Journal of Physical Education and Sport ® (JPES), 13(4), Art 80, pp.511 - 516, 2013
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Effect of high intensity activity on children's aerobic power

REIN JENSEN BRØGGER[1], GUNNAR MATHISEN[2], SVEIN ARNE PETTERSEN[3]
[1] Department of Education, Oslo and Akershus university College of Applied Sciences, NORWAY
[2, 3] Department of education, University of Tromsø, NORWAY

Published online: December 25, 2013
(Accepted for publication November 15, 2013)

DOI:10.7752/jpes.2013.04080;

Abstract:
Several studies in recent years have reported significant fitness improvements in children after exercise interventions, given sufficient training intensity, frequency and duration. However the knowledge of how fast children respond to exercise is limited and most research protocols are performed on cycle ergometers or other training devices using exercise programs are not applicable for practical purposes such as children's sports programs or physical education classes.
The aim of this study was to investigate the effect of high intensity aerobic activity in five weeks, two sessions per week, on children's VO_{2peak}. Additionally we wanted to test whether ten-year old boys were able to sustain intensity over 80 % of reart $rate_{peak}$ (HR_{peak}) for a relative long period of time (up to 4 minutes), using aerobic games and play. Results from the present study showed a significant increase in VO_{2peak} from 178.5 (± 12.6) ml x $kg^{-0.67}$ x min^{-1} to188.4 (± 12.6) ml x $kg^{-0.67}$ x min^{-1}). Conclusion: Children can increase their VO_{2peak} after five weeks of exercise with two high intensity sessions per week. This study also revealed that children can exercise near their HR_{peak} in time periods lasting up to four minutes.
Key words: Aerobic power, high intensity.

Introduction

Aerobic fitness is associated with physiological and psychological health factors (Andersen et al., 2006; Anderssen et al., 2007; Hussey, Bell, Bennett, O'Dwyer, & Gormley, 2007; Ortega, Ruiz, Castillo, & Sjostrom, 2008; Resaland, Mamen, Boreham, Anderssen, & Andersen, 2010; Strong et al., 2005).

When addressing training induced adaptations to aerobic activity in children, direct measurement of oxygen uptake is generally accepted as the most acknowledged measuring method (Krahenbuhl, Skinner, & Kohrt, 1985). Some studies have been conducted using direct measurements of oxygen uptake in healthy children, with conflicting results regarding improvement in aerobic power (Rowland & Boyajian, 1995; Stewart & Gutin, 1976; Welsman, Armstrong, & Withers, 1997). However, there is a growing body of knowledge supporting significant improvements in exercise induced aerobic capacity, provided a sufficient training intensity, frequency and duration (Baquet et al., 2010; Obert et al., 2003; Ratel et al., 2004; Resaland, Andersen, Mamen, & Anderssen, 2009; Zahner et al., 2006).

It has been suggested that it is essential to work above 70 % of HR_{max} to achieve a significant improvement in aerobic power and some authors even suggest intensities from 80-95 % of HR_{max}, to improve aerobic fitness (Strong et al., 2005). The intervention periods have usually had a duration of 6-12 weeks, some as short as 4 weeks while others have lasted for several years (Baquet, van Praagh, & Berthoin, 2003). Furthermore, it has been shown that short duration all out sprints with intensities above the maximal aerobic speed can increase both anaerobic power and VO_{2max} (Ratel et al., 2004). Previous experiments have used both continuous and intermittent training methods and it appears that both exercise modes can enhance aerobic power (McManus, Cheng, Leung, Yung, & Macfarlane, 2005). Most of the experiments involving high intensity exercise < 90% of HRpeak in children have used 10 sec. and 30 sec. intervals, and only a few have used longer work periods (Araujo et al., 2011; Baquet et al., 2003; Ratel et al., 2004). In adults, long intervals lasting from 2-4 minutes, is a common approach to endurance training, and it has been shown to be a faster and more effective mode of exercise than continuous work at lower intensity (Helgerud et al., 2007). Exercise variety, competitions and playful activities are important factors in motivating children for further exercise participation, and are more closely related to the spontaneous physical activity of children and adolescents (Barkley, Epstein, & Roemmich, 2009; Ratel et al., 2004). However, the need for controlled studies has often led to research using the same training protocols used in studies designed for adults. Thus, the aim of this study was to investigate the effect of high intensity aerobic games on improving aerobic power. Another objective was to monitor the multitude of HR

Corresponding Author: REIN JENSEN BRØGGER, E-mail: rein.jensen-brogger@hioa.no

above 80 % of HR $_{peak}$ elicited by aerobic games, and whether children may sustain very high intensity defined as > 95% of HR_{peak} over a relatively long period of time.

