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Pulmonary Oxygen Uptake Kinetics Assessment in Basketball-Trained Boys During Early Adolescence

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ABSTRACT

Background: Dynamic change of the pulmonary oxygen uptake is one of the core parameters determining the bodies' adaptability to the varying physical load. It is equally important in both everyday life and sports. Regardless of the importance, this physiological mechanism is understudied, especially in younger population. Therefore, the aim of this study was to examine oxygen uptake kinetics at the onset and offset of exercise in terms of basketball training and maturity level in adolescent boys.

Methods: Our subjects were 28 basketball-trained (BT) and 22 actively untrained (UT) boys (average age: 11.83 ± 0.43 years). Subjects performed 6-minute-long constant speed walking tests on a treadmill and a static recovery afterwards with a 1-year interval between the sessions to determine oxygen uptake, heart rate, and muscle oxygenation time constants and other parameters. Maturity level was determined by the maturity offset.

Results: Basketball-trained group showed faster oxygen uptake kinetics (1st session: 13.10 ± 2.68 s and 15.02 ± 2.96 s in basketballers and control-group boys, respectively; 2nd session: 12.02 ± 2.86 s and 14.07 ± 4.18 s) during both testing sessions, while heart rate kinetics were faster in basketballers only during the 1st session (28.15 ± 10.59 s compared to 37.18 ± 15.23 s). Maturity level in both groups correlated with some of the kinetics parameters during the 2nd session.

Conclusion: Young basketballers possess a faster on-transient oxygen uptake kinetics compared to their untrained peers because of the improved oxygen delivery and utilisation. A possible maturational threshold regarding pulmonary oxygen uptake kinetics in adolescents should be investigated in the future.

Keywords: team sports, physical fitness, time constant, aerobic kinetics

1. INTRODUCTION

Sport improves health and well-being (Bize et al., 2007), therefore leisure-time physical activity is widely spread in all population groups. Basketball is one of the most popular sports in the world (Ziv & Lidor, 2009), and because of the fun and game-based nature, it is a frequent choice among children (FIBA, 2023). High level of both aerobic and anaerobic capacity seems essential for elite basketball players, and participation in basketball training improves these abilities (Ben Abdelkrim et al., 2010). Aerobic fitness (AF) may be defined as the ability to deliver oxygen to the working muscles and to utilise it there for energy production (Armstrong et al., 2011). Peak oxygen uptake ($\dot{V}O_2$peak) is most commonly known as a criterion measure of AF (Welsman & Armstrong, 2019). On the other hand, in many sports and in everyday life $\dot{V}O_2$peak is rarely achieved, hence transient VO_2 kinetics ($\dot{V}O_2$) may be at least as important as $\dot{V}O_2$peak in defining the individual AF profile (Fawkner & Armstrong, 2003). It has been shown that faster $\dot{V}O_2$ kinetics can delay fatigue (Glaister, 2005) by a faster replenishment of phosphocreatine level inside the muscles between the bouts of high-intensity activity (Latzel et al., 2018).

Extensive data on $\dot{V}O_2$ is available in adult population, although there is still little consensus on this topic in youth, especially in terms of how it is affected by age, maturity, and training status (McNarry, 2019). Obert et al. (2000) reported no significant difference in the Phase II of $\dot{V}O_2$. However, in another study a significant difference was observed between trained and untrained adolescent football players when appropriate mode of exercise was applied (Marwood et al., 2010). Dynamics of $\dot{V}O_2$ can be affected by both oxygen delivery and oxygen utilisation mechanisms (Tschakovsky & Hughson, 1999), and the near-infrared spectroscopy (NIRS) allows to noninvasively measure the balance between these two processes by detecting changes in deoxyhemoglobin (HHb) in the working muscle.

