross-country cycling, young athlete, peak power output, Wingate, talent identification*

1 **Introduction**

2 Cross-country mountain biking (XCO) is an endurance discipline that in recent years has received
3 significant attention from scientific literature. Indeed an increasing number of studies have been
4 published regarding physiological demands of competitions and characteristics of the best XCO
5 cyclists (Impellizzeri & Marcora, 2007; Impellizzeri, Sassi, Rodriguez-Alonso, Mognoni, &
6 Marcora, 2002; Lee, Martin, Anson, Grundy, & Hahn, 2002; Stapelfeldt, Schwirtz, Schumacher, &
7 Hillebrecht, 2004), as well as optimal training approach for this kind of cycling performance (Inoue
8 et al., 2016).

9 Overall, XCO cycling has been defined as an intermittent high intensity discipline where both the
10 aerobic and the anaerobic systems are strongly involved (Impellizzeri & Marcora, 2007). XCO
11 cycling races are mass-start endurance events, performed on an off-road circuit with significant
12 uphill and downhill sections, and last about 90-105 minutes, with some variations due to different
13 age categories and race specialities (<http://www.uci.ch>). Studies report an average heart rate during
14 competitions close to 90% of the maximum (HR_{max}), corresponding to ≈85% of maximal oxygen
15 uptake (VO_{2max}) (Impellizzeri & Marcora, 2007), and a large amount of time, ≈40% of total race
16 time, spent in a high intensity domain, above the power at individual anaerobic threshold
17 (Stapelfeldt et al., 2004). In addition, due to the significant involvement of anaerobic metabolism
18 some authors suggest the importance of anaerobic power and capacity indices in the requirements of
19 XCO cycling (Baron, 2001; Impellizzeri & Marcora, 2007; Stapelfeldt et al., 2004).

20 For these reasons, high level XCO bikers present the physiological profile of best endurance
21 athletes (Joyner & Coyle, 2008), with highly developed aerobic and anaerobic systems to sustain
22 performance demand (Stapelfeldt et al., 2004). Top level male XCO bikers have values of maximal
23 oxygen consumption (VO_{2max}) >70 ml/kg/min and high peak power output (PPO) normally >6.5
24 W/kg (Impellizzeri & Marcora, 2007; Lee et al., 2002; Wilber, Zawadzki, Kearney, Shannon, &
25 Disalvo, 1997). For best female athletes these values are generally VO_{2max} >60 ml/kg/min and PPO
26 >5.5 W/kg (Impellizzeri et al., 2008). Studies report, in the best XCO bikers, high percentages of

1 VO_{2max} associated with predictor parameters of endurance performance (Impellizzeri, Marcora,
2 Rampinini, Mognoni, & Sassi, 2005; Lee et al., 2002; Wilber et al., 1997) and the ability to sustain
3 high power productions for prolonged periods of time, with values that appear to be extremely high
4 when we consider the power-to-weight ratio (W/kg). These values are partially explained by
5 specific anthropometric characteristics. XCO bikers have low values of body mass and body fat
6 (Impellizzeri et al., 2005; Lee et al., 2002) and characteristic similar to climbing specialists
7 (Impellizzeri et al., 2008; Impellizzeri & Marcora, 2007). Overall, authors have suggested all these
8 specific physiological and anthropometric factors as a prerequisite to compete successfully in elite
9 male and female categories of XCO cycling (Impellizzeri et al., 2008; Impellizzeri & Marcora,
10 2007).

11 Despite previous studies have already described the anthropometry and the physiological
12 characteristics of XCO bikers, few data are available about the evolution of these characteristics in
13 young athletes. Young XCO bikers, depending on age, compete in junior and youth categories of
14 XCO cycling championships. According to UCI rules, the junior category is the first international
15 category, for bikers of 17-18 years old, while younger bikers mainly compete at national level.
16 According to national rules (<http://mountainbike.feder ciclismo.it>) athletes between 13 and 16 years
17 old compete in four different categories, from the 1st to the 4th year category, organized by age and
18 gender. Overall, competitions for youth cyclists generally present many characteristics of
19 international races with some differences in circuit length and race duration. Competitions for youth
20 bikers last from 20 to 60 minutes, with variation mainly due to gender and increasing with age.

