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

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## Abstract

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



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

## Introduction

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

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

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

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

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

Taking into account cycling literature, only few studies have investigated physiological parameters and characteristics of young athletes, but focusing their attention on junior categories (Menaspà et al., 2012; Menaspà, Sassi, & Impellizzeri, 2010) or road cycling (Rodriguez-Marroyo et al., 2011). To the best of our knowledge there aren't any reference data about youth XCO cyclists. The main purpose of this study was to analyze anthropometric characteristics and physiological qualities of some of the best young bikers, belonging to a national youth XCO cycling team. Considering all the characteristics presented, required to compete successfully in adult age, we hypothesise that a group of high level bikers should present a specific athletic profile already at young age, reflecting the high physiological demand of this sport. Moreover, considering few literature data about anaerobic characteristics of XCO cyclists, the second purpose of the study was to report important reference values of some international level bikers.

## Methods

### *Participants*

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

### *Anthropometric and physiological assessment*

Stature was measured to the nearest millimeter with a wall-mounted stadiometer (Gima, Milano, Italy) and body mass to within ± 100 g with a digital weighing scale (Seca, Hamburg, Germany). A graded exercise test was performed for the aerobic assessment. All tests were conducted with an electromagnetically-braked bicycle ergometer (Excalibur Sport, Lode BV, Groningen, Netherland) that was adjusted for each participant replicating his own bicycle. Before the test cyclists performed a 10 min warm-up at a power of 70 W. The graded exercise started at a workload of 75 W for 3 min, then, the workload was increased by 25 W every 1 min until the volitional exhaustion of the athlete. Cardio-respiratory measures were collected continuously using an automated breath-by-breath open-circuit gas analysis system (Quark PFT Ergo, Cosmed Srl, Rome, Italy). Careful calibrations of flow sensors and gas analyzers were performed before each measurement according to the manufacturer's instructions. After a recovery period of 1 hour the athletes performed a 30 s Wingate test for the anaerobic evaluation on a mechanically-braked cycle ergometer (Ergomedic 894-Ea, Monark, Vansbro, Sweden). Before the test a 15-min warm-up, including 2–3 sub-maximal sprints, was performed. Cyclists were instructed to pedal as fast as possible from the start and not to conserve energy for the last part of the test, producing an "all-out" effort. Athletes started pedaling without braking resistance and were instructed to maintain a cadence of 60 revolutions/min before sprinting. Then cyclists started sprinting maximally and the braking resistance, a load of 0.075 kg per kg of athletes body mass, was applied automatically when reached 100 revolutions/min. Cyclists pedaled maximally for all the 30 s of the test remaining seated, and strong verbal encouragement was provided throughout.

*Data Analysis*

For the graded exercise test, peak power output (PPO), achieved at athlete's exhaustion, was determined according to the equation P(W) = power output for the last stage completed (W) + [*t* (s)/step duration (s) * step increment (W)], where *t* is the time of the uncompleted stage (Kuipers, Verstappen, Keizer, Geurten, & Van Kranenburg, 1985). $VO_{2max}$ was defined as the highest values of a 20-s average (Robergs, Dwyer, & Astorino, 2010). Other breath-by-breath data were averaged over 10s for further analysis in which we calculated a number of physiological parameters that have been shown to be important determinants of cycling performance (Lucià, Hoyos, Paèrez, & Chicharro, 2000). Respiratory Compensation Point (RCP) was determined from different measures including: 1) the second disproportionate increase in minute ventilation; 2) the first systematic increase in $VE/VCO_2$; 3) the first systematic decrease in end-tidal CO2 tension (Ahmaidi et al., 1993). Therefore, it was possible to determine the specific power values associated with this parameter (P@RCP). Power was recorded continuously during Wingate Test and analyzed to obtain anaerobic performance indices. The highest mechanical power (PMax) was recorded and expressed as the peak power achieved during the first 5 seconds of the test. The mean mechanical power (PMean) was expressed as the average power over the entire 30 seconds of the trial.

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

**Results**

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

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

Physiological aerobic characteristics are reported in Table 2. In males absolute $VO_{2max}$ (L/min) was significantly different among categories ($P=0.002$), showing higher values in 3rd ($P=0.018$) and 4th year (P=0.002) compared to 1st. Absolute $VO_{2max}$ was not significantly different among female categories (P=0.091). Relative $VO_{2max}$ (ml/kg/min) was not significantly different among categories, in males (P=0.130) and females (P=0.309).

