Longitudinal changes in maximal oxygen uptake in adolescent girls and boys with different training backgrounds

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Running Head: Maximal oxygen uptake during puberty.

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Abstract

The purpose of this study was to investigate the effects of high-volume endurance training on the development of maximal oxygen uptake (VO2max) in physically active boys and girls between the ages of 12 and 15 years, using a longitudinal design. The children participated in organized training in sports clubs for an average of 7 to 10 hours per week, with one group undertaking a high volume of endurance training (~ 7 hours per week; End boys, n=23 and End girls, n=17) and the other group having a primary focus on technical and tactical skill development, undertaking low volumes of endurance training (~ 1.6 hours per week; non-End boys, n=29 and non-End girls, n=9). VO2max and anthropometrics were assessed at age 12, 13 and 15. At age 12, VO2max was 58.9 (5.6), 65.5 (7.2), 56.5 (6.5) and 58.8 (7.9) $ml \cdot kg^{-1} \cdot min^{-1}$ in End girls, End boys, non-End girls and non-End boys, respectively. Over the three years, there was no difference between the training groups in the development of VO2max independent of scaling. In boys, VO2max relative to body mass (BM) did not change from age 12 to 15, while VO2max tended to decrease relative to fat-free mass (FFM). In girls, VO2max relative to BM decreased slightly from age 12 to 15, with no changes over the years relative to FFM. The present longitudinal study suggests that in growing active children during puberty, high volumes of systematic endurance training do not have an additional effect on VO2max compared with similar volume of training mainly aiming at developing motor skills.

Keywords: Aerobic power, VO2max, Puberty, Adolescence, Growth, Maturation

1 Introduction

Physical activity has many beneficial health effects and physical fitness may reflect an individual's health status [1]. In a recent study of 3800 Canadian children and youth, physical fitness, and especially cardiorespiratory fitness, was found to be a significant indicator of physical health and was seen as a potentially useful tool in monitoring pediatric health status [2]. Maximal oxygen uptake (VO2max) is considered to be the best single measure of aerobic fitness [3].

The trainability of VO2max in adolescents is still controversial, despite the fact that the question has been addressed using a variety of approaches over several decades [4]. Some authors conclude that proper endurance training in prepubertal and circumpubertal children affects VO2max even if the effect is lower than in adults [5,6], while others claim that there is a maturational threshold below which children are not able to increase their VO2max [7]. Discrepancies between studies may be due to different study designs as well as training protocols [6,8].

Many factors determine performance in a specific sport. In a typical endurance sport, where performance relates to the average speed over a specific distance, VO2max has been regarded as the single best measure of performance. However, VO2max is not the only factor that determines performance [9]. Running economy and the ability to use a high percentage of the VO2max, anaerobic capacity, as well as motor competence and coordination will affect performance in these sports [10]. Hence, performance may improve without a significant increase in VO2max. In healthy young adults, VO2max may vary by more than 100% between a sedentary person and an athlete in a typical endurance sport. This variation in VO2max is partly an effect of genetics and partly results from environmental factors; mainly physical activity and training. Even though it is difficult to determine the contribution of the different factors, it has been estimated that 50% of the VO2max in adult individuals is inherited [11].

Endurance training in adults generally increases VO2max, although trainability varies between individuals and may be zero in some [12]. Experimental interventions, with pre- and post-training measurements, are the most common approach when investigating the effects of training in adults. In children and adolescents, several approaches have been used. Training interventions are difficult to perform in children for many reasons and relatively few randomized controlled training studies have been carried out [5,6]. In cross-sectional studies, it has been shown that endurance-trained children have higher VO2max values than non-endurance trained children [13-16]. However, cross-sectional studies cannot establish whether this is due to endurance training, initial selection or both.

In observational cohort studies, the development of factors of interest can be compared between training groups and non-training groups over a period of years. Again, relatively few of these cohort studies have been conducted and those that have been carried out have involved low numbers of participants, especially for girls. In Norway, a possible challenge with this approach may be recruiting inactive children to the non-training group. Reports from Statistics Norway [17] showed that in 2013 the number of hours spent engaged in physical activity outside school hours varied between 8 and 9 hours per week for boys and girls aged 10-12 years.