Method

Experimental approach

The study was designed to investigate whether high intensity exercise would affect aerobic power when using aerobic games and play as training method. One training group took part in a five week training program consisting of two, one hour sessions with high intensity aerobic activities while another group served as controls. Both groups were evaluated through pre- and post-testing of VO_{2peak}. All participants undertook familiarization trails before the tests.

Participants

The training group included ten 10.6 (± 0.7) year old boys (table 1). The children were recruited from a local soccer club. The control group consisted of six 10.8 (± 0.7) year old boys from another team within the same soccer club. Written informed consent to participate in the study was obtained from children and parents in both experimental- and control group. The study was given institutional ethical approval.

Initially the training group consisted of 15 participants. Injuries, long term illness, a lack of participation (either in training or the final test), resulted in 10 boys meeting the inclusion criteria. The control group originally consisted of 10 boys, but 4 were excluded; one because of the inclusion criteria and three who did not show up for the final test.

Table I: Anthropometric characteristics (weight and height), displayed in mean (±SD) in pre and posttest for intervention group and control groups *

	Intervention group N=10		**Control group N=6**	
	Pre-test mean values	Post-test mean values	Pre-test mean values	Post-test mean values
Weight (kg)	37.9 (5.04)	37.5 (4.93)	35.3 (5.71)	35.5 (5.31)
Height (cm)	145.2 (6.75)	145.8 (6.73)	140.4 (5.30)	140.9 (5.0)

Training program

The training program consisted of two one hour sessions per week, one indoor and one outdoor. In addition the boys participated in a one hour soccer practice and school activity (some even in other sports). Normally they participated in two one hour soccer practices; the extra training load was one session per week since one of the soccer sessions was used for the intervention program. In order to monitor the participant's additional activity, the participants completed an activity scheme and they were informed not to alter their regular exercise routines. The training program was based on playful aerobic activities similar to physical education lessons, but with a focus on maintaining a high intensity throughout the full hour. Activities with balls, different variations of catching games, relay races and other aerobic games were used frequently both out- and indoor. The outdoor sessions were conducted on snow. Outdoor activities also included cross-country skiing and sleighing. The training sessions were organized according to the interval principle with interval periods from 10 seconds up to 4 minutes. The control group continued with their normal soccer practice twice a week.

Laboratory testing

Anthropometrics were collected wearing shorts, t-shirt and socks to the nearest 0.5 kg (weight) (Seca 750, Hamburg, Germany), and height to the nearest 0.5 cm. Expired air was analyzed continuously for O2 and carbon-dioxide (CO2) by a Erich Jaeger Oxycon Pro (Jaeger–Viasys, Healthcare, Hoechberg, Germany) oxygen analyzer, calibrated with standardized gases before each test. The subjects breathed through a Hans Rudolph valve (2700 series, USA) with registration of ventilation, VO2, CO2, and respiratory exchange ratio at an average of every 30 seconds.

A modified Oslo protocol; designed for testing children, based on the principle of increasing the speed or the inclination every second minute was used. The test starts at a rather low intensity with moderate increase in oxygen demand from one stage to the next, equivalent to 2 - 4 ml kg^{-1} min^{-1} of VO_2/stage. Before the initial test, every test subject had a practice run to familiarize to the treadmill and test equipment. The reproducibility of the test has been validated (Armstrong, Welsman, & Winsley, 1996; Fredriksen, Ingjer, Nystad, & Thaulow, 1998).

