TITLE:

INDIVIDUAL RESPONSE TO DIFFERENT FORMS OF RESISTANCE TRAINING IN SCHOOL AGED BOYS

BRIEF RUNNING HEAD: INDIVIDUAL RESPONSE TO RESISTANCE TRAINING IN BOYS

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ABSTRACT

The aim of this study was to examine individual responses to different forms of resistance training on measures of jumping and sprinting performance in school-aged boys. Eighty boys were categorized into two maturity groups (pre- or post-PHV) and randomly assigned to a plyometric training, resistance training, combined training, or control group. Intervention groups participated in training twice weekly for six weeks, with measures of acceleration, maximal running velocity, squat jump height and reactive strength index collected pre and post intervention. In the pre-PHV cohort, plyometric training and combined training resulted in significantly more positive responders than the other two groups in both sprint variables (standardized residual values > 1.96). In the post-PHV cohort, significantly more positive responders for acceleration and squat jump height resulted from traditional strength training and combined training groups, compared with other groups. Conversely, plyometric training and combined training resulted in a significantly greater number of positive responders than the other two groups for maximal velocity and reactive strength index. Control participants rarely demonstrated meaningful changes in performance over the six-week period. Irrespective of maturation, it would appear that combined training provides the greatest opportunity for most individuals to make short-term improvements in jump and sprint performance. Taking maturation into account, our data show that a plyometric training stimulus is important for individuals in the pre-PHV stage of development, whether as a standalone method or in combination with traditional strength training, when attempting to improve jumping and sprinting ability. However, individuals in the post-PHV stage require a more specific training stimulus depending on the performance variable that is being targeted for improvement.

Key words: plyometrics, strength training, children, adolescents, youth

INTRODUCTION

The concept of children and adolescents participating in resistance training has received growing interest among researchers, clinicians and practitioners over recent years. It is well established that developmentally appropriate and properly supervised resistance training programs are safe and effective for children and adolescents (18). Researchers have identified that a range of different resistance training modalities can lead to positive responses in paediatric populations, including traditional strength training, plyometric training, weightlifting, and combined strength and plyometric training (18).

Research suggests that the effectiveness of training interventions to enhance sprinting and jumping performance in young boys may be influenced by maturation (21). Lloyd and colleagues (21) reported that boys who were pre-peak height velocity (PHV) benefitted more from plyometric training, while boys who were post-PHV responded more favourably to a combined plyometric and traditional strength training intervention. The authors proposed that these maturity-dependent responses were indicative of "synergistic adaptation", which refers to the symbiotic relationship between specific adaptations of an imposed training demand and concomitant growth and maturity-related adaptations (21).

While many studies have reported that youth respond positively to various resistance training modalities, such studies typically only consider the group response to an intervention. While this is important, the mean change within a training group may conceal a wide range of individual responses, inclusive of high responders, non-responders, and negative responders. Albeit based on adult data, previous research has emphasized individual responses in cardiorespiratory fitness following endurance training, or in combination with resistance training (7,8,13). However, there has been little research on the individual responsiveness to resistance training alone. One such study identified a large range in individual responsiveness in muscle cross sectional area and maximal strength following a 12 week resistance training program (11). These studies indicate that in adult populations, discrepancies exist between individuals who respond and those that fail to respond to certain training methods, but this has yet to be determined in children and adolescents. Considering that the timing and tempo of maturation differs between individuals (5), the large variations in responsiveness to training seen in adults may be more pronounced within a youth population. Therefore, the purpose of this study was to determine the individual responsiveness to different resistance training interventions (traditional strength training, plyometric training and combined strength and plyometric training) on measures of neuromuscular performance (squat jump height, reactive strength index, acceleration, and maximal running velocity) in boys who were pre- or post-PHV.

METHOD

Experimental Approach to the Problem

Participants were divided into one of three training groups (traditional strength training, plyometric training, or combined strength and plyometric training) or a control group (n = 10 x pre-PHV and n = 10 x post-PHV per group). The experimental groups participated in their respective training programs twice weekly for 6 weeks, whereas the control group continued with their regular physical education lessons. All participants were tested before and after the 6-week intervention for the following independent variables: squat jump height, reactive strength index, acceleration, and maximal running velocity. Smallest worthwhile change was calculated and expressed as a percentage of the group mean. A frequency count was then used to determine the number of individuals that made changes larger than the smallest worthwhile change, and chi-squared (χ^2) analysis was used to investigate between-group differences for the number of positive responders for each performance variable.