Understanding the effect of endurance training during puberty is important for future health effects, for coaches when designing training programs, and for developing successful athletes. Hence, the aim of the present study was to compare the development of VO2max from age 12 - 15 in two groups of active children; active boys and girls performing high volumes of endurance training and active boys and girls performing low volumes of endurance training.

2 Materials and methods

2.1 Participants and study design

Using a repeated-measures design, we assessed anthropometrics, VO2max, sexual maturity, predicted age at peak height velocity (PHV) and the amount and type of training in 78 young athletes. They were assigned to an endurance training group (End group) and a non-endurance training group (non-End group) based on type of sport and volume of endurance training, and were tested at age 12.1 (0.4), 13.4 (0.3), and 15.3 (0.3) years). The End group (23 boys,17 girls) consisted mainly of cross-country skiers (93%) and the non-End group (29 boys, 9 girls) participated mainly in team sports (96%). Every year, the participants completed a questionnaire to assess types of sports participation and the amount of weekly training hours. Participants were also interviewed (at age 15) in order to get a more detailed picture of their weekly training content during the preceding year. All tests were performed in one day on each testing occasion. Written parental consent was obtained prior to any testing. All experimental procedures were approved by the Norwegian Regional Committee for Medical Research Ethics and conformed to the standards set by the Declaration of Helsinki.

2.2 Training

Athletes in both the End group and non-End group participated in organized workouts in sport clubs. In the non-End group most of the training had a focus on technical and tactical skill development, while in the End group, the training became gradually more focused on endurance training over the years, including continuous training as well as high intensity interval training 2 to 3 times per week (average 2.2 (0.8) times per week). This type of training was normally carried out year-round except for 1 to 3 months with less training. The months before the testing period were the prime period for a high volume of endurance training. Volumes of total sport participation and typical endurance training are listed in Table 1.

2.3 Anthropometry

All measurements were conducted with the participants wearing shorts, t-shirt and no shoes. Stature and sitting height were measured to the nearest 0.1 cm using a stadiometer (Seca, Hamburg, Germany) and body mass (BM) to the nearest 0.1 kg using a digital scale (Seca, Hamburg, Germany). Sitting height was used to predict years from peak height velocity [18]. Body composition was assessed by bioelectrical impedance analysis (InBody, 720, Biospace Co, Ltd, Seoul, Korea). In 5 out of 78 participants, one out of the three measurements of body composition was missing due to technical errors. On average, percent fat mass (%FM) changed in a nearly linear manner from age 12 to age 15, with similar changes per year in each group (Table 1). Based on this, the third missing %FM value was calculated by interpolation or extrapolation from the two valid assessments. Fat-free mass (FFM) was then calculated based on BM and %FM.

2.4 Venous blood sample

Emla cream (AstraZeneca 55, Lidocain 25 mg, Prilocain 25 mg) was used as a topical anaesthetic before venepuncture to reduce pain and distress for the participants. Blood samples were drawn from an antecubital vein into 4 mL EDTA glass tubes (EDTA glass, BD vacutainer K2E 7.2 mg) and 5 ml serum gel tubes (VACUETTE® TUBE 5 ml Z Serum Separator Clot Activator). The EDTA coated tubes were sent to a medical laboratory (Fürst, Oslo, Norway) the following morning to be analysed. The serum tubes were left to rest for at least 30 min before centrifuging at 3500 G for 10 minutes at 4°C. The serum was then transferred to Eppendorf tubes and frozen. All samples were stored at -80°C until analysis. When all the samples had been collected, the serum tubes were sent to a medical laboratory, (Fürst, Oslo, Norway) and analysed for serum ferritin (Advia Chemistry XPT, Siemens Medical Solutions Diagnostics, Japan) and sex hormones (Advia Centaur XPT, Siemens Helathcare Diagnostic Inc., USA).

2.5 Sexual maturity

All participants underwent a brief health check by a medical doctor. In girls, breast development was assessed according to Tanner [19] and they were asked about menarche. In boys, blood samples were analysed for testosterone. Age at peak height velocity (APHV) and deviation from APHV, labelled maturity offset, were predicted according to Mirwald, Baxter-Jones, Bailey, Beunen [18]. Chronological age was calculated as the difference between date of birth and date of testing.