21 Taking into account cycling literature, only few studies have investigated physiological parameters
22 and characteristics of young athletes, but focusing their attention on junior categories (Menaspà et
23 al., 2012; Menaspà, Sassi, & Impellizzeri, 2010) or road cycling (Rodriguez-Marroyo et al., 2011).
24 To the best of our knowledge there aren't any reference data about youth XCO cyclists. The main
25 purpose of this study was to analyze anthropometric characteristics and physiological qualities of
26 some of the best young bikers, belonging to a national youth XCO cycling team. Considering all the

1 characteristics presented, required to compete successfully in adult age, we hypothesise that a group
2 of high level bikers should present a specific athletic profile already at young age, reflecting the
3 high physiological demand of this sport. Moreover, considering few literature data about anaerobic
4 characteristics of XCO cyclists, the second purpose of the study was to report important reference
5 values of some international level bikers.

6

7 **Methods**

8 *Participants*

9 For a period of four years we conducted the physiological and anthropometric assessment of a
10 group of young high level XCO cyclists, involved in a larger national project for talent
11 development. Data were collected every year, with a testing session during the competition period
12 (July). In each session, the year's best 10 to 15 cyclists by age and gender, members of the national
13 team, were included. The study involved 45 cyclists, 26 males and 19 females, aged between 13 and
14 16 years old, all members of the Italian youth XCO cycling team, competing in youth categories of
15 national championships. Many of them were youth national champions and have achieved excellent
16 results during, or also in the following years of the project in junior categories at international level.
17 Additionally, some of them have become Youth Olympic and World Junior Champions. Informed
18 consent was obtained from all individual participants included in the study. The study was
19 conducted in accordance with the ethical principles of the Declaration of Helsinki and approved by
20 the institutional ethics committee.

21

22 *Anthropometric and physiological assessment*

23 Stature was measured to the nearest millimeter with a wall-mounted stadiometer (Gima, Milano,
24 Italy) and body mass to within ± 100 g with a digital weighing scale (Seca, Hamburg, Germany). A
25 graded exercise test was performed for the aerobic assessment. All tests were conducted with an
26 electromagnetically-braked bicycle ergometer (Excalibur Sport, Lode BV, Groningen, Netherland)

1 that was adjusted for each participant replicating his own bicycle. Before the test cyclists performed
2 a 10 min warm-up at a power of 70 W. The graded exercise started at a workload of 75 W for 3
3 min, then, the workload was increased by 25 W every 1 min until the volitional exhaustion of the
4 athlete. Cardio-respiratory measures were collected continuously using an automated breath-by-
5 breath open-circuit gas analysis system (Quark PFT Ergo, Cosmed Srl, Rome, Italy). Careful
6 calibrations of flow sensors and gas analyzers were performed before each measurement according
7 to the manufacturer's instructions. After a recovery period of 1 hour the athletes performed a 30 s
8 Wingate test for the anaerobic evaluation on a mechanically-braked cycle ergometer (Ergomedic
9 894-Ea, Monark, Vansbro, Sweden). Before the test a 15-min warm-up, including 2–3 sub-maximal
10 sprints, was performed. Cyclists were instructed to pedal as fast as possible from the start and not to
11 conserve energy for the last part of the test, producing an “all-out” effort. Athletes started pedaling
12 without braking resistance and were instructed to maintain a cadence of 60 revolutions/min before
13 sprinting. Then cyclists started sprinting maximally and the braking resistance, a load of 0.075 kg
14 per kg of athletes body mass, was applied automatically when reached 100 revolutions/min.
15 Cyclists pedaled maximally for all the 30 s of the test remaining seated, and strong verbal
16 encouragement was provided throughout.