Subjects

Eighty male school children aged between 12 and 16 years (n = 40 pre-PHV and n = 40 post-PHV) volunteered to participate in the study. Participant characteristics per maturation group and training intervention are presented in *table 1*. All participants had previously been engaged in physical education–based activities; however, they were not involved in any formalized strength and conditioning programs. Parental informed consent and participant assent were obtained in advance of the study. The University Research Ethics Committee, in accordance with the Declaration of Helsinki, granted ethical approval for the research.

Table 1 near here

Procedures

Prior to testing, all participants completed a standardized dynamic warm-up followed by a familiarization session. During this session, participants were allowed to complete as many practice trials of the test protocols as required until they could demonstrate consistent technical execution. Following the warm-up and practice attempts, participants completed the battery of tests in the following order: anthropometrics, squat jump test, 5-maximal rebound test, 10 m and flying 20 m sprint tests. For each test, participants completed three trials, with the best of three trials being used for further analyses. Two- and five-minute rest periods were given between each trial and test respectively to limit the effects of fatigue on consecutive efforts.

Anthropometrics. Standing height (centimeters) and seated height (centimeters) were measured using a stadiometer (SC126; Holtan, Wales), while body mass (kilograms) was measured using a balance beam scale (Seca 700; Seca, Germany). These data were then incorporated into a sex-specific regression equation to predict maturity offset (28). The equation has previously been validated for boys with standard error of estimates reported as 0.57 years [equation 1]

(28). This assessment is a non- invasive and practical method of predicting years from PHV as a measure of maturity offset. Pre-PHV participants were categorized as being between -3 years to -1 years from PHV, while post-PHV were between +1 to +3 years from PHV (33).

Maturity offset = -[9.236 + 0.0002708* leg length and sitting height interaction]-[0.001663*age and leg length interaction]+[0.007216* age and sitting height interaction]+[0.2292*weight by height ratio]

[equation 1]

Jump Protocols. Using a mobile contact mat (Smart Jump; Fusion Sport, Australia), jump height (cm) was calculated from a squat jump, while reactive strength index (mm/ms) was measured during a 5-maximal rebound test. Both protocols have been shown to be a valid and reliable means of assessing neuromuscular performance in male youth (19). The squat jump was performed starting from an initial semi-squat position (90^0 knee flexion as determined subjectively by the principal researcher) before jumping vertically for maximum height (19). Hands remained on the hips for the entire movement and participants were instructed to maintain fully extended lower limbs throughout the flight period. Reactive strength index was determined during a 5-maximal rebound test, with participants required to perform five consecutive maximal vertical rebounds on the mobile contact mat. Participants were instructed to maximize jump height and minimize ground contact time (6). The first jump in each trial served as a countermovement jump and consequently was discounted for analysis, whereas the remaining 4 rebounds were averaged for analysis of reactive strength index (19).

Sprinting Protocols. Sprint times were recorded using wireless timing gates (Smart Speed;

Fusion Sport, Australia) in an indoor sports hall. Data were instantaneously collected via a handheld PDA (iPAQ; Hewlett Packard, USA). Acceleration was measured over 0–10 m with a stationary start from a line 30 cm behind the first timing gate. Using a flying start, maximal running velocity was measured between 10 and 30 m, giving a value for speed over a 20 m distance.

Training Programs

Training took place twice per week for 6 weeks, with sessions designed and implemented by a fully accredited strength and conditioning coach. To be included in the final analyses, participants were required to complete at least 80% of the total training sessions within their respective program. Correct technical execution was stressed at all times and relevant feedback provided on an individual basis when required. Throughout the intervention period, the control group continued with their physical education curricula, consisting of games-based physical education lessons commensurate with the requirements of the United Kingdom national curriculum. A more detailed overview of each training program is included in *tables 2-4.*

Traditional Strength Training Group. Participants completed three sets of 10 repetitions of a barbell back squat, barbell lunge, dumbbell step up, and leg press. To enable the prescription of individualized training intensities, 10 repetition maximum (10RM) loads were calculated for participants in the traditional strength-training group before the start of the training period using a protocol previously identified in the literature (12). In the event of technical failure, the set was stopped to avoid potential risk of injury to the participant. To progressively overload the training stimulus, intensity was increased each week via a 5% increment in external load for all participants on the proviso that technical competency was maintained.

Plyometric Training Group. Training prescription included a combination of exercises that were geared toward developing both safe jumping and landing mechanics (e.g., drop landings, vertical jumps in place, single-leg forward hop and stick) and also to stress stretch-shortening cycle activity (e.g., pogo hopping, drop jumps, multiple horizontal rebounds). Within each session, participants were exposed to multiple sets of four exercises to provide repetition for motor control development. The plyometric training program was progressed conservatively and never at the expense of technical competency. Foot contacts were monitored throughout the training intervention and increased at a conservative rate (week 1 foot contacts = 74 per session, week 6 foot contacts = 88 per session).