2.6 Exercise testing

VO2max was determined by an incremental running test to exhaustion on a treadmill (Woodway Elg 70 or PPS 55, Weil am Rhein, Germany). The protocol was the same for all 3 years and each participant was tested with the same equipment each time and by the same experienced test leader. Before the incremental test, the participants warmed up for 5 minutes at an incline of 5.3% and at a speed of 8 $km \cdot h^{-1}$. The incremental test started at incline 6.3% and speed 7 $km \cdot h^{-1}$ and both incline and speed were increased by 1% and 1 $km \cdot h^{-1}$ every minute until a speed of 11 $km \cdot h^{-1}$ was reached. For further increase in intensity, only the incline was increased (1% per minute). The test was terminated when the participant could no longer complete the desired workload despite vigorous verbal encouragement. A facemask (Hans Rudolph Instr., USA) was used during the test and oxygen uptake was measured continuously with an automated system (Oxycon Pro, Jaeger-Toennis, Hochberg, Germany or Moxus Modular Metabolic System, AEI Technologies Inc., Pittsburgh, USA). Each individual participant was tested with the same equipment each year. Heart rate was measured continuously (Polar RS800; Polar Electro Oy, Kempele, Finland). The exercise test was considered maximal if clear signs of maximal effort such as sweating, facial flushing and unsteady gait were demonstrated and, despite strong verbal encouragement, the participant was unwilling or unable to continue. In addition this was supported by a respiratory exchange ratio greater than 1.0 [20].

The highest 60-s averaged oxygen uptake achieved on the test was accepted as VO_2max. Time to exhaustion (TTE) was defined as the total number of minutes the participants ran during the maximal test (measured from the start of the incremental test to the time at which the test was terminated).

2.7 Statistical analyses

A three-way mixed ANOVA was run to examine the effects of sex, training group (group) and age on the different variables. Data are mean (standard deviations) unless otherwise stated. A Shapiro-Wilk test ($p > 0.05$) was used to test whether the variables for the different groups and time points (78 dataset) were normally distributed. In 73 out of 78 datasets, the variables were normally distributed. Testosterone at age 12 and 13 was not normally distributed. For unpaired comparisons, the Student's t-test was run when data were normally distributed, and a Mann-Whitney U Test was used when data were not normally distributed. Graphpad Prism 8 (GraphPad Software Inc., La Jolla, CA) and Microsoft Excel 2013 were used for statistical analyses.

3 Results

3.1 Age and biological age

The girls were on average at predicted PHV (0.0 (0.5) years) at the first examination, while the boys were 1.7 (0.5) years before predicted PHV. There was no difference in predicted years from APHV between End girls and non-End girls nor between End boys and non-End boys. However, levels of S-Testosterone were higher in non-End boys than in End boys at age 12 (1.9 (2.3) vs 0.8 (1.2) $nmol \cdot L^{-1}$; $p=0.038$), at age 13 (5.1 (5.4) vs 2.7 (3.6) $nmol \cdot L^{-1}$; $p=0.07$) and age 15 (11.9 (5.5) vs 7.5 (4.6) $nmol \cdot L^{-1}$; $p=0.004$). At age 12, forty-six out of the 52 boys had S-Testosterone levels below 3.5 $nmol \cdot L^{-1}$ (100 $ng \cdot dL^{-1}$) at age 12. Four out of 26 girls were at Tanner stage 3 in breast development while the remaining 22 girls were at Tanner stage 1 and 2 (11 in each category). Menarche had not occurred in any of the girls. At age 15, 89% of the non-End girls and 75% of the End girls had begun menstruation.

3.2 Anthropometry (Table 1)

Between the ages of 12 and 15, height ($p<0.001$), BM ($p=0.018$) and FFM ($p<0.001$) increased more in boys than in girls, with no differences between training groups. At age 15, boys were taller ($p<0.001$), had higher FFM ($p<0.001$) and tended to be heavier ($p=0.055$) than girls (Table 1). At age 12, there was no difference in %FM between girls and boys, but at age 13 ($p=0.006$) and at age 15 ($p<0.001$), girls had higher %FM than boys. At all ages, End boys had lower %FM than non-End boys ($p<0.001$ – 0.01) (Table 1).

3.3 Performance (Figure 1)

There was a significant 3-way interaction between sex, group and age for TTE ($p=0.009$). This suggests that the age effect on TTE was dependent on both group and sex. In boys, but not in girls, TTE increased with age ($p<0.001$) and more so in End boys than non-End boys ($p<0.001$). In addition, End boys were already performing better than non-End boys at age 12 ($p=0.021$). On average over the three years, End girls performed better than non-End girls ($p=0.038$), but this was only statistically significant at age 13 ($p=0.003$).