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

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

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

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

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

*Youth vs adults high level bikers*

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

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

## Discussion

*Anthropometric characteristics*

A mean stature and body mass increase was reported from 13 to 16 year old both in male and female cyclists, however no significant differences were shown. Considering that athletes belonged to a national cycling team, represented by year's best cyclists, it was possible a specific selection of early-maturing athletes that could explain similar anthropometric characteristics and some high physiological values reported in lower categories. Nevertheless, it is worth noting that these characteristics both in males and in females, although belonging to young bikers, define a morphological profile similar to that shown in literature for elite XCO cyclists, where a weight-optimization is required (Impellizzeri & Marcora, 2007; Lee et al., 2002). Studies on best adult bikers report mean values of stature of 176-180 cm with body mass of 65-69 kg in male athletes (Impellizzeri & Marcora, 2007), 162-166 cm and 54-57.5 kg in best female athletes (Impellizzeri et al., 2008; Wilber et al., 1997), defining a specific anthropometry for XCO cyclists. In cycling low values of body weight and body fat are known to optimize climbing performance, improving relative physiological and power values (Swain, 1994). This could explain low BMI values reported in this study both in female and male athletes and the high physiological values observed when body-mass normalization was considered for the analysis.

*Aerobic characteristics*

In this study absolute $VO_{2max}$ (L/min) increased with increasing age in males but not in females. Considering literature about aerobic fitness during youth, differences in $VO_{2max}$ evolution between male and female were reported (Armstrong, Tomkinson, & Ekelund, 2011). Longitudinal studies showed a linear increase in aerobic power in relation to age throughout adolescence in male, while for female a slower trend were reported, with a gradual leveling-off from age 14 years (Armstrong et al., 2011). This phenomenon could explain different behavior in $VO_{2max}$ evolution observed in this study between genders and different timing in male and female performance evolution. In the last year of youth category (≈16 years old) the $VO_{2max}$ of male bikers (4.32 L/min) was lower than the one reported for elite adult bikers (5.11 L/min) (Impellizzeri et al., 2005). On the contrary, the $VO_{2max}$ of female bikers (3.33 L/min) was comparable to elite adults (3.30 L/min) (Impellizzeri et al., 2008). Studies on high level bikers show mean values of $VO_{2max}$ >70 ml/kg/min for males (Impellizzeri & Marcora, 2007; Lee et al., 2002; Wilber et al., 1997) and $VO_{2max}$ >60 ml/kg/min in females (Impellizzeri et al., 2008), suggesting these characteristics as a prerequisite to compete successfully in adult age. This is confirmed here also for young bikers, showing how these high relative physiological parameters were already developed, with values exceeding≈75 ml/kg/min in males and ≈65 ml/kg/min in females. In addition the values of $VO_{2max}$ normalized to body mass (ml/kg/min) presented in this study appear to be higher than those reported in national youth road cyclists (Rodriguez-Marroyo et al., 2011) and older junior road cyclists (Menaspà et al., 2012). This is in line with XCO cycling literature that have already established higher $VO_{2max}$ in elite XCO bikers, compared with flat road cyclists, both in males and females (Impellizzeri et al., 2008; Lee et al., 2002). The body mass normalization better describes the cyclist's climbing ability and this is why, also a higher power-to-weight ratio, that contributes uphill performance, is generally observed in best XCO bikers and climbers (Impellizzeri et al., 2005). For the reasons mentioned above we can speculate this occurrence also in younger XCO bikers, compared with same age road bikers, reflecting different characteristics and physiological demands of XCO cycling compared to road cycling.

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

Notwithstanding methodological differences in determining high intensity domain and sub-maximal performance indices all previous studies demonstrate that bikers can utilise a high percent of their maximum aerobic power to produce high and prolonged work rates (Impellizzeri & Marcora, 2007; Lee et al., 2002; Wilber et al., 1997). Studies report values of power at respiratory compensation 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 (Impellizzeri et al., 2008). In this study, as previously observed in peak power productions, sub-maximal performance indices appear to be comparable to other older bikers, when body-mass normalization is considered. Overall this occurrence showed, also in youth athletes, specific physiological qualities that permit the production of high power-to-weight ratios required for XCO cycling performance.