Combined Training Group. The combined training program involved exposure to two traditional strength-training exercises (barbell back squat and barbell lunge) and two varied plyometric exercises taken from the plyometric training program, per session. As per the traditional strength-training group, individualized training intensities were prescribed based on baseline 10RM loads. Similarly, a 5% increment in external load was selected to progressively overload the traditional strength training exercises, while plyometric exercises were progressed according to total foot contacts per exercise, per session.

Tables 2-4 near here

Statistical Analysis

The group change in performance was examined for each maturity group using a 4 x 4 mixed-model ANOVA (intervention group x test variable). Where Maulchy's test revealed a violation of the assumption of sphericity, the Greenhouse-Geisser adjustment was used. All post-hoc testing employed a Bonferroni adjustment. Homogeneity of variance between groups was examined using Levene's test of equality of variance. Percentage change from baseline testing was calculated for all individuals in each of the performance variables. To facilitate examination of individual responsiveness to training, the smallest worthwhile change (SWC) was calculated as 0.2 of the between-subject standard deviation for the total sample of pre-PHV (n=40) and post-PHV (n = 40), using pre-intervention data (10). The SWC was expressed as a percentage of the group mean and a frequency count was then used to determine the number of individuals that made changes greater than the SWC, with this being used to identify individuals that made a "positive response" in performance. Chi-squared (χ^2) analysis was used to investigate between-group differences for the number of positive responders for each performance variable. In the Chi-Squared test, analysis of the standardized residuals was completed to identify frequencies that would be considered larger in magnitude than might be expected by chance (35). Standardized residual values were interpreted using the > 1.96 criteria, whereby cell residuals that are greater than what might be expected by chance (22). Additionally, if a difference of > 1.96 between groups from the chi-squared analysis was revealed, it was treated as significantly different. Statistical significance for all tests was set at alpha level $p < 0.05$.

RESULTS

The mean group response to each intervention is shown in *table 5*. Interaction effects for intervention x variable were observed for both pre ($F = 6.01$, $p < 0.001$) and post-PHV ($F = 15.34$, $p < 0.001$) groups. Significant between group differences in percentage change for all performance variables are displayed in *table 5*.

Table 5 near here

The individual percentage change for each participant in acceleration, maximal running velocity, squat jump height and reactive strength index is shown in *table 5* and *figures 1-4*.

For the pre-PHV cohort, chi-squared analysis revealed significant differences between training groups for the number of positive responders across all sprinting and jumping variables. For both sprint variables, there were significantly more positive responders from the plyometric and combined training groups than the traditional strength training and control group. While all training groups resulted in significantly more positive responders for squat jump height than the control group, the only training method that resulted in significantly more positive responders than the control group for reactive strength index was plyometric training. Only in 3 instances did one of the four performance variables show a positive response from a member within the control group.

In the post-PHV cohort, chi-squared analysis revealed significant differences between training groups for the number of positive responders across all sprinting and jumping variables. For acceleration and squat jump height, there were significantly more positive responders from traditional strength training and combined training than the other two groups. Conversely, plyometric training and combined training resulted in significantly more positive responders than the other two groups for maximal velocity and reactive strength index. Akin to the pre-PHV group, only in 3 instances did one of the four performance variables show a positive response from a member within the control group.

Figures 1-4 near here

In the pre-PHV cohort, 30% and 50% of individuals made improvements greater than the SWC across all performance variables in the plyometric training and combined training groups respectively, whereas no individuals from the traditional strength training group showed a comparable response. In the post-PHV cohort, 10% of the plyometric training group and 40% of the combined training made changes greater than the SWC for all performance variables, but as per the pre-PHV cohort, no individuals from the traditional strength training group made changes above the SWC across all variables.

DISCUSSION

The major finding of the current study was that individual responses to resistance training in a group of school-age boy appear to be dependent on the mode of resistance training and maturity status. Irrespective of maturation, combined training resulted in a significantly greater number of positive responders than the control group in most performance variables. Within the pre-PHV group, plyometric training and combined training resulted in significantly more positive responders than traditional strength training in both sprinting variables. Analysis of the post-PHV group demonstrated that the number of individuals achieving positive responses from each training group was dependent on the performance variable measured. Combined training and traditional strength training resulted in a greater number of positive responders for tasks that placed a high demand on concentric strength (acceleration and squat jump), whereas combined and plyometric training groups resulted in significantly more positive responders in tasks that required higher levels of reactive strength (maximal running velocity and reactive strength index).

