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A preliminary investigation into concurrent aerobic and resistance training in youth runners

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Abstract.
BACKGROUND: Studies in adults have shown benefits in endurance performance by combining aerobic and resistance training. However, whether concurrent strength and aerobic training is beneficial in children remains to be identified.
OBJECTIVE: The purpose of this study was to examine the effect of a 10 week aerobic training programme compared to a concurrent aerobic and resistance training programme on leg strength, fat free mass (%FFM), forced vital capacity (FVC) and 3 km-running performance in youth athletes.
METHODS: Twelve trained youth competitive runners were pair matched into either an aerobic (AT) or concurrent (CT) training group based on maturational status and initial 3 km-running performance. The aerobic training consisted of continuous and interval training twice weekly for all participants. The CT group additionally performed resistance training twice weekly.
RESULTS: There were no statistically significant differences between groups for any parameters pre-training. Significant correlations were found between 3 km-running performance and leg strength, FVC and %FFM. No significant interaction or main effects for any of the key outcome variables were found. There was however, a 38 s group difference in 3 km-running time post intervention indicating some interference of the resistance training on ERP.
CONCLUSIONS: These findings suggest that concurrent endurance and resistance training should be avoided in trained youth athletes.

Keywords: Training, 3-km running, body composition, lung function, isokinetic strength

1. Introduction

Many studies have examined the influence of aerobic training on improving VO_2 in children but the proposed adaptations with training are poorly understood [26]. A recent IOC consensus statement on training the elite youth athlete suggests that for aerobic adaptations to occur during childhood the training must include both continuous and interval training, be at a high intensity (85–90% heart rate max), and occur 3 to 4 times per week for at least 40 min [34]. The impact of both anaerobic and aerobic training on improvements in aerobic performance may be related to the concept that children are non-metabolic specialists [25]. Mahon [26] suggests that this 'Hard-Easy' principal of training seems to lead to aerobic adaptations in children, but also reinforces the need for continuous training which may improve endurance, without concomitant increases in VO_2.

Although there is the potential for resistance training to enhance running performance of young athletes [20,32,37], empirical evidence is limited due to

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the multivariate nature of athletic performance [11]. Data on children is sparse, possibly due to the difficulty in partitioning out the influence of growth and maturation from the training effect. However, properly designed and supervised resistance training programmes can not only enhance the muscular strength and power of youth, but also improve motor skill competency, and may contribute to enhanced sports performance [11,24].

There is developing evidence identifying positive increases in muscle strength after short-duration resistance training programmes [22,48]. However, the duration of the resistance training programme required to observe significant increases in strength has ranged from 5–20 weeks, and it is apparent that the longer durations of training (10–20 weeks) result in significantly greater strength changes in children (22). Comprehensive meta-analysis studies involving participants under the age of 18 y (in which overall improvements in strength of 30–40% were observed) and prepubertal children, have suggested that training duration should be between 8 and 12 weeks [39,48]. Conflicting data are available and in their recent meta-analysis Behringer et al. [1] noted no relationship between training duration and strength gains, but reported that a higher frequency of sessions per week, inducing a larger dose response, resulted in greater training effects in children. This minimum period of 8 weeks, combined with a relatively larger training dose, is probably required to differentiate the performance contributions of training adaptations from those associated with normal growth and maturation [22].

Current evidence suggests that neuromuscular and anaerobic capability may have a considerable influence on endurance running performance (ERP) in well-trained distance runners, which may have implications for resistance training as a factor in increasing running economy and ERP during childhood [6,20,32,37]. Certain studies on prepubescent and adolescent runners have found that although there are neurological adaptations and increases in anaerobic performance following resistance training, these do not transfer into improved ERP [6,30]. Conflicting data are available and Hickson et al. [20] reported that resistance training improved short-term ERP of teenagers and young adults. These contrasting findings highlight the difficulty in partitioning the effects of a training programme from expected changes associated with normal growth and maturation [5]. Inconsistent results for resistance training in young distance runners may also have arisen from study design limitations. For example, Cole et al. [6] measured muscle strength of the lower limbs of adolescent runners using peak torque measurements obtained during slow isokinetic movements which do not replicate joint angular velocity when running. It may be important to also measure isoinertial strength pre and post a resistance training study as the movement patterns and loading stressors inherent to such protocols are most replicable of sports performance.