Data collection and analysis

We used the inclusion criteria described by Pettersen et al. (Pettersen, Fredriksen, & Ingjer, 2001). To be included in the study, the subjects had to successfully complete two criteria:

1. The respiratory exchange ratio (RER) over 1.05
2. Leveling off of heart rate near or above 200

In addition we used subjective criteria to establish if they were to be included in the study. The subject was asked if he was totally exhausted, and we considered whether the subject could continue to run properly or if body language expressed total exhaustion and subjects were blanching and in danger of falling caused by fatigue. The highest oxygen uptake reached (30 seconds average) was recorded as VO_2peak.

During the VO_{2peak} test, heart rate was continuously monitored by a Polar S 610 I (Kempele, Finland) wrist watch. Maximal heart rate was defined as the peak heart rate (HRpeak) at the end of the VO_{2peak} tests or the highest heart rate measured during the training sessions. The pre and post maximal oxygen uptake test was completed one week before and one week after the training period.

Results from earlier studies show that it is inappropriate to express VO2peak in growing children in the conventional form (ml x kg^{-1} x min^{-1}) (Armstrong & Welsman, 1994; Rogers, Turley, Kujawa, & Harper, 1995). The increase in body mass, functional changes of the aerobic system, changes in anaerobic threshold and changes in running economy may contribute explaining this (Rowland, 1990). When it comes to the exponential relationship between VO2peak and mass the most common exponents used are 0.67 and 0.75. In growing children the power function 0.67 seems to be a more reliable method of expressing aerobic power compared to ml x kg^{-1} x min^{-1}) (Armstrong & Welsman, 1994; Pettersen et al., 2001).

Statistical analyses

Two-way ANOVA for repeated measurements were adopted to analyze the time effect (different measurement points), treatment effect (training or control), and their interactions if there is any regarding Vo_{2peak} from pre- to post-tests between groups. A two-tailed independent t-test was used to analyze differences in anthropometrics between the intervention group and the control group. Two-tailed paired t-test was applied to analyze changes in anthropometrics and performance between pre- and post-tests within groups. All analyses were performed using SPSS v.20.0 (SPSS, Inc., Chicago USA). The accepted level of significance was set at < 0.05.

Results

The main finding was that the intervention group significantly ($p< 0.05$) improved their VO_{2peak} expressed as ml x $kg^{-0.67}$ x min^{-1} (from 178.5 (± 12.6) to 188.4 (± 12.6)) but not when it is expressed as ml x kg^{-1} x min^{-1} (from 54.0 (± 5.4) to 57.1 (± 5.5)) (see table 2). The control group had a slight, non-significant decrease in their VO_{2peak} independent of scaling factor. There was no difference in respiratory exchange values or heart rate values between groups or from pre- to post test.

Table II: Absolute (ml/m) and relative (ml kg^{-1} min^{-1} and ml $kg^{-0.67}min^{-1}$) oxygen consumption, respiratory exchange ratio and peak heart rate in tests displayed in mean (±SD) in pre and posttest for the intervention group and the control group.

	Intervention group		Control group	
	Pre-test (SD)	Post-test (SD)	Pre-test (SD)	Post-test (SD)
VO2 ml min^{-1}	2036.8 (260.0)	2134.9 (266.8) *	1891.7 (179.9)	1871.2 (130.7)
VO2 ml $kg^{-0.67}$	178.5 (12.6)	188.4 (12.6) *	174.9 (12.7)	172.4 (14.6)
VO2 ml kg^{-1} min^{-1}	53.9 (3.7)	57.1 (3.8)	54.3 (6.0)	53.5 (6.6)
Respiratory exchange ratio	1.09 (0.02)	1.09 (0.03)	1.05 (0.05)	1.11 (0.05)
Heart rate (in tests)	205 (5.6)	203.1(5.3)	207 (8.0)	207.8 (4.9)

* Denotes significant ($p < 0.05$) change in performance between intervention- and control-group.

Measurements from the exercise sessions showed that the children's intensity levels were above 80 % of HR_{peak} throughout more than 30 minutes (>50 %) of the one hour sessions in average (as told in figure 1). Surprisingly they achieved intensities above 90% of HR_{peak} for 19 minutes (31.5 %) of the sessions, and approximately 4.5 minutes (7.1 %) of the time they exercised at intensities above 95% of HR_{peak}.