3.4 Maximal oxygen uptake parameters (Figure 2)

There was no significant 3-way interaction between sex, group and age for any of the measures of VO2max. There was a simple 2-way interaction between age and sex for absolute VO2max ($p<0.001$) and VO2max relative to BM ($p=0.004$), but not for VO2max relative to FFM ($p=0.667$). There was no 2-way interaction between age and group for any of these measures. This indicates that the age effects on these variables were dependent on sex, but not on training group. Absolute

VO2max increased with age in all groups, and more so in boys than girls (p<0.001). VO2max relative to BM did not change with age for the boys (p=0.972) and decreased with age for the girls (p=0.003). VO2max relative to FFM tended to decrease slightly with age for the boys (p=0.059), with no change with age for the girls (p=0.342). VO2max relative to BM and FFM was higher in End boys than in non-End boys (p<0.001), with no differences between the two groups of girls.

4 Discussion

Both training groups in the present study participated in organized sport. In the non-End group, most of the training was focused on technical and tactical skill development, while in the End group, the training became gradually more focused on endurance training over the years. One main finding of the present study was that the increased focus on systematic endurance training did not influence the development of VO2max. In boys, VO2max relative to BM did not change from age 12 to 15, while VO2max tended to decrease slightly relative to FFM. In girls VO2max relative to BM decreased slightly from age 12 to 15 with no changes over the years relative to FFM. The lack of differences between the End group and non-End group in the development of VO2max between the ages of 12 and 15 years indicates that it is more difficult to improve a specific form of fitness with training in children than in adults, thus supporting child-adult differences in trainability [21]. Importantly, the participants' performance, measured as time to exhaustion in the VO2max test, increased in both training groups of boys, but the increase in End boys was 3 times the increase in non-End boys. Performance did not change in either of the training groups of girls.

4.1 VO2max

Both groups measured higher values of VO2max than many previous studies with the same age group. However, all our subjects were physically active and similar values have been reported in other studies from other countries in endurance athletes as well as young lean controls [22-24]. End boys already had higher VO2max at age 12 compared with non-End boys independent of scaling. This could be due either to prior training or to a selection bias. In Norway, most 12-year-old children are participating in one or more organized sports during their leisure time after school hours. The average activity levels were relatively high in both groups (on average 6.5 (2.4) hours per week). However, activities in any organized sports in Norway in children younger than 12 are mostly play-based and geared towards motor skill development, and to a lesser extent towards the development of physical capacities. Therefore, we do not consider it likely that the higher VO2max in our End boys at age 12 was training-induced even if we cannot exclude this possibility. When a child selects a sport, both the child's own interests and the parent's interests will influence the choice. Several factors will determine their interest and may cause a selection bias towards specific sports. The boys in our End group tended to have lower BM at age 12 (p=0.06) and had lower body fat percentages as well as lower testosterone levels at all ages. Hence, it seems like the End boys were on average later maturers compared with the non-End boys. This cannot, by itself, explain the difference in VO2max since VO2max relative to BM and FFM changed minimally with age. However, it indicates that the End group was a selected group compared with the non-End group.

The %FM was lower in the End boys, meaning that their relative FFM was higher; this may partly explain their higher VO2max relative to BM. However, this factor does not explain the whole difference, since VO2max relative to FFM was also higher in the End boys. If we exclude the possibility that the difference in VO2max relative to FFM between the groups was training-induced, other factors must play a role and these factors may be inherited. The difference could either be related to the pumping capacity of the heart, or the muscles’ ability to extract the available oxygen. From previous studies, it seems most likely that the difference is due to the pumping capacity of the heart [25].

Sundberg, Elovainio [26] found similar results in a cross-sectional study on 12-, 14- and 16-year-old boys, when comparing runners to a control group. The runners had lower BM at age 12 and lower %FM and higher VO2max relative to body mass at all ages. As the authors pointed out, the possibility that these differences were training induced cannot be excluded; neither can the possibility that there was a selection bias. In the present study, the End boys also had lower testosterone levels and therefore our study supports the selection bias option. Altogether, this indicates that one should be careful in using cross-sectional studies to evaluate the effects of different types of training.