Data on how $\dot{V}O_2$ is affected by age and maturity is also contradictory. On one side, Phase II time constant (τ) was found to be similar in paediatric and adult populations (Hebestreit et al., 1998). After further studies, it was suggested that the Phase II response to exercise is fully mature in early childhood and remains unchanged until adulthood (Fawkner & Armstrong, 2004b). On the other hand, other authors reported Phase II τ to be significantly faster in children compared to adults, mainly because of the enhanced oxidative metabolism in youth (Fawkner et al., 2002; Leclair et al., 2013). Hence, additional data is needed to bring more clarity to this topic.

To our knowledge, $\dot{V}O_2$ of young basketball players at the onset and offset of exercise was never reported before. In addition, only two earlier studies evaluated not only the effect of age but also the effect of maturity status on $\dot{V}O_2$ in children (Doncaster et al., 2018; Mcnarry et al., 2012). Since improved pulmonary oxygen uptake kinetics has the potential to delay fatigue, it is crucial to extend our knowledge regarding the timing, tempo, and trainability of this physiological parameter. Given these and the aforementioned reasons, the purpose of this study was to examine oxygen uptake kinetics at the onset and offset of exercise in young basketball-trained boys in comparison with their sedentary peers. Based on earlier studies, we hypothesise that young male basketballers would show faster on-transient $\dot{V}O_2$ and off-transient HHb compared to their untrained peers. Secondly, we believe that the parameters of pulmonary oxygen uptake kinetics would correlate with the maturity level of young boys.

2. METHODS

Subjects

A total of 87 young age boys volunteered to participate in our study. Thirty-seven of them skipped the 2^{nd} testing session and were excluded, therefore we analysed the data of 50 (age during the first session: 11.83 ± 0.429) subjects who attended both sessions. They were separated into two groups: basketball-trained (BT) and control group (CG), and there were 28 boys in BT group and 22 boys in CG. More descriptive and anthropometric data can be found in Table 1.

BT subjects were recruited from two local basketball schools. CG in our study consisted of 22 boys from a nearby public school. BT boys were attending practice sessions three or more times/week, while CG subjects were attending physical education classes and no more than two leisure time practice sessions of any kind per week.

All subjects from both groups were healthy and had no chronic diseases. They had doctors' approvals to participate in high-intensity training activities. Subjects and their parents/guardians were given a written explanation of our survey and afterwards only those who volunteered and had their parents'/guardians' permission were allowed to participate. Written consents were signed by boys and their parents/guardians before starting any tests.

Table 1. **Descriptive and anthropometric characteristics of basketball-trained and untrained boys during both testing sessions**

	Basketball-trained boys (n = 28)				Control group boys (n = 22)			
	1st testing session		2nd testing session		1st testing session		2nd testing session	
Characteristics	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**
Age (years)	11.84	0.38	12.88 #	0.40	11.81	0.49	12.88 #	0.56
Height (cm)	158.4 *	6.5	165.7 #	7.3	154.3	7.6	162.4 #	9.1
Weight (kg)	44.09	7.44	50.31 #	9.57	43.68	7.97	48.96 #	8.76
BMI (kg/m²)	17.48	1.96	18.18 #	2.28	18.23	2.19	18.50	2.34
FFM (kg)	38.79	5.41	44.37 #	7.17	36.72	5.57	41.74 #	6.72
Fat percentage (%)	11.6 *	4.5	11.3	4.2	15.4	4.8	13.5	5.2
APHV (years)	13.61	0.38	13.56	0.49	13.79	0.39	13.79	0.56
Offset (years)	–1.73	0.46	–0.65 #	0.54	–1.98	0.59	–0.92 #	0.77
PAT (h/week)	8.07 *	2.19	8.84 *	2.40	4.01	1.62	4.05	1.83

Notes: ** – significant difference between-groups on certain testing sessions ($p < 0.05$); # – significant difference within-groups between testing sessions ($p < 0.05$). BMI – body mass index; FFM – fat-free mass; APHV – age at peak-height velocity; PAT – high-intensity physical activity time; SD – standard deviation.*

Study design

Subjects from both groups participated in two testing sessions with one year in between. The tests were conducted in spring because it is the end-season of children basketball leagues and young players are usually at their peak form at this time of the year.