17

18 *Data Analysis*

19 For the graded exercise test, peak power output (PPO), achieved at athlete's exhaustion, was
20 determined according to the equation $P(W) = \text{power output for the last stage completed (W)} + [t$
21 $(s)/\text{step duration (s)} * \text{step increment (W)}]$, where t is the time of the uncompleted stage (Kuipers,
22 Verstappen, Keizer, Geurten, & Van Kranenburg, 1985). $VO_{2\max}$ was defined as the highest values
23 of a 20-s average (Robergs, Dwyer, & Astorino, 2010). Other breath-by-breath data were averaged
24 over 10s for further analysis in which we calculated a number of physiological parameters that have
25 been shown to be important determinants of cycling performance (Lucià, Hoyos, Paèrez, &
26 Chicharro, 2000). Respiratory Compensation Point (RCP) was determined from different measures

1 including: 1) the second disproportionate increase in minute ventilation; 2) the first systematic
2 increase in VE/VCO₂; 3) the first systematic decrease in end-tidal CO₂ tension (Ahmaidi et al.,
3 1993). Therefore, it was possible to determine the specific power values associated with this
4 parameter (P@RCP). Power was recorded continuously during Wingate Test and analyzed to obtain
5 anaerobic performance indices. The highest mechanical power (PMax) was recorded and expressed
6 as the peak power achieved during the first 5 seconds of the test. The mean mechanical power
7 (PMean) was expressed as the average power over the entire 30 seconds of the trial.

8 All test data are presented as means with standard deviations, and expressed in absolute and relative
9 to body mass values. Furthermore, all data were reported by the year of youth category. Due to the
10 limited sample size (n=3) 1st female category was excluded from statistical analysis. The
11 assumption of normality was verified using a Saphiro-Wilk Test. A one-way analysis of variance
12 (ANOVA) was used on each dependent variable both for male and female to identify differences
13 among categories. When a significant F-value was found, Bonferroni's post hoc test was applied. In
14 addition a comparison of characteristics in last year of youth category and data available in
15 literature for high level athletes was conducted using an independent t-test. All statistical analysis
16 was completed using a statistical software (SPSS Inc, Chicago, Illinois, USA). The level of
17 statistical significance was set at P<0.05.

18

19 **Results**

20 Anthropometric characteristics are presented in Table 1. Results from ANOVA showed no
21 differences among categories in body mass, both for males (P=0.100) and females (P=0.171), and
22 stature both for males (P=0.054) and females (P=0.423). Body mass Index (BMI) was not different
23 among categories, neither for male (P=0.483) nor for female bikers (P=0.530).

24 *****Table1 about here*****

25 Physiological aerobic characteristics are reported in Table 2. In males absolute VO_{2max} (L/min) was
26 significantly different among categories (P=0.002), showing higher values in 3rd (P=0.018) and 4th

1 year (P=0.002) compared to 1st. Absolute VO_{2max} was not significantly different among female
2 categories (P=0.091). Relative VO_{2max} (ml/kg/min) was not significantly different among categories,
3 in males (P=0.130) and females (P=0.309).

4 *****Table2 about here*****

5 PPO changed significantly among categories in males (P<0.001) and in females (P=0.039). In males
6 PPO showed higher values in 3rd (P=0.003) and 4th year (P<0.001) compared to 1st. In females
7 absolute PPO was greater in 4th compared to 2nd (P=0.038). PPO relative to body mass reached
8 significance in males (P=0.018), with 4th year PPO significantly greater than 1st (P=0.026).
9 Absolute values of power at RCP was significantly different among categories only in male athletes
10 (P=0.025), with 4th year values greater than 1st year (P=0.036). These values relative to body mass
11 were not significantly different in males (P=0.349) and females (P=0.890).

12 *****Table3 about here*****

13 Results from anaerobic evaluation tests, with peak anaerobic power (PMax) and mean anaerobic
14 power (PMean) expressed in absolute and relative values, are reported in Table 3. Anaerobic indices
15 were significantly different among categories only in male athletes. Absolute value of PMax was
16 significantly different among categories (P=0.004), with 4th and 3rd category values greater 1st year.
17 Considering maximal anaerobic power relative to body mass (W/kg), this appear different among
18 years (P=0.009), with 4th year higher than 1st (P=0.009). PMean (W) was significantly different in
19 4th year compared to 1st (P=0.008). PMean (W/kg) was significantly higher in 3rd (P=0.020) and 4th
20 (P=0.004) compared to 1st. In Fig.1 were reported, VO_{2max}(ml/kg/min), PPO (W/kg) and PMax
21 (W/kg) distribution in male and female athletes.