4.2 Development of VO2max in boys and girls from age 12-15

The development of VO2max was similar in the two groups of boys and the two groups of girls, respectively, both in absolute values and relative to BM and FFM. Both groups were relatively active with on average more than 6 hours of participation in leisure time organized sports. However, the End group engaged in systematic endurance training for more than 5 hours per week (average 7.3 (1.8)) including continuous and interval workouts, to increase their aerobic power. Hence, the significant difference in the volume of endurance training (7.3 (1.8) hours vs 1.5 (1.2) hours) had no additional effect on the development of VO2max. In both training groups and both sexes, VO2max relative to FFM stayed rather constant over the years. Together, these findings indicate that the development of VO2max was proportional to the growth of FFM in both girls and boys and was independent of training type. That FFM is the most powerful determining factor for VO2max in adolescents agrees with the conclusion of Armstrong, Welsman [27] who studied more than 300 teenagers aged 12 – 18 years.

Intervention studies in pubertal children are scarce. In a review of the available intervention studies, Baquet, van Praagh, Berthoin [5] found that children did respond to endurance training, but less than adults did. Armstrong, Barker [6] suggest in their review that both trained and untrained youth can improve their VO2max with endurance training and that the critical variable appears to be training intensity. From seven intervention studies on children aged 11-16, they concluded that the optimum intensity should be 85-90% of maximum heart rate. The End group in the present study did include high intensity training (interval training) on average 2-3 times per week. This is a traditional training regimen that has been performed for years in the clubs in questions and, although we did not obtain any heart rate recordings, we have good reason to trust that the training met the requirements for high intensity endurance training. In young adults (18 years), it has been shown that adding systematic high intensity endurance training to regular soccer training can increase VO2max by 10% [28]. The regular soccer training consisted of four 1.5-hour workouts per week with technical, tactical, strength, and sprint training, including 1 hour playing a simulated soccer game. This indicates that regular soccer training is not an optimal aerobic training for increasing VO2max in adults. In our non-End group, 96% of the subjects participated in team sports with a main focus on technical and tactical skills, while the End group performed high volumes of endurance training. Opposite to the findings of Helgerud et al. [28], the increased volume of endurance training did not further increase VO2max in our 12 to 15 year-old children.

The hypothesis that there may be a maturational threshold for the effects of endurance training has been challenged over the years. However, the evidence to refute the hypothesis is limited. The majority of the evidence suggests that training does have effects on VO2max, but the effect is less than in adults [4]. The present study supports the “maturational threshold hypothesis” but has also some limitations. Specifically, the End group was a selected group and had higher VO2max at the onset of the study. This may be part of the reason why these children did not increase their VO2max more than the non-End group since it has been shown that the response to training is related to the initial VO2max in children [6,8,29]. Furthermore, both training groups in the present study were physically active, with participation in organized team and endurance sports averaging from 6.7 hours per week at age 12 to 9.5 hours per week at age 15, with no significant differences between groups. Hence, the present study may indicate that in growing active children, a specific focus on endurance training may not have an additional effect on VO2max compared with similar volume of general physical training. Children with a more sedentary lifestyle may have responded positively to systematic endurance training. Furthermore, we cannot refute the possibility that even higher intensity and/or higher volumes than those used in our End group may affect VO2max. Importantly, systematic endurance training may still have effects on performance through other mechanisms than an increase in VO2max.

4.3 Development of performance in boys and girls from age 12-15

Performance, measured as TTE in the VO2max test, was superior in the End boys compared with the non-End boys at all ages. End girls also performed better than the non-End girls, but the difference was only statistically significant at age 13. The longer TTE in the End boys compared with the non-End boys fits with their higher VO2max.