Anthropometric measurements were collected at the beginning of each session. Vertical stadiometer (*Leicester HM-250P, Marsden*, *Rotherham, UK*) was used to measure standing height and sitting height. Weight, body-mass index (BMI), fat-free mass (FFM), and fat percentage were measured automatically using a leg-to-leg body composition analyser (*TBF-300A, Tanita, Tokyo, Japan*).

A written informed consent was obtained from all participants and their parents or guardians before conducting the tests. The study was approved by the Lithuanian National Committee for Bioethics (date: 30/05/2018; No. BE-2-28) and adhered to the guidelines of the declaration of Helsinki.

6 km/h walking test

Subjects performed two identical 6-minutes-long constant speed walking tests on a treadmill (*Lode, Lode BV Medical Technology, Groningen, the Netherlands*). This test was selected due to its similarity to everyday life in terms of walking speed and distance. Secondly, our young subjects were easily mastering the test procedure enabling us for a more seamless examination. First phase of each test was a 3 min slow walk at the constant 3 km/h speed and 1% incline to get used to the procedure and the treadmill. Afterwards, subjects dismounted the treadmill belt and had 1 min of rest. Average value of each cardiorespiratory parameter during the last 30 s of rest were used as baseline values. During 1 min of rest, the speed and the inclination of the treadmill belt were increased to 6 km/h and 4% incline. After stepping on a treadmill belt again, subjects continued walking for 6 min. Treadmill automatically stopped after 6 min and participants had to lay down calmly on a bunk bed placed nearby for additional 5 min while their recovery parameters were being recorded. Two identical walking tests were separated by a 1-hour passive break.

Data recording

Portable gas analyser (*Oxycon™ Mobile, Jaeger Inc., Hoechberg, Germany*) was used to continuously record oxygen consumption of the subjects. $\dot{V}O_2$ change was recorded and saved on a breath-by-breath basis. Gas analyser was calibrated before each measurement using a gas mixture of known concentration and the procedures provided by the manufacturer.

Chest-placed heart rate monitor (*Polar S810, Polar Electro Oy*, *Kempele, Finland*) continuously recorded HR of subjects. HR was presented and saved parallelly to $\dot{V}O2$ data in the software provided by the manufacturer of the gas analyser.

Local HHb was recorded using three NIRS devices (*Moxy, Fortiori Design LLC, Hutchinson, MN, USA*). The devices were attached to the *Gastrocnemius Medialis* (GM), *Gastrocnemius Lateralis (*GL), and *Vastus Lateralis* (VL) muscles of the right leg of the participants. Sensors on the GM and GL were placed on the thickest part of the muscles' belly, approximately at the point which corresponded to the 1/3 of the distance between the *Medial and Lateral* (respectively) *Femoral Condyle* and

Calcaneus. In the case of VL, the sensor was placed on the belly of the muscle, approximately in the middle between the *Lateral Epicondyle and Greater Trochanter* of the *Femur*. Nontransparent elastic bands were applied over the devices to block extraneous light that may corrupt the measurement, as in the previous studies (Leclair et al., 2013; Marwood et al., 2011). HHb data of 26 BT boys and 19 CG boys were used for the calculations since the data of the other subjects were not correctly recorded.

Data analysis

$\dot{V}O_2$ breath-by-breath data and parallel HR data were linearly interpolated second-by-second. When analysing the $\dot{V}O_2$ measurements, first 15 s after the onset and the offset of exercise (representing Phase I, or the cardiodynamic phase) were excluded from further analysis (Marwood et al., 2010, 2011). HHb measurements were collected every 2 s. These measurements were interpolated to get a second-by-second data. Data of $\dot{V}O_2$, HR, and HHb from two identical walking sessions were time-aligned and the average of the two were used for further calculations to decrease the influence of abnormal data registration.