Data from adult studies suggest that the improvement in ERP after a resistance training programme is a direct result of the neuromuscular adaptations that occur after resistance training interventions [31]. However, the potential contributing factors to improved ERP in children after systematic resistance training, alongside aerobic training remains unclear. There is evidence to suggest that muscle power is a significant determinant of ERP in children [25,27,38], however, further research is required in order to determine whether muscle strength has a similar effect on ERP in children. An 'interference hypothesis' has been proposed suggesting that concurrent strength and endurance training reduces the adaptations that occur during aerobic training, subsequently blunting the aerobic training response [10]. However, to our knowledge no studies have explored this phenomenon in well trained youth runners.

The proposed benefits of resistance training for children that could have implications for improving ERP may include increased muscle strength, local muscular endurance and optimal body composition [14,21]. Adult studies have also suggested that resistance training can improve running economy due to the improvement in rebounding qualities (e.g. greater energy return to the muscle from the series elastic component) [47]. However, data from children are either sparse or conflicting with some studies demonstrating a significant increase in FFM following a 34 week training programme [54], and significant decreases in body fat percentage (%BF) in prepubescent children after 12 weeks of upper body resistance training [14,43,44]. In contrast to these findings some studies looking at the effects of short-term resistance training programmes have found no change in fat free mass [17,36,40]. The inconsistency in results may highlight the variability of test protocols typically adopted to determine %FFM and %BF (e.g. skinfold measurement) and reinforces the need for more sensitive measures of FFM.

When examining the effects of resistance training on aerobic parameters, many studies in adults have shown that resistance training has no effect on aerobic characteristics [19,20,45]. In support of this, Mikkola et al. [30] observed that explosive resistance training improved anaerobic and selective neuromuscular performance characteristics of post-pubertal (16–18 years old) distance runners with no effect on aerobic characteristics. Studies on children are limited and have shown either no change [4], or an increase [9,52] in peak O_2 uptake. Increases in aerobic power may be attributed to the reciprocal concentric nature of the exercises prescribed and a high volume programme, however, continuation of other sports activities was allowed during these studies, and therefore further evidence is required in order to establish a link between resistance training, exercise volume and the potential for improvements in aerobic power [48]. Also no studies appear to have explored the link between additional resistance training and improved ERP in youth athletes.

Despite growing evidence that suggests muscle strength and power are significant determinants of ERP in adults [32,37], as well as evidence to suggest that muscle power is a significant determinant of ERP in children [25,27,38], further research is required in order to determine the effects of muscle strength on ERP in children. Previous studies have failed to adequately account for maturational status and therefore matching training groups based on maturation is essential. The purpose of this study was to investigate the effects of a 10 week AT versus concurrent CT on 3-km running time, isokinetic leg muscle strength, FVC and %FFM in 10–13 years old distance runners.

2. Methods

2.1. Participants

A total of 12 children (6 girls and 6 boys) aged 10–13 y participated in this study. Participants were recruited from a local athletic club, and had a minimum of 12 months endurance training experience but no previous resistance training experience or current involvement within a resistance training programme. Participants were permitted to take part in normal activities, such as PE and school/community sports, and were asked to state in the pre-intervention health questionnaire the types of activities regularly participated in, and the weekly frequency and duration of each activity. Permission and written consent was granted by the head coach of a local athletics club, with written informed consent being gained from the participants and their parents/carers. The study was approved by the University Research Ethics Committee. Participants were pair matched into either a CT ($N = 6$) or AT ($N = 6$) group. Participants in each group were matched according to maturational status based on predicted age from peak height velocity [PHV] [33]. Participants recorded both endurance and resistance training sessions completed in each week in a training log book, and those that had completed a minimum of 80% of the training programme were included in the analysis. Participants also logged additional activity undertaken outside of the training programme to examine group differences in extra physical activity.

2.2. Design

Participants trained for a total period of 10 weeks. Measurements for outcome variables were made prior to commencement of the 10 week training programme, with repeat measurements undertaken following completion of the training programme. Following the 10 week resistance training programme, the second 3-km time trial was performed a minimum of 48 hours after the first training session in order to eliminate any muscle soreness that may have occurred due to the eccentric component of resistance training [50]. There was a rest period of one week between the 3km-time trial and assessment of FVC, %FFM and isokinetic leg strength both pre and post intervention. Extraneous variables were controlled for by undertaking the 3km-time trial during similar weather conditions. All laboratory testing occurred at the same time of day and participants filled out food and clothing diaries to ensure consistent practice prior to all testing. Age was computed from date of birth and date of testing. Stature and body mass were measured according to the techniques described by Weiner and Lourie [53]. Stature was measured using a Holtain Stadiometer (Crymych, Dyfed, UK) and body mass was measured using Weylux calibrated scales (Birmingham, UK). Sitting height was measured with a Holtain Stadiometer (Crymych, Dyfed, UK) with the posterior surface of the knee tight against the measuring box. Age from PHV was determined using the equation of Mirwald et al. [33].