Examination of the pre-PHV group mean data showed that the combined training and plyometric training interventions resulted in significantly greater percentage improvements in acceleration and maximal running velocity compared to the control group, while combined training also elicited a significantly greater percentage change than traditional strength training alone. While percentage improvements in squat jump height were significantly greater following all training interventions when compared to the control group, plyometric training also resulted in significant percentage improvements in reactive strength index. Similar maturity-related outcomes have been reported in previous literature, with meta-analysis data showing that plyometric training leads to the greatest improvements in sprint speed for young boys (34). Furthermore, recent research highlights the effectiveness of plyometric training over other forms of resistance training when aiming to improve sprinting and jumping ability in boys that are pre-PHV (21).

The current study revealed that combined training and plyometric training resulted in significantly more pre-PHV individuals making positive responses in acceleration and maximal running velocity when compared against traditional strength training and control groups. In comparison to the control group, all forms of resistance training resulted in a significantly higher number of positive responders for squat jump height following the intervention. However, only plyometric training group showed a significantly higher number of positive responsders for reactive strength index in comparison to the control group. Interestingly, 50% of individuals from the combined training group and 30% of individuals from the plyometric training group achieved positive changes across all performance variables, whereas no individuals from the traditional strength training group demonstrated a similar response. Cumulatively, these findings highlight the importance of a plyometric training stimulus for boys that are pre-PHV, whether as a standalone method or in combination with traditional strength training. Intuitively, this may be due to the fact that children experience a natural increase in neural coordination and central nervous system maturation during childhood (23,29), which in combination with the fast contraction velocities demonstrated during plyometric training may provide an augmented training response, recently termed ‘synergistic adaptation’ (21).

The group response in the post-PHV cohort demonstrated the importance of combined training, as this was the only intervention group that achieved significantly greater percentage improvements than the control group for all performance variables. In terms of acceleration and squat jump height, traditional strength training elicited significantly greater percentage change than the plyometric training and the control group. Conversely, plyometric training resulted in significantly greater percentage improvements than the traditional strength training group for reactive strength index. Cumulatively, these results support previous findings demonstrating the importance of a varied resistance training stimulus for improving jumping (21) and sprinting (21,34) abilities in boys that have already experienced PHV.

In terms of the individual response in the post-PHV cohort, combined training and traditional strength training resulted in significantly more positive responders than the other groups for acceleration and squat jump height. Conversely, the number of individuals who improved maximal running velocity and reactive strength index was significantly greater following plyometric and combined training compared with traditional strength training. Thus, individual responsiveness appears to be training mode dependent, whereby adaptations are specific to the nature of the training stimulus (36). Traditional strength training typically involves relatively slower movement velocities involving both concentric and eccentric contractions (36), whereas the plyometric training program in the current study incorporated a number of exercises which stressed the stretch-shortening cycle, a rapid muscle action which uses eccentric-concentric coupling (14). Both acceleration and squat jump performance are reliant on concentric strength (17,37), which may explain the lack of positive responders from the post-PHV plyometric training group, as this mode of training may not have adequately increased concentric strength enough to improve acceleration and squat jump performance. Similar results have been noted in previous studies, where plyometric training did not improve squat jump height (26) or acceleration (4) in young boys. Specific adaptations to the imposed training demand was also evidenced by the combined and plyometric training resulting in a significantly greater number of positive responders in maximal running velocity and reactive strength index than the traditional strength training group. For these performance variables, there is a larger emphasis on the need for reactive strength and high rates of force development (9), both of which have been significantly improved in response to plyometric training in boys (20,24). These findings support previous studies where combined plyometric and strength training was found to result in the greatest improvements in sprint speed for boys that are post-PHV (34). While no individuals from the traditional strength training group and only 10% of individuals in the plyometric training group showed positive responses across all performance variables, 40% of the individuals in the combined training achieved this feat. Cumulatively, this demonstrates that the varied stimulus from the combined training group was able to increase a wider range of performance variables in post-PHV boys; whereas improvements from independent forms of plyometric training or traditional strength training appeared to be more task specific.

Research has shown that responses to resistance training are influenced by the intensity, frequency, and volume of training in both children and adults (2,16,30). Additionally, recent research has identified that growth and maturation (27) and the training method (21) can both influence the training response in children. However, individual responsiveness to training is complex, and the factors affecting the training response are less clear. Variation in individual responses to training could potentially be explained by the variation in timing, tempo and magnitude of maturation (5). While all subjects were grouped as pre- and post-PHV, the tempo of maturation will likely differ within these specific groups. As maturation has been shown to influence natural development (32) as well as trainability of jumping and sprinting ability (27), the rate at which these individuals are experiencing maturation may in part explain the variation in individual responsiveness to training. Additional factors influencing the individual response to training that have been determined in adult studies, include; genetics (3), baseline fitness (7), perception of training intensity (25), individual recovery rates (15), training status (31), and stress (1). While these influencing factors have been established in adults, there remains a dearth of empirical evidence within pediatric-based research.