$\dot{V}O_2$, HR, and HHb kinetic response at the onset and at the offset of a steady-state exercise was then analysed using two mono-exponential equations: $X_{(t)} = X_{(b)} + A(1 - e^{-(t - TD)/\tau})$ and $X_{(t)} = X_{(b)} - A(1 - e^{-(t - TD)/\tau})$, where $X_{(t)}$ is $\dot{V}O_2$, HR, or HHb at any given time point, $X_{(b)}$ is the baseline $\dot{V}O_2$, HR, or HHb level recorded as average of the last 30 s before the exercise transition, A is the amplitude of $\dot{V}O_2$, HR, or HHb change from the baseline level to the plateau, t is time, TD is time delay, and τ is the time constant or time required to achieve 63% of steady-state amplitude value. $\dot{V}O_2$ kinetic response to the onset and offset of exercise was modelled from 15 s to 300 s, while the respective HR and HHb kinetics were modelled from 0 s to 300 s.

A and τ parameters of $\dot{V}O_2$, HR and τ parameter of HHb modelling at the onset and offset of exercise were saved for further analysis.

Biological maturation evaluation

A mathematical equation published earlier (Mirwald et al., 2002) was used to calculate maturity offset (OS). Age at peak height velocity (APHV) is considered to mark the peak growth period in adolescents. Depending on morphological body characteristics, Mirwald's equation helps to calculate APHV. OS of our participants was found by subtracting their APHV from their chronological age. Therefore, lower OS result means lower maturity level reached.

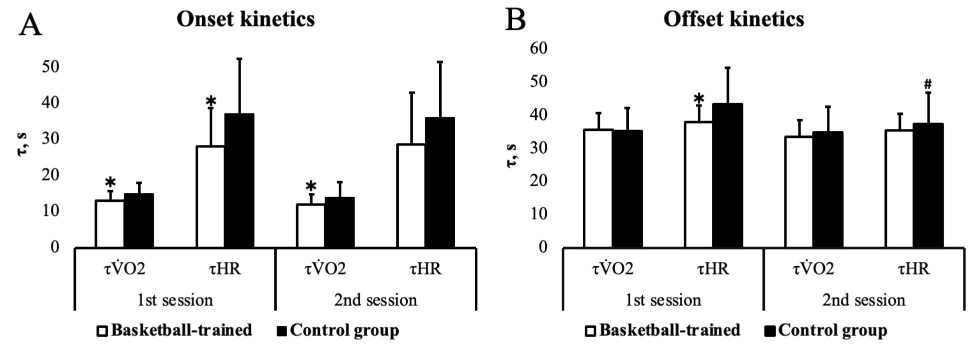
Statistical analysis

Normality of data distribution was checked using the Shapiro–Wilk test. Levene's test was used to check homogeneity of variances between groups. A 95% confidence interval was set in all statistical calculations. The *t* test for paired samples was used to calculate within-group differences between testing sessions. Between-group differences on certain testing sessions were calculated using ANOVA. Influence of basketball training to different parameters was calculated using a repeated measures ANOVA. IBM SPSS 26 (*IBM Statistics for MacOS, 2019, Version 26.0, IBM Corp., Armonk, NY, USA*) software was used for all statistical calculations.

3. RESULTS

BT boys had significantly more high-intensity physical activity time (PAT) during the period around 1st ($p < 0.001$) and 2nd ($p < 0.001$) testing sessions. Both groups were statistically similar during both sessions in terms of age and maturity evaluation. Mean values and standard deviations of the abovementioned parameters are presented in Table 1 together with other morphological characteristics of the subjects.