22 *****Fig1 about here*****

23

24 *Youth vs adults high level bikers*

25 In the following analysis we compared the data that we recorded in our 16 years old cyclist with the
26 values reported in the studies of Impellizzeri & coll. (2005) for males and Impellizzeri & coll.

1 (2008) for females adult athletes. The absolute $\text{VO}_{2\text{max}}$ (L/min) was significantly lower in 16 years
2 old male bikers than in adult high level athletes (4.32 ± 0.39 vs 5.11 ± 0.46 L/min) ($P<0.0001$),
3 whereas the $\text{VO}_{2\text{max}}$ relative to the body mass (mL/kg/min) was not different (72.7 ± 4.4 vs 75.9 ± 5.3
4 mL/kg/min) ($P=0.121$). In females $\text{VO}_{2\text{max}}$ was not significantly different from adults both for
5 absolute (3.33 ± 0.20 vs 3.30 ± 0.28 L/min) ($P=0.807$) and for values normalized to the body mass
6 (62.9 ± 4.9 vs 61.4 ± 4.8 mL/kg/min) ($P=0.523$). Absolute PPO (W) was not significantly different
7 from adults both in males (395 ± 41 vs 426 ± 40 W) ($P=0.074$) and in females (316 ± 30 vs 314 ± 26 W)
8 ($P=0.880$). Relative PPO (W/kg) was not different from adult bikers in males (6.7 ± 0.6 vs 6.4 ± 0.6
9 W/kg) ($P=0.233$) and in females (5.9 ± 0.4 vs 5.9 ± 0.6 W/kg) ($P=0.891$). Absolute $P@RCP$ (W) was
10 significantly lower in 16 y.o. athletes than in adults males (320 ± 34 vs 360 ± 29 W) ($P=0.004$) not in
11 females (251 ± 37 vs 247 ± 23 W) ($P=0.757$). Relative $P@RCP$ (W/kg) was not significantly different
12 from adults both in males (5.4 ± 0.4 vs 5.4 ± 0.4 W/kg) ($P=0.903$) and in females (4.6 ± 0.6 vs 4.6 ± 0.6
13 W/kg) ($P=0.887$).

14

15 **Discussion**

16 *Anthropometric characteristics*

17 A mean stature and body mass increase was reported from 13 to 16 year old both in male and
18 female cyclists, however no significant differences were shown. Considering that athletes belonged
19 to a national cycling team, represented by year's best cyclists, it was possible a specific selection of
20 early-maturing athletes that could explain similar anthropometric characteristics and some high
21 physiological values reported in lower categories. Nevertheless, it is worth noting that these
22 characteristics both in males and in females, although belonging to young bikers, define a
23 morphological profile similar to that shown in literature for elite XCO cyclists, where a weight-
24 optimization is required (Impellizzeri & Marcora, 2007; Lee et al., 2002). Studies on best adult
25 bikers report mean values of stature of 176-180 cm with body mass of 65-69 kg in male athletes
26 (Impellizzeri & Marcora, 2007), 162-166 cm and 54-57.5 kg in best female athletes (Impellizzeri et

1 al., 2008; Wilber et al., 1997), defining a specific anthropometry for XCO cyclists. In cycling low
2 values of body weight and body fat are known to optimize climbing performance, improving
3 relative physiological and power values (Swain, 1994). This could explain low BMI values reported
4 in this study both in female and male athletes and the high physiological values observed when
5 body-mass normalization was considered for the analysis.