2.3. Forced Vital Capacity (FVC)

Forced Vital Capacity (FVC) was measured using a Microloop 3535 medical spirometer and mouthpiece (Micro Medical). Measurements were taken with the participants standing upright. Participants were instructed to take a deep breath in through their mouth, and their nose and then breathe into the mouthpiece as hard and as fast as possible. The best of three measurements was recorded.

2.4. *Fat Free Mass (FFM)*

A BodPod Body Composition System (Life Measurement Instruments, USA) was used to determine percentage of fat free mass. Body mass was measured using the BodPods' electronic scale, calibrated and graduated to 100 g. The BodPod was calibrated prior to testing, using a 50 L cylinder and in accordance with the manufacturers guidelines. The BodPods' electronic scales were also calibrated prior to testing using the manufacturers' guidelines. For measuring body mass, participants wore a swimsuit but no footwear. Body mass was measured to 0.1 kg. During the BodPod measurement, participants wore a swimsuit, swimming cap and nose clip. During testing, participants were asked to relax, sit still and breathe normally in the chamber. The measurement generated two readings of which the average was taken for each participant. The correction for thoracic gas volume was undertaken using the 'entered' method using the highest FVC recorded.

2.5. *Isokinetic testing*

Isokinetic concentric knee extension and flexion were performed using a calibrated Biodex system 3 (Shirley, New York, USA). Prior to testing participants were habituated to the testing environment and isokinetic procedures, which primarily involved practicing the range of movement at the test velocity. They were asked to perform several sub-maximal and maximal concentric actions until torque could be achieved consistently. All testing sessions involved a standardised procedure, including a warm up of 2 min cycling on a Monark cycle ergometer 814E (Varberg, Sweden) at 60 W. Participants were placed in a seated position with the seatback tilted at 85° hip flexion from the anatomical position. The lever arm of the dynamometer was aligned with the lateral epicondyle of the knee, and the force pad placed approximately 3 to 5 cm superior to the medial malleolus with the foot in a plantigrade position. Range of motion during testing was 90° using voluntary maximal full extension as 0° and cushioning was set using a hard deceleration. At the start of each test session the participant was asked to relax their leg so that passive determination of the effects of gravity on the limb and lever arm could be accounted for according to the manufacturers' procedures. The dominant limb, determined from kicking preference [41], was examined and testing occurred as follows: 3 repetitions at 30°/s, followed by 3 repetitions at 90°/s and 6 repetitions at 180°/s with a 30 s rest between velocities. Participants were instructed to push and pull the lever arm 'as hard and fast as possible' for concentric actions. A 120 s rest period was then given between velocities. Participants were encouraged to give a maximal effort for each action by using both visual feedback and strong verbal encouragement from the tester. Immediately after the test participants completed a 2 min cool down on the cycle ergometer at 60 W.

2.6. *3-km running time trial*

The two 3-km time trials were run on a 400 metre outdoor track. In accordance with Behm et al. [2], participants completed a warm-up prior to the time trial. The warm-up took place indoors in a sports hall and consisted of 10 minutes of low-intensity aerobic exercise and 10 minutes of dynamic movements (lunges, skips, high knees and heel flicks) [12]. The time trial was timed using handheld FCTtime 10 triple display stopwatches (Cranlea and Company), and the time recorded to the nearest second. Participants did not perform any endurance or resistance training on test days, and aimed to eat similar foods and in the same quantity on test days, which was achieved by participants keeping a food diary. Participants were informed not to eat 2 hours prior to each time trial, and that liquids were limited to water only. Participants were asked to wear similar clothing and shoes for each time trial.

2.7. *Aerobic training programme*

The aerobic training sessions were undertaken twice a week by all participants and consisted of both continuous aerobic training and interval training (Table 1), as recommended in the IOC consensus statement for training the elite child athlete [34]. Increases in training load over the 10 weeks was determined by the running coach for each individual.