Figure 1. **Comparison of V̇O2 and HR kinetics at the onset (part A) and offset (part B) of a steady-state exercise transition**



Note: ** – significant difference between groups on certain testing session (p < 0.05); # – significant change within groups between different sessions (p < 0.05).*

On-transient $\tau\dot{V}O_2$ and τHR values are shown in part A of Figure 1. Faster $\dot{V}O_2$ kinetics were observed in BT group during both testing sessions compared to untrained (UT) boys (1st session: 13.10 ± 2.68 s and 15.02 ± 2.96 s, $p = 0.02$; 2nd session: 12.02 ± 2.86 s and 14.07 ± 4.18 s, $p = 0.045$). In addition, during the 1st session BT boys showed significantly smaller τHR values (28.15 ± 10.59 s, compared to 37.18 ± 15.23 s, $p = 0.017$). During the 2nd session, τHR was similar between BT and control groups (28.71 ± 14.24 s and 36.09 ± 15.47 s, $p = 0.086$).

Off-transient kinetics are presented in part B of Figure 1. The only between-groups difference was found during the first testing session where BT group's τHR was significantly shorter than the UT boys (38.10 ± 6.98 s and 43.44 ± 11.05 s, $p = 0.042$). On the other hand, we observed an improved τHR kinetics in UT boys during the 2nd session ($p < 0.001$), hence τHR results were similar between BT and UT subjects during the 2nd testing session (35.49 ± 6.73 s and 37.47 ± 9.53 s, $p = 0.393$). Off-transient kinetics were similar between groups regarding $\tau\dot{V}O_2$ (1st session: 35.81 ± 6.03 s and 35.33 ± 6.99 s, $p = 0.796$; 2nd session: 33.55 ± 4.71 s and 35.02 ± 7.63 s, $p = 0.406$).

Additional $\dot{V}O_2$, HR, and HHb kinetics parameters are presented in Table 2.

Table 2. **Data of pulmonary, cardiac, and muscle metabolism kinetics at the onset and offset of a steady-state exercise**

	Basketball-trained boys				Untrained boys			
	1st testing session		2nd testing session		1st testing session		2nd testing session	
Onset of physical activity	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**
AHR (1/min)	41.66*	9.11	37.16*#	7.65	50.84	9.42	46.86#	12.52
HR_{pct} (%)	66.41*	4.92	65.67*	5.84	73.79	7.08	72.09	7.10
$A\dot{V}O_2$ (ml)	855.68	157.54	1,000.12#	148.17	887.10	130.49	983.42#	149.30
$\dot{V}O_{2pct}$ (%)	55.21*	7.03	51.31*#+	6.62	59.86	5.62	60.01	8.08
τGM (s)	9.48	2.69	9.61	2.42	10.56	4.53	11.04	4.93
τGL (s)	12.76	4.42	12.19	3.84	12.20	4.77	12.68	7.48
τVL (s)	18.68	7.35	19.70	10.51	23.24	8.61	25.71	11.31
Offset of physical activity								
AHR (1/min)	54.41*	9.70	54.58*	7.52	65.13	7.76	63.80	11.04
$A\dot{V}O_2$ (ml)	933.93	172.44	1,054.21#	167.97	976.75	165.95	1,033.51#	174.19
τGM (s)	44.38	13.11	44.64	16.12	48.94	15.29	47.71	14.62
τGL (s)	42.90	9.66	45.75	15.76	46.32	16.57	47.17	12.42
τVL (s)	49.40	13.78	52.05	13.62	56.99	16.33	56.78	15.29

Notes: ** – significant difference between-groups on certain testing sessions (p < 0.05); # – significant difference within-groups between different sessions (p < 0.05); + – significant factor (group) influence to between-sessions change (p < 0.05). AHR – heart rate amplitude of change; HR_{pct} – heart rate value reached in percentages compared to peak; $A\dot{V}O_2$ – oxygen uptake amplitude of change; $\dot{V}O_{2pct}$ – oxygen uptake value in percentages compared to peak; τGM – HHb time constant in Gastrocnemius Medialis muscle; τGL – HHb time constant in Gastrocnemius Lateralis; τVL – HHb time constant in Vastus Lateralis.*

Correlation between oxygen uptake kinetics and subjects' maturity level is shown in Table 3. A significant τHR ($p = 0.030$) and τGL ($p = 0.004$) correlation at the onset of exercise and $\tau\dot{V}O_2$ ($p = 0.002$) at the offset of exercise during the 2nd session was observed in CG boys. In BT boys, the only significant correlation was observed in τGM during the offset of the 2nd year session.