6

7 *Aerobic characteristics*

8 In this study absolute VO_{2max} (L/min) increased with increasing age in males but not in females.
9 Considering literature about aerobic fitness during youth, differences in VO_{2max} evolution between
10 male and female were reported (Armstrong, Tomkinson, & Ekelund, 2011). Longitudinal studies
11 showed a linear increase in aerobic power in relation to age throughout adolescence in male, while
12 for female a slower trend were reported, with a gradual leveling-off from age 14 years (Armstrong
13 et al., 2011). This phenomenon could explain different behavior in VO_{2max} evolution observed in
14 this study between genders and different timing in male and female performance evolution. In the
15 last year of youth category (≈ 16 years old) the VO_{2max} of male bikers (4.32 L/min) was lower than
16 the one reported for elite adult bikers (5.11 L/min) (Impellizzeri et al., 2005). On the contrary, the
17 VO_{2max} of female bikers (3.33 L/min) was comparable to elite adults (3.30 L/min) (Impellizzeri et
18 al., 2008). Studies on high level bikers show mean values of $VO_{2max} > 70$ ml/kg/min for males
19 (Impellizzeri & Marcora, 2007; Lee et al., 2002; Wilber et al., 1997) and $VO_{2max} > 60$ ml/kg/min in
20 females (Impellizzeri et al., 2008), suggesting these characteristics as a prerequisite to compete
21 successfully in adult age. This is confirmed here also for young bikers, showing how these high
22 relative physiological parameters were already developed, with values exceeding ≈ 75 ml/kg/min in
23 males and ≈ 65 ml/kg/min in females. In addition the values of VO_{2max} normalized to body mass
24 (ml/kg/min) presented in this study appear to be higher than those reported in national youth road
25 cyclists (Rodriguez-Marroyo et al., 2011) and older junior road cyclists (Menaspà et al., 2012).
26 This is in line with XCO cycling literature that have already established higher VO_{2max} in elite XCO

1 bikers, compared with flat road cyclists, both in males and females (Impellizzeri et al., 2008; Lee et
2 al., 2002). The body mass normalization better describes the cyclist's climbing ability and this is
3 why, also a higher power-to-weight ratio, that contributes uphill performance, is generally observed
4 in best XCO bikers and climbers (Impellizzeri et al., 2005). For the reasons mentioned above we
5 can speculate this occurrence also in younger XCO bikers, compared with same age road bikers,
6 reflecting different characteristics and physiological demands of XCO cycling compared to road
7 cycling.

8 Previous studies on elite adult XCO bikers, using similar protocol consisting in 25 W/min power
9 increase until volitional exhaustion, allow to compare the peak power output with our results. In the
10 last year of youth category (16 years old) the peak power output of bikers was not significantly
11 lower than the ones reported for adults (Impellizzeri et al., 2008; Impellizzeri et al., 2005). In
12 addition, when the peak power output was normalized to cyclists' body mass, these values were
13 similar to those reported for high level adults in female (Impellizzeri et al., 2008) and rather higher
14 in males (Impellizzeri et al., 2005). This fact obviously reflects the high condition of athletes but
15 attests the importance, also in youth categories, of specific physiological and anthropometric
16 profiles for optimal peak power-to-weight ratios and performances.

17 Notwithstanding methodological differences in determining high intensity domain and sub-maximal
18 performance indices all previous studies demonstrate that bikers can utilise a high percent of their
19 maximum aerobic power to produce high and prolonged work rates (Impellizzeri & Marcora, 2007;
20 Lee et al., 2002; Wilber et al., 1997). Studies report values of power at respiratory compensation
21 point (P@RCP) of 5.4 ± 0.4 W/Kg in male (Impellizzeri et al., 2005) and 4.6 ± 0.6 W/Kg in female
22 (Impellizzeri et al., 2008). In this study, as previously observed in peak power productions, sub-
23 maximal performance indices appear to be comparable to other older bikers, when body-mass
24 normalization is considered. Overall this occurrence showed, also in youth athletes, specific
25 physiological qualities that permit the production of high power-to-weight ratios required for XCO
26 cycling performance.