In boys, TTE increased in both groups, but the increase was nearly 3 times larger in the End boys than in the non-End boys, while the development of VO2max did not differ between the training groups. In girls, the performance did not change with time, which fitted with the fact that VO2max relative to BM decreased, while VO2max relative to FFM did not change. Comparing girls in the two training groups, this decrease was only significant in End girls from age 13 to 15. Performance in aerobic exercise is closely related to VO2max and VO2max has been regarded the single best measure of an individual's aerobic fitness. However, VO2max is not the only factor that determine performance [9]. Running economy and the ability to utilize a high percentage of the VO2max as well as anaerobic capacity will affect performance [10]. This suggests that endurance training may have had a significant effect on determinant factors other than VO2max. Krahenbuhl, Morgan, Pangrazi [30] tested six children at age 10 and again 7 years later at age 17. The participants did not perform any regular training for distance running during these years. The 9-minute run distance increased by 29%. While VO2max did not change during these years, both running economy (13%) and estimated values for the utilization of VO2max during the 9-min test improved (16%). In a subset of our participants (only boys) oxygen cost at a given submaximal running speed was reduced similarly in End boys and non-End boys. The superior improvement in performance in the End boys may therefore be explained by a superior utilization of their VO2max and/or superior anaerobic capacity.

In conclusion, the present longitudinal study suggests that in active adolescents, development of VO2max is mostly determined by the development of FFM both in boys and in girls. In girls, VO2max relative to BM decreased, while VO2max relative to FFM and performance (measured as TTE) did not change from age 12 to 15, even in girls who included a significant volume of endurance training. In boys, the high volume of endurance training seemed to influence performance, but not VO2max. The increased performance was probably due to improved anaerobic capacity and/or improved utilization of VO2max. The present study does not exclude the possibility that less physically active children may respond to systematic endurance training. However, the data indicates that in growing active children during puberty, there seems to be no difference in the effect on VO2max between high volume of systematic endurance training and high volume of general physical training with the main aim of developing motor competence and with little inclusion of systematic endurance training.