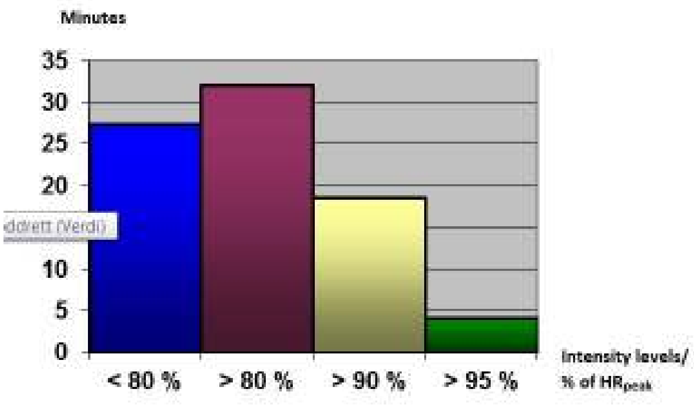

Figure I: Heart rate during the one-hour training sessions, under 80 % of HR_{peak} and above 80, 90 % and 95% of HR_{peak}.

The children were given different assignments during exercise varying form catching games, relays ballgames and obstacle courses. The catching games and ballgames lasted up to four minutes and as seen in figure 1 the children were able to sustain intensity levels up to 95% in average during those four minutes. The relays were often organized in pairs with each lap varying from 10 sec x 10 up to 8 minutes total time (as seen in figure 2).

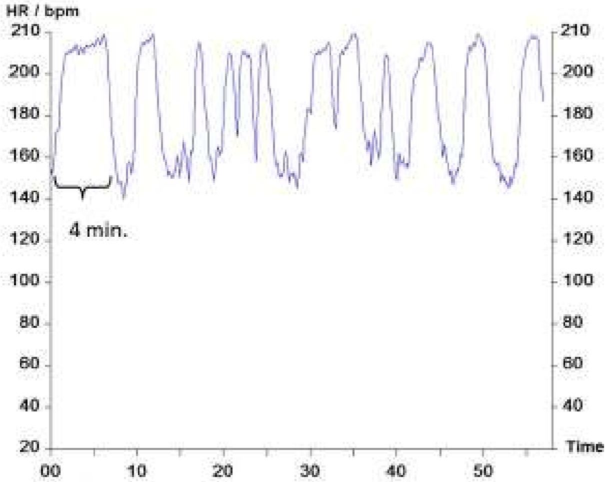

Figure II: Example of HR-monitoring during a training session. The test subject has a HR_{peak} of 218 bpm.

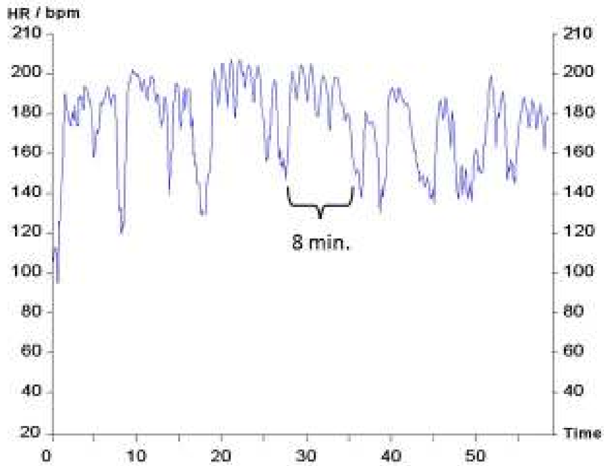

Figure III: Example of HR-monitoring during a training session. Test subject has a HR_{peak} of 206 bpm