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Anaerobic characteristics

Some authors underlined that XCO competitions, although predominantly aerobic, also require high anaerobic power and capacity (Stapelfeldt et al., 2004). In addition a recent study found a significant correlation between performance and the peak and mean power expressed during a an intermittent test consisting in 5 maximal sprints (Inoue, Sà Filho, Mello, & Santos, 2012). This could justify our findings and values reported in current study, showing highly developed anaerobic systems in young athletes. Other few studies have investigated anaerobic performance in XCO cyclists, reporting values obtained with anaerobic tests. In a study on elite national cyclists mean peak power output of 14.9 ± 1.1 W/kg has been reported during a 10 s maximal laboratory test (Baron, 2001). Data obtained from our laboratories (unpublished data) in 3 high level male cyclists (range 51°-508° ranking 2015 UCI) and 4 high level female cyclists (range 12°-86° ranking 2015 UCI) showed values of maximal anaerobic power (PMax) of 1105 ± 81 W (range 1014 – 1168 W) in males and 759 ± 63 W (range 670 – 816 W) in females; with values relative to body mass of 16.1 ± 0.6 W/kg (range 15.6 – 16.8 W/kg) and 13.9 ± 1.6 W/kg (range 12.3 – 15.3 W/kg), respectively. Mean power production in 30s Wingate test for these athletes was 688 ± 65 W in male (range 625 - 754 W) and 492 ± 40 W in female (range 441-537 W), with values relative to body mass of 10.0 ± 0.7 W/kg (range 9.6-10.8 W/kg) and 9.0 ± 0.6 W/kg (range 8.1-9.5 W/kg), respectively. More information about anaerobic involvement in XCO cycling are available by analyzing power profile data obtained during races (Stapelfeldt et al., 2004). The ability to generate relatively high power output of short duration is extremely important in a mass start event (Impellizzeri & Marcora, 2007). In elite categories this generally means an explosive pace at the start, followed by continuous intermittent efforts: during steep climbing, when sprinting to pass slower riders or in sprints at the finish of the race (Stapelfeldt et al., 2004). Considering similar characteristics of youth races and shorter duration we can speculate an equal or higher importance of high intensity efforts and anaerobic metabolism that can justify values here reported. Overall, data here presented attest the

1 presence of highly developed anaerobic systems in athletes, reporting important reference data
2 about best youth XCO cyclists.

3

4 **Conclusions**

5 The physiological and anthropometric characteristics required to compete successfully in XCO
6 cycling, previously investigated (Impellizzeri et al., 2008; Impellizzeri & Marcora, 2007; Lee et al.,
7 2002; Wilber et al., 1997), are already developed in high level youth bikers. At the age of 16, just
8 before passing in junior categories and competing at international level, best youth XCO bikers
9 show normalized physiological values similar to those reported in literature for high level athletes.
10 High values of aerobic power, that seems to be a prerequisite in elite categories and in best youth
11 bikers are already developed, probably underlining a natural talent selection for XCO competitions,
12 where best athletes already present specific physiological as well as advantageous anthropometric
13 characteristics, at young age. This occurrence is observable also for other physiological values
14 when a normalisation for body mass is considered, showing specific abilities that permit the
15 production of high power-to-weight ratios and high peaks of anaerobic power required for XCO
16 cycling performance also in youth categories.

17 Even though, as it has been shown by previous authors, values such as VO_{2max} , or other
18 physiological measures cannot predict the professional career of young cyclists, they can be useful
19 to identify cyclists who can excel in their age category (Menaspà et al., 2010). In particular this
20 data, belonging to a selected group of high level athletes, can be taken as reference values for talent
21 identification in youth XCO cycling, reporting important missing data about the evolution of young
22 XCO bikers.

23

24 **Disclosure statement**

25 No potential conflict of interest was reported by the authors

26

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12 **Table 1.** Anthropometric characteristics of young XCO bikers

13 **Table 2.** Physiological characteristics of young XCO bikers

14 **Table 3.** Physiological anaerobic parameters of young XCO bikers

15
16 **Figure 1.** Physiological characteristics distribution of young XCO bikers