4.4 Perspectives

Participation in organized sports is a popular leisure time activity and contributes significantly to the physical activity level in children in many countries. In Norway and Finland, participation in organized sports clubs has increased the last 30 years and the association between participation in sport clubs and volume of physical activity was stronger in 2014 than in 1985 [31]. Furthermore, participation in organized sport in youth may contribute to a physically active lifestyle in adulthood [32]. Some of the children are aiming at becoming adult athletes. Preparation for a specific sport includes both developing fundamental movement competence, training of specific motor skills as well as training for developing the physical capacities as maximal strength and VO2max. The present study indicates that during pubertal growth, as long as the children are active, adding more training for specifically developing VO2max had no additive effects compared just to be active in sports with more focus on developing fundamental and sport-specific motor skills. More intervention studies are needed to explore the effects of training on physical capacities during puberty.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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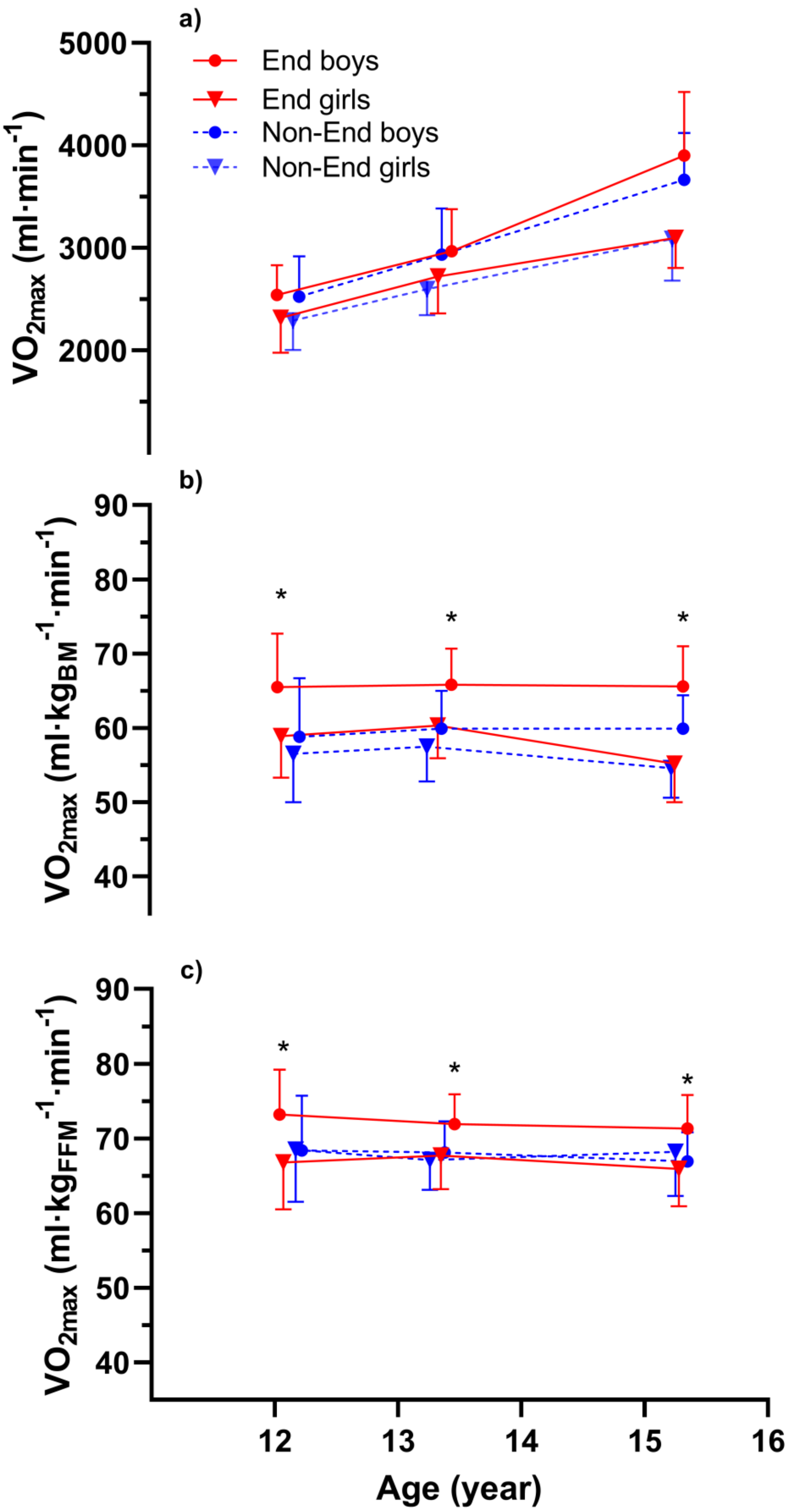
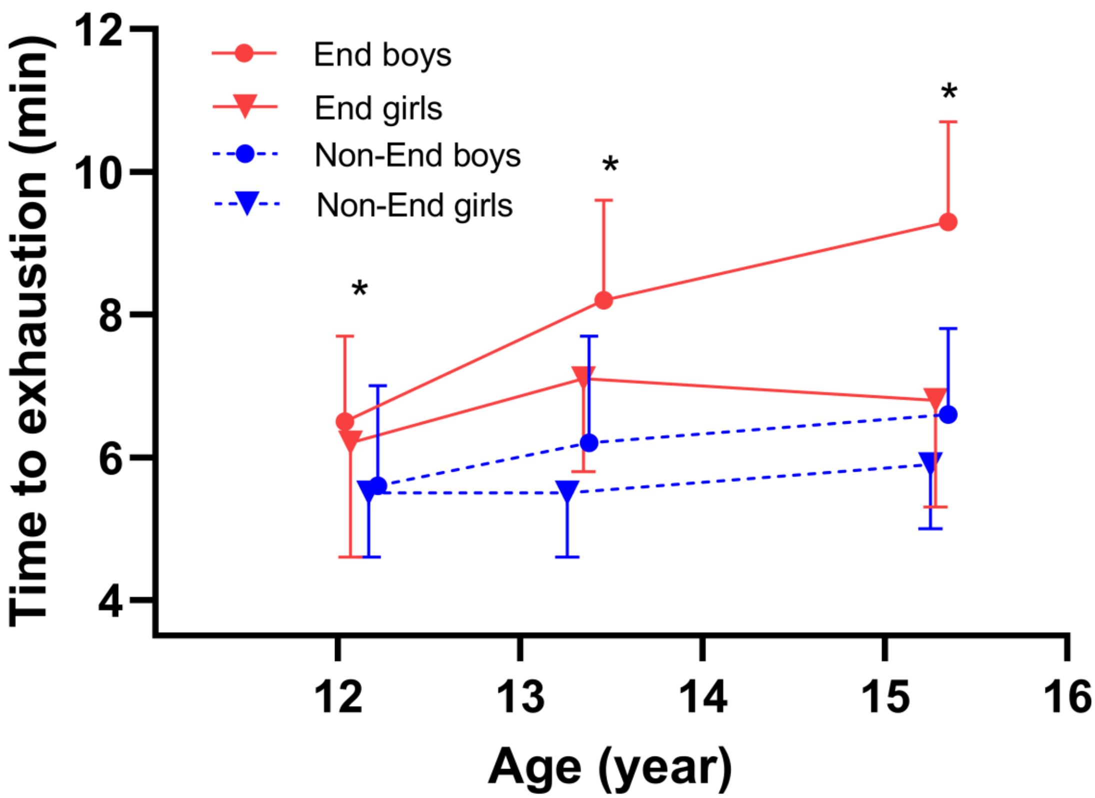
Figure Captions