Discussion

The main finding in the present study was a significant improvement in VO_{2peak} from 178.5 (± 12.6) - 188.4 (± 12.6) ml x $kg^{-0.67}$ min^{-1} in the intervention group. The improvement in VO_{2peak} after two one hour aerobic training sessions per week over 5 weeks is probably explained by the high intensity. When taking into account that one of the training sessions replaced one of the soccer practices the results are even more conclusive – high intensity is probably an important factor for improving children's VO_{2peak}. The findings are in line with previous studies, which show improvement in aerobic power if the intensity level is high, more than 70% of HR_{max} (Baquet et al., 2010; Strong et al., 2005). However, to our knowledge, significant improvement in aerobic power by executing playful activities has not previously been reported in short term training periods such as this experiment. Heart rate data from the training sessions revealed that many of the children reached intensity levels near their HRpeak several times per session. Although there were individual differences the overall trend showed very high HR levels. Our study showed HR intensities above 80% of HR_{peak} through more than 30 minutes (50 %) of the one-hour sessions in average. The participants even played with intensity above 90% of HR_{peak} for 19 minutes (31.5 %) of the sessions in average, and for approximately 4.5 minutes (7.1 %) above 95% of HR_{peak} (figure 1). 4 x 4 minutes interval training is considered to be a strenuous and very efficient training method in adults (Helgerud, Rodas, Kemi, & Hoff, 2011), but not suited children's natural play patterns. This study shows that high intensity aerobic playful activity might also be an efficient method to improve VO_{2peak} in children. The phenomena of relatively long periods of near HR_{peak} intensity (figure 2 and 3), are supported by studies which show that children are capable of exercising near their VO_2peak with little accumulation of lactate (Ratel, Duche, & Williams, 2006). This study has shown that children are able to maintain activities above 95% of their HR_{peak} up to four minutes without breaks, and up to eight minutes above 85% of HR_{peak}, if the activity is split by short breaks. The use of playful activities may have enhanced the motivation to sustain the high intensity, and these activities are applicable for children's sports programs and physical education classes with the intention of improving aerobic power or learning to cope with high intensity aerobic activity. When exploring time spent in different intensity zones, research has shown that vigorous activity is associated with lower body fat and higher cardiovascular fitness (Gutin, Yin, Humphries, & Barbeau, 2005; Hussey et al., 2007; Ness et al., 2007; Ruiz et al., 2006), indicating that exercise intensity may have a larger effect on children's health than physical activity in general, but further studies are needed to rule out methodological misinterpretations in assessing physical activity (Ekelund, 2008). Research has also shown tracking effects of physical fitness from childhood into adulthood which makes exercise even more important in preventing negative health factors (Matton et al., 2006). Consequently, an improvement in aerobic power would be considered a beneficial health investment for children as well as for adults. Further studies are essential to elucidate the influence of short interval, high intensity training on aerobic power and general fitness. There is also a need to investigate the motivational implications of high intensity exercise programs, PE-lessons and leisure sport.

Conclusions

Children can increase their VO_{2peak} after five weeks of exercise with two high intensity sessions per week and exercise near their HR_{peak} in time periods lasting up to four minutes without pausing.

Aerobic play and games are an activity mode that may initiate a sufficient intensity level for improving aerobic power. These activities are more similar to the natural play patterns of children, and can be used as a source of motivation towards increased activity level with high intensity.

We recognize that achieving comparable improvements to the present study could be more challenging in school classes than in soccer teams, due to a more heterogeneous group composition. Nevertheless, by organizing vigorous playful activities, the intensity level may provoke training induced improvements in aerobic power in children.

References

Andersen, L. B., Harro, M., Sardinha, L. B., Froberg, K., Ekelund, U., Brage, S., & Anderssen, S. A. (2006). Physical activity and clustered cardiovascular risk in children: a cross-sectional study (The European Youth Heart Study). *Lancet, 368*(9532), 299-304. doi: 10.1016/S0140-6736(06)69075-2

Anderssen, S. A., Cooper, A. R., Riddoch, C., Sardinha, L. B., Harro, M., Brage, S., & Andersen, L. B. (2007). Low cardiorespiratory fitness is a strong predictor for clustering of cardiovascular disease risk factors in children independent of country, age and sex. *European Journal of Cardiovascular Prevention & Rehabilitation, 14*(4), 526-531. doi: 10.1097/HJR.0b013e328011efc1

Araujo, A. C. C., Picanço, A. R., Pinto, A. L. S., Perondi, M. B., Prado, D. M. L., Roschel, H., . . . Gualanox, B. (2011). Effects Of Sprint Interval And Traditional Endurance Training In Childhood Obesity. *Medicine & Science in Sports & Exercise, 43*(5), 897. doi: 10.1249/01.MSS.0000402510.76471.9c

Armstrong, N., & Welsman, J. R. (1994). Assessment and interpretation of aerobic fitness in children and adolescents. *Exercise & Sport Sciences Reviews, 22*, 435-476.