Table 1. Anthropometric characteristics of young XCO bikers

Category (year)	Age (yy)				Stature (cm)				Body Mass (kg)				BMI (kg/m ²)			
	m		f		m		f		m		f		m		f	
1st (n = 8 m; 3 f)	13.6	± 0.2	13.2	± 0.2	165.8	± 6.0	157.8	± 4.6	53.1	± 7.3	48.5	± 4.4	19.2	± 1.8	19.5	± 1.2
2nd (n =12 m; 9 f)	14.3	± 0.3	14.4	± 0.3	168.9	± 5.3	160.9	± 5.2	57.8	± 5.6	50.2	± 5.3	20.3	± 1.6	19.4	± 1.8
3rd (n = 7 m; 9 f)	15.5	± 0.2	15.4	± 0.3	172.4	± 5.9	162.3	± 4.5	58.4	± 3.0	53.7	± 4.3	19.7	± 1.0	20.4	± 1.6
4th (n =12 m; 7 f)	16.3	± 0.2	16.2	± 0.2	172.9	± 6.6	164.5	± 5.9	59.5	± 5.4	54.0	± 4.4	19.9	± 1.3	20.0	± 1.0

m = male ; f = female;

Table 1. Anthropometric characteristics of young XCO bikers

Table 2. Physiological characteristics of young XCO bikers

Category (year)	VO _{2max} (L/min)		VO _{2max} (mL/kg/min)		PPO (W)		PPO (W/kg)		P@RCP (W)		P@RCP (W/kg)	
	m	f	m	f	m	f	m	f	m	f	m	f
1st (n = 8 m; 3 f)	3.56 ± 0.49	2.85 ± 0.10	67.1 ± 3.0	59.0 ± 3.2	310 ± 31	263 ± 14	5.9 ± 0.4	5.4 ± 0.2	272 ± 30	216 ± 21	5.2 ± 0.4	4.5 ± 0.4
2nd (n =12 m; 9 f)	4.03 ± 0.35	2.97 ± 0.33	70.0 ± 6.7	60.5 ± 5.9	359 ± 43	276 ± 36	6.2 ± 0.7	5.5 ± 0.5	297 ± 42	227 ± 21	5.1 ± 0.6	4.5 ± 0.4
3rd (n = 7 m; 9 f)	4.24 ± 0.46 *	3.09 ± 0.33	72.5 ± 6.7	58.3 ± 6.1	387 ± 37 *	288 ± 21	6.6 ± 0.5	5.4 ± 0.4	320 ± 33	247 ± 21	5.5 ± 0.4	4.6 ± 0.5
4th (n =12 m; 7 f)	4.32 ± 0.39 *	3.33 ± 0.20	72.7 ± 4.4	62.9 ± 4.9	395 ± 41 *	316 ± 30 **	6.7 ± 0.6 *	5.9 ± 0.4	320 ± 34 *	251 ± 37	5.4 ± 0.4	4.6 ± 0.5

VO_{2max} = maximal oxygen uptake; PPO = Peak Power Output; P@RCP = Power at Respiratory Compensation Point; m = male ; f= female;

* significantly different from 1st category

**significantly different from 2nd category

Table 2. Physiological characteristics of young XCO bikers

Table 3. Physiological anaerobic parameters of young XCO bikers

Category (year)	PMax (W)		PMax (W/kg)		PMean (W)		PMean (W/kg)	
	m	f	m	f	m	f	m	f
1st (n = 8 m; 3 f)	772 ± 139	607 ± 44	14.5 ± 1.4	12.6 ± 1.3	490 ± 79	405 ± 14	9.2 ± 0.4	8.4 ± 0.6
2nd (n=12 m; 9 f)	903 ± 117	663 ± 124	15.6 ± 1.2	13.2 ± 2.1	564 ± 63	426 ± 36	9.8 ± 0.5	8.5 ± 0.8
3rd (n = 7 m; 9 f)	960 ± 103 *	714 ± 92	16.4 ± 1.2	13.4 ± 1.7	581 ± 53	454 ± 21	9.9 ± 0.5 *	8.5 ± 0.7
4th (n=12 m; 7 f)	987 ± 130 *	731 ± 110	16.6 ± 1.4 *	13.5 ± 1.6	593 ± 62 *	473 ± 30	10.0 ± 0.3 *	8.8 ± 0.4

PMax= maximal anaerobic power in 30-s Wingate Test; PMean= mean anaerobic power in 30-s Wingate Test; m = male ; f = female;