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

## Conclusions

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

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

## Disclosure statement

No potential conflict of interest was reported by the authors

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

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

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

**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

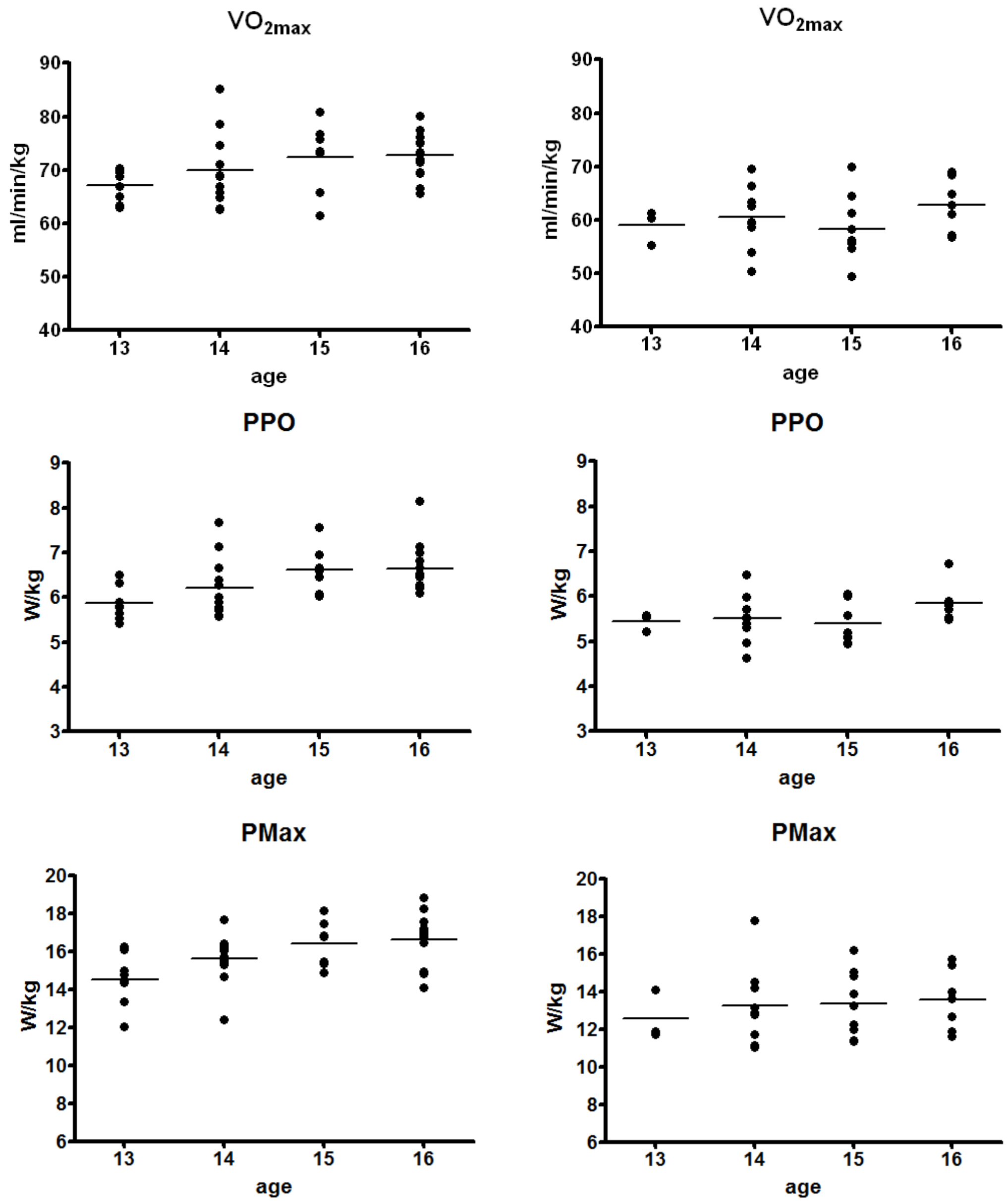


**Fig.1**. Physiological characteristics of young male (on the left) and female XCO bikers (on the right)