Figure 1: Development of a) VO2max; b) VO2max relative to body mass; c) VO2max relative to fat-free mass from ages 12 to 15 years. * denotes significant difference between End boys and non-End boys at the different time points.

Figure 2: Development of time to exhaustion for End boys and -girls and non-End boys and -girls from ages 12 to 15 years. * denotes significant difference between End boys and non-End boys at the different time points.


a)
5000
4000
3000
2000
VO2max (ml·min-1)
End boys
End girls
Non-End boys
Non-End girls
b)
90
80
70
60
50
40
VO2max (ml·kgBM-1·min-1)
*
c)
VO2max (ml·kgFFM-1·min-1)
12
13
14
15
16
Age (year)

457


Time to exhaustion (min)
12
10
8
6
4
End boys
End girls
Non-End boys
Non-End girls
*
*
*
12
13
14
15
16
Age (year)

458

Table 1: Participants characteristics at age 12, 13 and 15, total training, and endurance training (only at age 14-15)

	n	Age (yr)	Height (cm)	BM (kg)	FFM (kg)	Fat mass (%)	Total training (hrs/week)	Endurance training (hrs/week)
Age 12.1 (0.4)								
End girls	*17*	12.1 (0.4)	153 (6.2)	39.5 (5.6)	35.0 (4.7)	12.1 (3.5)	7.4 (2.7)	
non-End girls	*9*	12.2 (0.4)	151 (3.7)	40.9 (7.4)	33.6 (4.1)	16.8 (8.3)	7.2 (1.1)	
End boys	*23*	12.0 (0.3)	152 (7.5)	39.3 (6.0)*	34.9 (4.0)	9.6 (4.4)*	6.7 (1.9)	
non-End boys	*29*	12.2 (0.4)	153 (8.0)	43.1 (6.8)	37.1 (4.8)	15.5 (6.1)	6.0 (2.1)	
Age 13.4 (0.3)								
End girls	*17*	13.4 (0.3)	160 (7.3)	45.5 (6.8)	40.1 (5.1)	13.8 (2.9)#	8.1 (2.4)	
non-End girls	*9*	13.3 (0.4)	158 (4.3)	46.9 (9.0)	38.9 (4.6)#	17.1 (6.7)	8.5 (2.3)	
End boys	*23*	13.5 (0.3)	161 (9.5)	45.1 (7.2)	41.2 (6.0)	9.5 (3.2)*	8.1 (2.4)	
non-End boys	*29*	13.4 (0.3)	162 (9.1)	48.9 (7.4)	43.7 (6.2)	13.5 (5.4)	7.1 (3.2)	
Age 15.3 (0.3)								
End girls	*17*	15.3 (0.3)	168 (6.7)#	56.6 (7.3)	47.6 (5.0)#	16.5 (4.6)#	10.7 (3.3)	6.5 (1.6)#*
non-End girls	*9*	15.2 (0.3)	166 (4.4)#	56.7 (7.1)	45.3 (5.2)#	19.6 (5.6)#	9.2 (4.0)	2.0 (1.3)
End boys	*23*	15.3 (0.3)	175 (10.6)	59.7 (10.3)	54.8 (8.7)	8.4 (3.3)*	10.6 (2.6)*	7.8 (1.9)*
non-End boys	*29*	15.3 (0.3)	175 (7.9)	61.4 (8.2)	55.4 (5.5)	10.9 (3.4)	7.9 (4.0)	1.4 (1.1)

Values are mean (SD). End, endurance (17 girls and 23 boys); nonEnd, non-endurance (9 girls and 29 boys). BM, body mass; FFM, fat free mass. Total training is the total amount of weekly training hours including training of technical and tactical skills and endurance training. denotes significant difference between training groups p<0.05, # denotes significant sex difference within the same training group p<0.05.*