Armstrong, N., Welsman, J., & Winsley, R. (1996). Is peak VO2 a maximal index of children's aerobic fitness? *International Journal of Sports Medicine, 17*(5), 356-359.

Baquet, G., Gamelin, F. X., Mucci, P., Thévenet, D., Van Praagh, E., & Berthoin, S. (2010). Continuous vs. interval aerobic training in 8- to 11-year-old children. *Journal Of Strength And Conditioning Research 24*(5), 1381-1388.

Baquet, G., van Praagh, E., & Berthoin, S. (2003). Endurance training and aerobic fitness in young people. *Sports Medicine, 33*(15), 1127-1143.

Barkley, J. E., Epstein, L. H., & Roemmich, J. N. (2009). Reinforcing value of interval and continuous physical activity in children. *Physiology & Behavior, 98*(1-2), 31-36. doi: 10.1016/j.physbeh.2009.04.006

Ekelund, U. (2008). Cardiorespiratory fitness, exercise capacity and physical activity in children: are we measuring the right thing? *Archives of Disease in Childhood, 93*(6), 455-456. doi: 10.1136/adc.2007.135202

Fredriksen, P. M., Ingjer, F., Nystad, W., & Thaulow, E. (1998). Aerobic endurance testing of children and adolescents--a comparison of two treadmill-protocols. *Scandinavian Journal of Medicine & Science in Sports, 8*(4), 203-207.

Gutin, B., Yin, Z., Humphries, M. C., & Barbeau, P. (2005). Relations of moderate and vigorous physical activity to fitness and fatness in adolescents. *American Journal of Clinical Nutrition, 81*(4), 746-750. doi: 81/4/746 [pii]

Helgerud, J., Høydal, K. , Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., . . . Hoff, J. . (2007). Aerobic High-Intensity Intervals Improve VO2max More Than Moderate Training. *Medicine & Science in Sports & Exercise, 39*(4), 665-671. doi: 10.1136/adc.2007.135202

Helgerud, J., Rodas, G., Kemi, O. J., & Hoff, J. (2011). Strength and endurance in elite football players. *International Journal of Sports Medicine, 32*(9), 677-682. doi: 10.1055/s-0031-1275742

Hussey, J., Bell, C., Bennett, K., O'Dwyer, J., & Gormley, J. (2007). Relationship between the intensity of physical activity, inactivity, cardiorespiratory fitness and body composition in 7-10-year-old Dublin children. *British Journal of Sports Medicine, 41*(5), 311-316. doi: 10.1136/bjsm.2006.032045

Krahenbuhl, G. S., Skinner, J. S., & Kohrt, W. M. (1985). Developmental aspects of maximal aerobic power in children. *Exercise and Sport Sciences Reviews, 13*, 503-538.

Matton, L., Thomis, M., Wijndaele, K., Duvigneaud, N., Beunen, G., Claessens, A. L., . . . Lefevre, J. (2006). Tracking of physical fitness and physical activity from youth to adulthood in females. *Medicine & Science in Sports & Exercise, 38*(6), 1114-1120. doi: DOI: 10.1249/01.mss.0000222840.58767.40

McManus, A. M., Cheng, C. H., Leung, M. P., Yung, T. C., & Macfarlane, D. J. (2005). Improving aerobic power in primary school boys: a comparison of continuous and interval training. *International Journal of Sports Medicine, 26*(9), 781-786. doi: 10.1055/s-2005-837438

Ness, A. R., Leary, S. D., Mattocks, C., Blair, S. N., Reilly, J. J., Wells, J., . . . Riddoch, C. (2007). Objectively measured physical activity and fat mass in a large cohort of children. *PLoS Med, 4*(3), e97. doi: 10.1371/journal.pmed.0040097

Obert, P., Mandigouts, S., Nottin, S., Vinet, A., N'Guyen, L. D., & Lecoq, A. M. (2003). Cardiovascular responses to endurance training in children: effect of gender. *European Journal of Clinical Investigation, 33*(3), 199.