* significantly different from 1st category

**significantly different from 2nd category

Table 3. Physiological anaerobic parameters of young XCO bikers

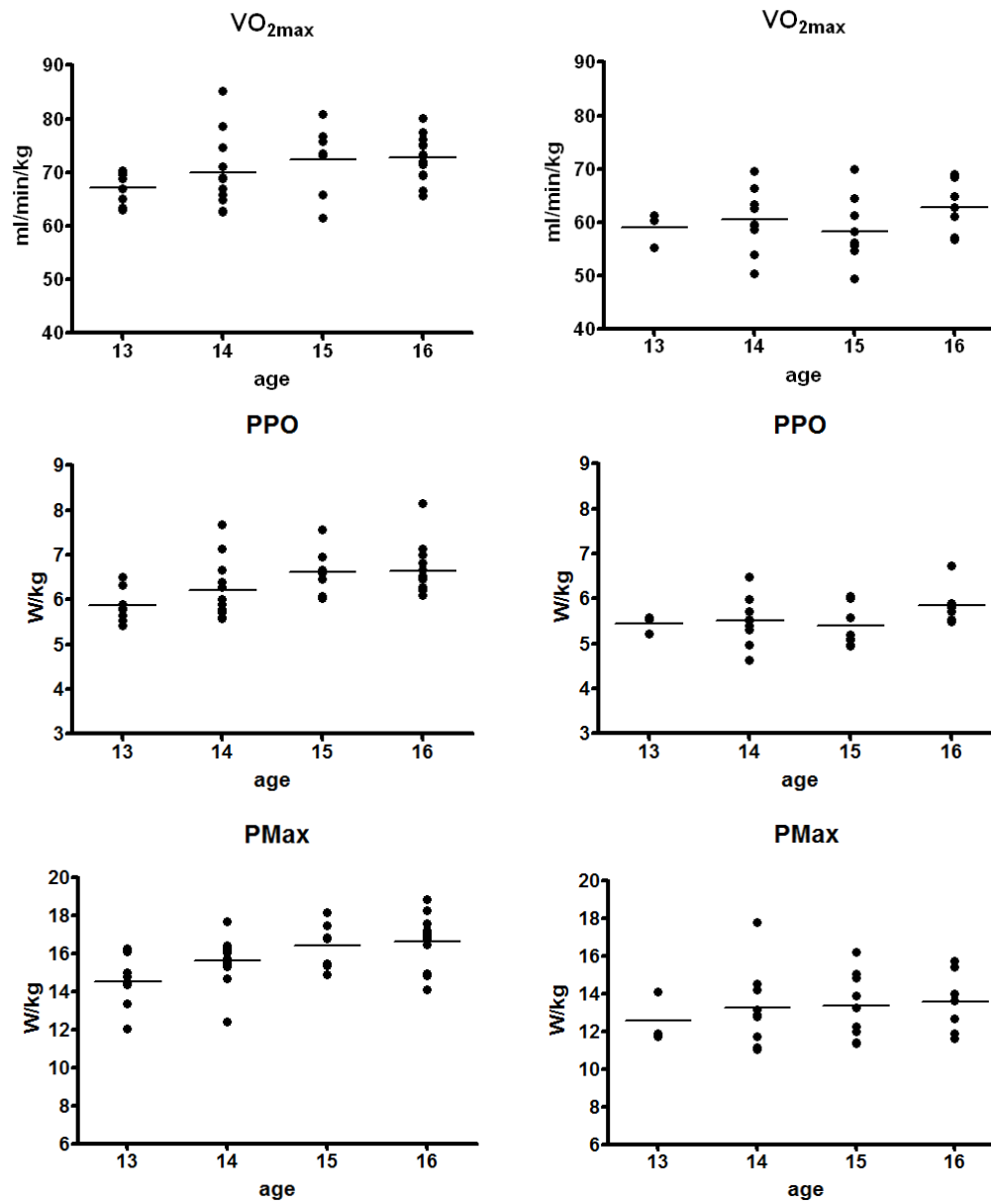


Fig.1. Physiological characteristics of young male (on the left) and female XCO bikers (on the right)