Table 3. **Correlation of oxygen uptake kinetics parameters with maturity**

	Basketball-trained boys				Untrained boys			
	Onset		Offset		Onset		Offset	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
τHR (s)	0.195	–0.024	0.325	0.364	0.328	0.463*	0.146	0.118
$\tau\dot{V}O_2$ (s)	–0.113	0.008	0.225	0.292	0.178	0.041	0.349	0.625*
τGM (s)	0.053	–0.027	–0.218	–0.411*	0.345	–0.166	–0.005	0.137
τGL (s)	–0.085	0.108	0.151	0.160	0.198	0.596**	–0.081	–0.072
τVL (s)	–0.158	–0.144	–0.020	–0.076	–0.118	0.123	–0.464	–0.008

Notes: * – *significant difference between-groups on certain testing sessions ($p < 0.05$); # – significant difference within-groups between different sessions ($p < 0.05$); + – significant factor (group) influence to between-sessions change ($p < 0.05$). τHR – heart rate time constant; $\tau\dot{V}O_2$ – pulmonary oxygen uptake time constant; τGM – HHb time constant in Gastrocnemius Medialis muscle; τGL – HHb time constant in Gastrocnemius Lateralis; τVL – HHb time constant in Vastus Lateralis.*

4. DISCUSSION

This study examined $\dot{V}O_2$ profile at the onset and offset of a steady-state physical exercise in young boys in the context of basketball training and maturity level. The main finding of this study was that BT boys had significantly faster on-transient $\dot{V}O_2$ during both testing sessions. On the other hand, no significant off-transient $\dot{V}O_2$ difference was observed. HHb kinetics were similar between BT and CG subjects in all examined muscles during the onset and the offset of exercise.

BT boys displayed faster on-transient $\tau\dot{V}O_2$ during 1st and 2nd testing sessions compared to CG subjects by 14.7% and 17.1%, respectively. The results of our study contradict that of Obert et al. (2000) since they recorded no difference in $\dot{V}O_2$ Phase II τ between trained and untrained children. Conversely, one later study recorded ~25% faster pulmonary oxygen uptake kinetics in male adolescent soccer players compared to their untrained peers (Marwood et al., 2010). The dichotomy between trained muscles and muscles that were predominantly exercised during the research tests may explain the results of the 1st study, since most of the subjects were swimmers and the tests were performed on a cycle ergometer. The faster attainment of a $\dot{V}O_2$ Phase II steady state may be explained by oxygen delivery and/or oxygen utilisation (Leclair et al., 2013).

Basketball is considered a high intensity intermittent sport (HIIT) (Sekine et al., 2019). Recently, HIIT was shown to be a superior training method in terms of improving aerobic fitness (Gist et al., 2014). First, aerobic training induces an increase in the stroke volume which translates to the improved cardiac output (Rowland, 2005). In addition, the process of angiogenesis or capillary densification is accelerated due to physical stimulus, in our case – basketball training (Bloor, 2005). Finally, volume of the circulating blood in the cardiorespiratory system also increases, even after applying only a moderate intensity training programme (Montero et al., 2015). Taken these factors together, more blood saturated with oxygen can flow throughout the muscles improving oxygen delivery. Inside the muscle, HIIT was shown to be a very effective method of increasing mitochondrial density, which in turn allows to soak in and use oxygen in a more effective way, thus increasing oxygen utilisation (MacInnis et al., 2016).