Ortega, F. B., Ruiz, J. R., Castillo, M. J., & Sjostrom, M. (2008). Physical fitness in childhood and adolescence: a powerful marker of health. *International Journal of Obesity, 32*(1), 1-11. doi: doi:10.1038/sj.ijo.0803774

Pettersen, S. A., Fredriksen, P. M., & Ingjer, E. (2001). The correlation between peak oxygen uptake (VO2peak) and running performance in children and adolescents. aspects of different units. *Scandinavian Journal of Medicine & Science in Sports, 11*(4), 223-228. doi: 10.1034/j.1600-0838.2001.110405.x

Ratel, S., Duche, P., & Williams, C. A. (2006). Muscle fatigue during high-intensity exercise in children. *Sports Medicine, 36*(12), 1031-1365.

Ratel, S., Lazaar, N., Dore, E., Baquet, G., Williams, C. A., Berthoin, S., . . . Duche, P. (2004). High-intensity intermittent activities at school: controversies and facts. *J Sports Med Phys Fitness, 44*(3), 272-280.

Resaland, G. K., Andersen, L. B., Mamen, A., & Anderssen, S. A. (2009). Effects of a 2-year school-based daily physical activity intervention on cardiorespiratory fitness: the Sogndal school-intervention study. *Scandinavian Journal of Medicine & Science in Sports, 21*(2), 302–309. doi: DOI: 10.1111/j.1600-0838.2009.01028.x

Resaland, G. K., Mamen, A., Boreham, C., Anderssen, S. A., & Andersen, L. B. (2010). Cardiovascular risk factor clustering and its association with fitness in nine-year-old rural Norwegian children. *Scandinavian Journal of Medicine & Science in Sports, 20*(1), e112–e120. doi: 10.1111/j.1600-0838.2009.00921.x

Rogers, D. M., Turley, K. R., Kujawa, K. I., & Harper, K. M. (1995). Allometric Scaling Factors for Oxygen Uptake During Exercise in Children. *Pediatric exercise science., 7*(1), 12-25.

Rowland, T. W. (1990). Developmental Aspects of Physiological Function Relating to Aerobic Exercise in Children. *Sports Medicine, 10*(4), 255-266.

Rowland, T. W., & Boyajian, A. (1995). Aerobic response to endurance exercise training in children. *Pediatrics, 96*(4), 654-658.

Ruiz, J. R., Rizzo, N. S., Hurtig-Wennlof, A., Ortega, F. B., Warnberg, J., & Sjostrom, M. (2006). Relations of total physical activity and intensity to fitness and fatness in children: the European Youth Heart Study. *American Journal of Clinical Nutrition, 84*(2), 299-303. doi: 10.3945/ajcn.2008.27261

Stewart, K. J., & Gutin, B. (1976). Effects of physical training on cardiorespiratory fitness in children. *Research Quarterly, 47*(1), 110-120.

Strong, W. B., Malina, R. M., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B., . . . Trudeau, F. (2005). Evidence based physical activity for school-age youth. *The Journal of Pediatrics, 146*(6), 732-737. doi: 10.1016/j.jpeds.2005.01.055

Welsman, J. R., Armstrong, N., & Withers, S. (1997). Responses of young girls to two modes of aerobic training. *British Journal of Sports Medicine, 31*(2), 139-142.

Zahner, L., Puder, J. J., Roth, R., Schmid, M., Guldimann, R., Puhse, U., . . . Kriemler, S. (2006). A school-based physical activity program to improve health and fitness in children aged 6-13 years ("Kinder-Sportstudie KISS"): study design of a randomized controlled trial *BMC Public Health, 6*(147). doi: 10.1186/1471-2458-6-147