2.8. *Resistance training programme*

Additionally, the CT group strength trained twice weekly, with at least one days rest between sessions [13] using a circuit training approach, under the supervision of a suitably qualified strength and conditioning coach [2]. The resistance training consisted of four sets of primary exercises and three sets of secondary exercises, with all but the first set of exercises being undertaken to volitional failure, and with rest periods of 2 minutes between exercises in accordance

Table 1
Aerobic endurance training programme

Session 1	Session 2
Continuous running 25–30 min at 60, 65, 70% effort	Continuous running 25–30 min at 60, 65, 70% effort
4 × 800 m at 70, 75, 80% effort with 800 m walking recovery	4 × 4 min at 70, 75, 80% effort with 30 s recovery
2 sets of 3 repetitions × 300 m at 90–100% effort with 3 min active recovery between repetitions and 5–10 min static recovery between sets.	2 sets of 3 repetitions × 300 m at 90–100% effort with 3 min active recovery between repetitions and 5–10 min static recovery between sets.

with Ramsay et al. [40] and Fleck and Kraemer [16]. The primary exercises provided specific overload to three major muscle groups that are of interest in this study: the elbow flexors, knee flexors and knee extensors). The secondary exercises provided a general conditioning effect. To introduce proper weight lifting technique and habituate participants to the gym environment, participants took part in two low volume (2 sets of each exercise) familiarisation sessions 1 week prior to the formal training period. Order of exercises was randomised at each session because of the circuit style of the sessions. In accordance with Ramsay et al. [40] and Behm et al. [2], maximal load for the CT group was 70–75% of the 1RM. 1RM performance strength was measured on Precor (Washington, USA) resistance machines in accordance with the procedures of Ramsay et al. [40] and Faigenbaum et al. [13]. After an initial warm-up of 3 sub-maximal sets, participants then performed a series of single repetitions with increasing loads. Failure was defined as a lift falling short of the full range of movement on two attempts spaced at least 2 minutes apart. The 1RM was found within 6 trials, with 2 minutes rest between each attempt [15]. In order to increase training intensity, individuals increased their training load when determined by the strength and conditioning coach. To ensure any strength gains were due only to participation in the prescribed resistance training programme, no resistance training activities were permitted outside of the supervised training sessions. None of the control group strength trained during the study; however, both groups were permitted to maintain their normal daily activities, including participation in various sports. Details regarding the training programme are given in Table 2.

Table 2
Resistance training programme for the CT group

Primary exercises	Secondary exercises
Sets: 4 Reps: 10, 3 × 10–12 RM Load (% 1 RM): 60, 3 × 70–75, 60	Sets: 3 Reps: 10, 2 × 10–12 RM, Load (% 1RM): 60, 2 × 70–75

Primary exercises: preacher arm curl, double leg curl & double leg extension; Secondary exercises: leg press, bench press, lat pull down & sit-ups/trunk curl.

Table 3
Percentage change in mean load during the 10-week resistance training programme

	Mean load (kg)		
Exercise	Week 1	Week 10	% change
Preacher arm curl	3.93	6.29	23.10 ↑
Double leg extension	13.57	22.14	24.00 ↑
Double leg curl	11.43	17.86	21.96 ↑
Leg press	25.71	32.86	12.20 ↑
Bench press	6.43	8.21	12.16 ↑
Lat pull down	10.71	15.71	18.92 ↑

2.9. *Statistical analysis*

Data were analysed using Statistical Package for Social Science (SPSS) for Windows (SPSS Inc., Chicago, USA, V16.0) and presented as the mean ± SD. Data was checked for homogeneity and skewness. Pearson product moment correlation coefficients were determined between 3km-running time and isokinetic leg strength, %FFM and FVC. A 2 (training group) × 2 (time) Repeated Measures Analysis of Variance (RMANOVA) were conducted on each dependent variable. The level of significance was set at $P \leqslant 0.05$.