On-transient τHR in BT boys was significantly faster during the 1st session and tended to be faster, only not significantly, during the 2nd session. Moreover, τHHb was similar between subject groups in all three tested muscles. All these results are in line with earlier findings (Marwood et al., 2010). The HHb signal reflects a balance between O2 delivery and O2 utilisation in the muscle (Ferreira et al., 2005). An increased τHR in young basketballers shows an increased O2 delivery, while similar τHHb results in both groups suggest that O2 utilisation was also elevated in trained boys. Based on earlier studies with adults and children, we can only speculate that training induced positive changes in

O2 delivery and the utilisation because of the improvements in arterial flow, enzyme activity, mitochondrial density, and Type I fibre activity (Eriksson et al., 1973; Krustrup et al., 2004; Marwood et al., 2010). However, further studies with similar population groups are required to address these possible causal factors.

Only two earlier studies compared off-transient kinetics of trained and untrained adolescents. Marwood et al. (2011) reported that trained young athletes matched their untrained peers in $\tau\dot{V}O_2$ and τHR, whereas the former showed faster τHHb results. On the other hand, McNarry et al. (2012) found significantly different $\tau\dot{V}O_2$ values but similar τHR and τHHb recovery kinetics values. These results only partly correspond to ours since we recorded similar $\tau\dot{V}O_2$ and τHHb kinetics during both testing sessions between subject groups. Factors including but not limited to training volume, gender, and exercise intensity may have a role in such dichotomy between the results (Mcnarry et al., 2012). Specifically, active subjects in Marwood et al.'s study were older adolescent males (15 ± 0.8 years vs. 11.84 ± 0.38 years in our study) with around 50% more physical activity per week than in our subjects (13 hours vs. 8 hours). McNarry et al. included only girls in their study while we only tested boys.

Subjects of Marwood et al.'s (2011) study were adolescent boys, while McNarry et al. (2012) investigated adolescent girls. Gender was shown to have an impact on-transient pulmonary oxygen kinetics in children (Fawkner & Armstrong, 2004a), thus it is possible that the recovery kinetics may also be affected. Furthermore, the training volume was 6 h/wk., 12 h/wk., and 8 h/wk. in the two earlier studies and our study, respectively; however, the hypothesis that higher training volume can improve pulmonary oxygen kinetics is yet to be elucidated. Lastly, the intensity of a steady state exercise before the recovery phase was different in all three studies. Marwood et al. (2011) used a moderate intensity exercise (80% of the workload which elicited the gas exchange threshold (GET)) and McNarry et al. (2012) applied heavy intensity exercise (40% difference between the GET and $\dot{V}O_2$peak). Since other studies observed no significant difference in Phase II time constant in children and adolescents between different intensity domains (Lambrick et al., 2013; McNarry et al., 2015; Obert et al., 2000), we used a constant speed exercise for all the subjects.

We found some oxygen uptake kinetics parameters to be correlated with maturity level in our young subjects. The interesting thing is that significant correlations were only apparent during the 2nd testing session in both groups. We could speculate that only during then, when the children were almost 13 years old, maturational changes have started to make significant effect. Hence, there is a possibility of a maturational threshold that unlocks important changes in the adolescents' aerobic system which consequently leads to alterations in oxygen uptake kinetics (Armstrong & Van Mechelen, 2017). Yet, more rigorous studies with larger sample size and longer follow-up are needed to get a better understanding about the nature, timing, and scale of changes in the pulmonary system of adolescents.

The findings of our study add to the positive image of basketball as a way to improve the overall fitness level and, consequently, everyday well-being. In addition, our data augments the still scarce knowledge in the field and highlights some possible directions for future studies.

Few things should be taken into account when considering our data. First, our subjects were males only from one city of Lithuania, therefore the study's population was very homogenous in terms of socioeconomic, racial, environmental, and other factors. In addition, we only had 50 subjects, therefore there is a likely possibility for high influence of inter-individual variations to final results. Furthermore, we were not controlling the training process of our BT group and we had boys from two basketball schools, thus training methods could be different. Finally, our control group subjects were not fully sedentary and had some amount of leisure-time physical activity. Slight variations in results could happen if testing fully sedentary children.

5. CONCLUSION

In conclusion, young basketball-trained boys showed a faster on-transient oxygen uptake kinetics time constant compared to their untrained peers because of the improved oxygen delivery and utilisation.

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