3. Results

All 12 participants completed at least 80% of the training programme according to the inclusion criteria. There were no significant differences ($p \geqslant 0.05$) pre-intervention between the CT and A groups in chronological age, stature, body mass, sitting height, %FFM or predicted years to PHV. There were also no significant differences ($p \geqslant 0.05$) in pre-intervention 3-km time trial time, FVC or isokinetic leg strength between the two groups, with the exception of peak torque for the left quadriceps at the velocity of 30°/s, which was significantly greater for the control group than the experimental group (Table 4). For further analysis a combined leg strength value was used with torque from both flexion and extension movements combined. There were no significant differences ($p \geqslant 0.05$) in

Table 4
Values for dependent variables (mean ± SD) at baseline and post-intervention for the CT and AT groups

Variable	Group	Baseline		Post-intervention		% change
		M	SD	M	SD	
FVC (L)	CT	2.23	0.4	2.34	0.3	2.4 ↑
	AT	2.53	0.5	2.61	0.4	1.5 ↑
Peak torque (Nm)	CT	174.6	23.4	184.6	30.1	2.8 ↑
	AT	208.4	51.4	212.4	58.5	1.0 ↑
Fat free mass (%)	CT	83.0	5.6	79.0	6.6	2.5 ↓
	AT	90.1	5.3	82.5	5.7	4.4 ↓
3-km time (mins)	CT	13.26	1.4	13.36	1.3	0.4 ↑
	AT	13.49	0.8	13.21	0.9	1.0 ↓

time spent on other activities outside of the intervention between the two groups.

Paired-sample t-tests revealed that post training, the CT group significantly increased 1RM for leg press ($p = 0.023$), and although the mean 1RM for bench press increased from 11.6 kg pre-intervention to 14.4 kg post-intervention, the increase was not statistically significant.

A significant correlation between 3-Km running time and FVC ($p = 0.038$; $r = 0.58$), %FFM ($p = 0.048$; $r = 0.59$) and isokinetic peak torque measurements ($p = 0.019$, $r = 0.64$) was observed. There were no statistically significant group by time interactions ($p \leqslant 0.05$) for isokinetic peak torque, FVC, %FFM, and 3-km running time. There was, however, a main effect of time for FVC whereby, regardless of group FVC increased significantly ($p = 0.025$) post intervention. Although not statistically significant ($p \geqslant 0.05$), there were percentage changes in 3km-running time, isokinetic leg strength, %FFM and FVC following the intervention period (see Table 4). There was a greater increase in the percentage change in peak torque measurements and FVC for the CT group than the AT group. Although both groups experienced an overall reduction in %FFM, a smaller overall decrease was observed for the CT group compared to the AT group. 3-km running time increased in the CT compared with a decrease in the AT group representing a 38 s difference between groups post-intervention.

4. Discussion

This investigation found that 10 weeks of AT or CT training had no statistically significant effect on 3-km running time, isokinetic peak torque, FVC or %FFM in a small number of trained youth endurance runners aged 10–13 years. The lack of statistically significant effects may be due to the small sample size used in this preliminary investigation and further work is required with larger sample sizes. Significant moderate correlations were found between %FFM, FVC and mean isokinetic peak torque measurements, and 3-km run time. Although not significant, a general trend towards the CT group experiencing greater overall % changes in FVC and mean isokinetic peak torque measurements was observed, however, these did not translate into improved 3-km performance run time. In performance terms a 38 s difference in running time was observed between groups post intervention with the AT group improving their time by 28 s and the CT group time running 10 s slower compared with their respective pre-intervention time.

Significant correlations between all of the measured variables and ERP measured as 3km-running time were found in the current study. These data suggest that a greater FVC, higher % FFM and greater leg strength are all associated with faster 3km-running times in 10–13 year-olds. Others have reported a significant correlation between VO_2max and 3-km time in 9–13 year old boys [25,51]. The correlation in the present study is lower than those reported by Unnithan et al. [51] and Mahon et al. [25] and may be explained by the fact that we only determined FVC and not VO_2max. It may also be that the sample in the current was homogenous (trained distance runners with a minimum of 12 months training) and therefore may have contributed to the lower correlation.

3-km run time was also significantly related to %FFM in the current study ($r = 0.59$) and is lower than that ($r = 0.72$) reported by Mahon et al. [25]. However, others have reported similar correlations ($r = 0.45$, and $r = 0.55$) between one and two-mile run times and % body fat in 7–12 years old boys [8] and 10–14 years old males and females [38] respectively. A possible explanation for the variation in correlations observed in the present study compared to previous studies could be that the influence of %FFM on run time may vary across different distances, age groups or maturation levels [25] and that we determined %FFM using air displacement plesmography.

The present study also found a significant correlation ($r = 0.64$) between mean isokinetic peak torque and 3-km running time. There are no direct studies to compare this data with, however Tharp et al. [49] reported a significant correlation ($r = 0.55$) between 10-km run time and isokinetic knee torque in adult female runners. In contrast, Cole et al. [6] found no significant relationship between isokinetic knee extension torque and 5km running performance in 17–18 years old boys. However, our findings seem to suggest that leg strength may be an important parameter in 3km-running time in trained young runners. The mechanisms underpinning the relationship between leg strength and ERP in children remains to be elucidated but it may be that increased leg strength improves running economy [47]. Further investigations are required in order to examine the interactions between peak torque and aerobic parameters in children.

Although changes in isokinetic strength were not significantly greater post-intervention for either group there was a trend for the small increase to be greater in the CT group. However, our findings suggest that by combining aerobic training with resistance training caused 'interference' and limited resistance training adaptations. Although the main purpose of this study was to examine if additional resistance training could improve ERP our findings suggest that if resistance training adaptations are sought in youth athletes then aerobic training should be reduced to minimise any interference effects. However, it is acknowledged that the sample size in the current study is relatively small and these findings need to be corroborated with larger samples across a range of chronological ages and maturational stages. It would also be interesting to observe whether the interference observed might also be the same for eccentric torque production, as eccentric actions are equally important for running performance.

Evidence suggests that neuromuscular and anaerobic characteristics may have a considerable influence on ERP in well-trained adult distance runners [6,20,32,37,46,47]. Studies on prepubescent and adolescent runners have found that although there are neurological adaptations and increases in anaerobic capacities following resistance training, these do not transfer into improved aerobic performance or 5-km running performance [6,30,36]. The results from the present study concur with that of previous studies, in that an additional resistance training programme did not significantly improve 3-km running time over aerobic only training. One of the reasons we found no statistically significant differences between training modes may be due to the fact that participants were pair matched, not only on maturational stage, but also on pre training 3-km running times. Previous studies that have failed to take maturational status into account are limited in that changes over time or between groups may be attributed to the physiological adaptations associated with growth and maturation rather than the intervention programme. From a statistical perspective our data suggest that youth athletes can undertake resistance training alongside endurance training without having a detrimental effect on ERP. However, these conclusions are limited by the relatively small sample size, and the observed trend for an increase in 3km-running time in the CT compared with a decrease in 3km-running time for the AT group may be more relevant.

The interference phenomenon suggests that simultaneous resistance and aerobic training reduce the training adaptation of one of the systems due to the conflicting physiological adaptations placed on the muscle during such training [10]. Although we did not find a statistically significant difference between groups post-intervention there may have been some interference as the CT group 3km-running time was 10 s slower post intervention compared to an improvement of 28 s in the AT group. This 38 s difference in 3km-running time between groups post intervention is important in terms of performance and points towards some form of interference. Interference effects have been attributed to a number of factors in adult studies [3,23]. For example a resistance training programme attempts to enhance protein synthesis and stress predominately anaerobic systems with corresponding increases in muscle lactate. In contrast with this, aerobic training creates hypoxia in the muscle requiring the muscle to increase its oxidative capability. It is possible that some form of interference occurred in the current study, however it is difficult to prescribe reasons to such interference as this phenomena has not previously been explored in paediatric populations. It is possible that residual fatigue may have reduced the quality of the resistance training and subsequent training effects, however, the increasing load lifted during the 10 weeks in the CT group (12–24%) would suggest that such fatigue effects did not influence progression and overload. The difference in 3km-running time occurred despite an attempt to reduce interference effects by using predominantly continuous aerobic training, which is centrally mediated by increases in cardiac output, haemoglobin and greater pulmonary perfusion rather than interfering with neural adaptations of muscle hypertrophy associated with resistance training. Likewise moderate intensity resistance training [11] was used because the training stimulus should place stress on the neural system rather than the metabolic system.

5. Practical applications

Our findings suggest that concurrent endurance and resistance training in youth athletes appears to compromise both aerobic and resistance training effects. This is based on the assumption that we would have expected to observe a reduction in 3 km-running time and increase in strength post intervention. However, we observed a decrement in ERP and only an increase in isoinertial strength of the legs (1RM leg press). Previous studies that have found improvements in ERP after strength and anaerobic training in children have suggested that these improvements are a direct result of the neuromuscular adaptations from resistance training [20,25]. However, our findings suggest that concurrent training compromises training effects in youth athletes and therefore such training should be viewed with a degree of caution. Utilisation of a larger sample size in future studies should facilitate statistical detection of any improvements or interference of combined training in ERP. More studies of this nature are required, not only for developing endurance programmes for children, but also in exploring the notion of interference which may influence the way we advocate resistance training in child athletes performing in aerobic based sports.

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