PRACTICAL APPLICATIONS

Data from the current study show that a plyometric training stimulus is important for individuals in the pre-PHV stage of development, whether as a standalone method or in combination with traditional strength training, when attempting to improve jumping and sprinting ability. As with all forms of resistance training, plyometric exercises should never be progressed at the expense of technical competency, and that qualified strength and conditioning coaches need to be present to monitor technique and training volume. Individuals in the post-PHV stage may require a more specific training stimulus depending on the performance variable that is being targeted for improvement. Results from the current study show that a form of traditional strength training is required when aiming to improve tasks that place a high demand on concentric strength, whereas plyometric training is necessary for tasks that require higher levels of reactive strength. Given the short-term nature of the current study, it should be stressed that the resistance training stimulus should be changed periodically in order to facilitate continued progressive neuromuscular adaptation. Thus, while a focus on plyometrics may initially provide a preferential training response for pre-PHV boys, practitioners should routinely change the primary training mode to facilitate long-term adaptation. Additionally, the wide range of individual responsiveness demonstrated in this study highlights the need to monitor the response to training on an individual basis.

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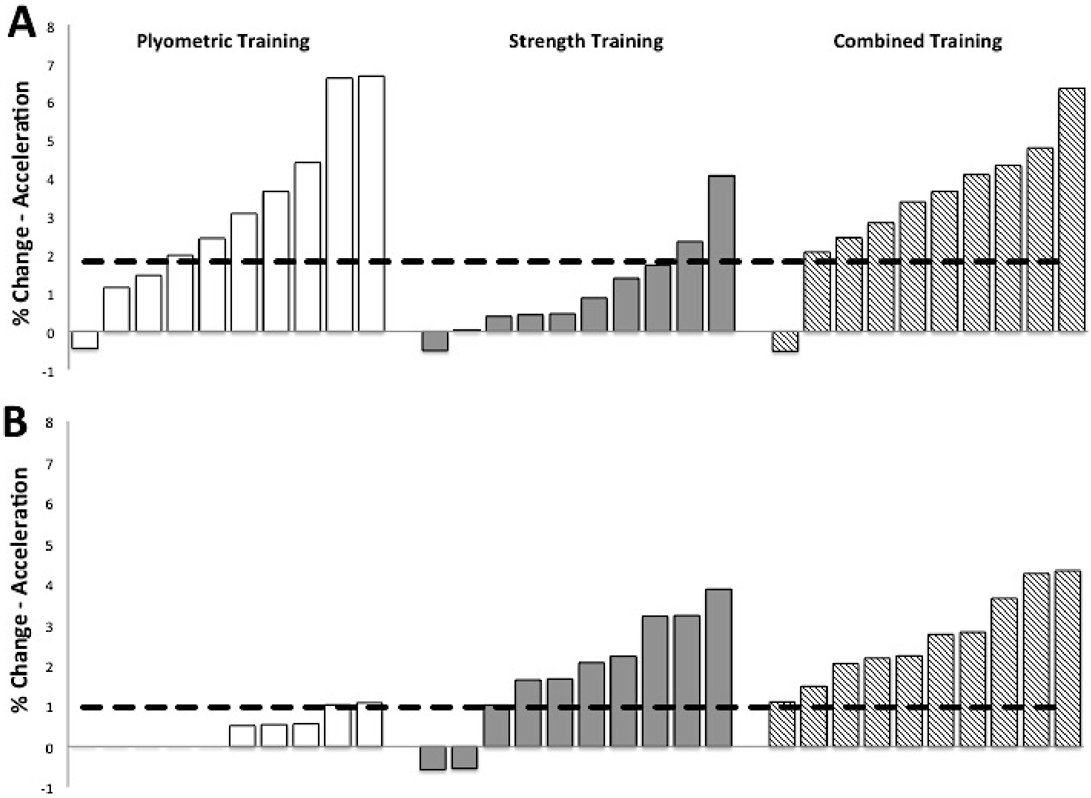

FIGURE 1 – Individual percentage change in acceleration in response to plyometric, strength training and combined training for pre-PHV (A) and post-PHV (B) subjects. Horizontal line represents the smallest worthwhile change (SWC) for all training groups combined.

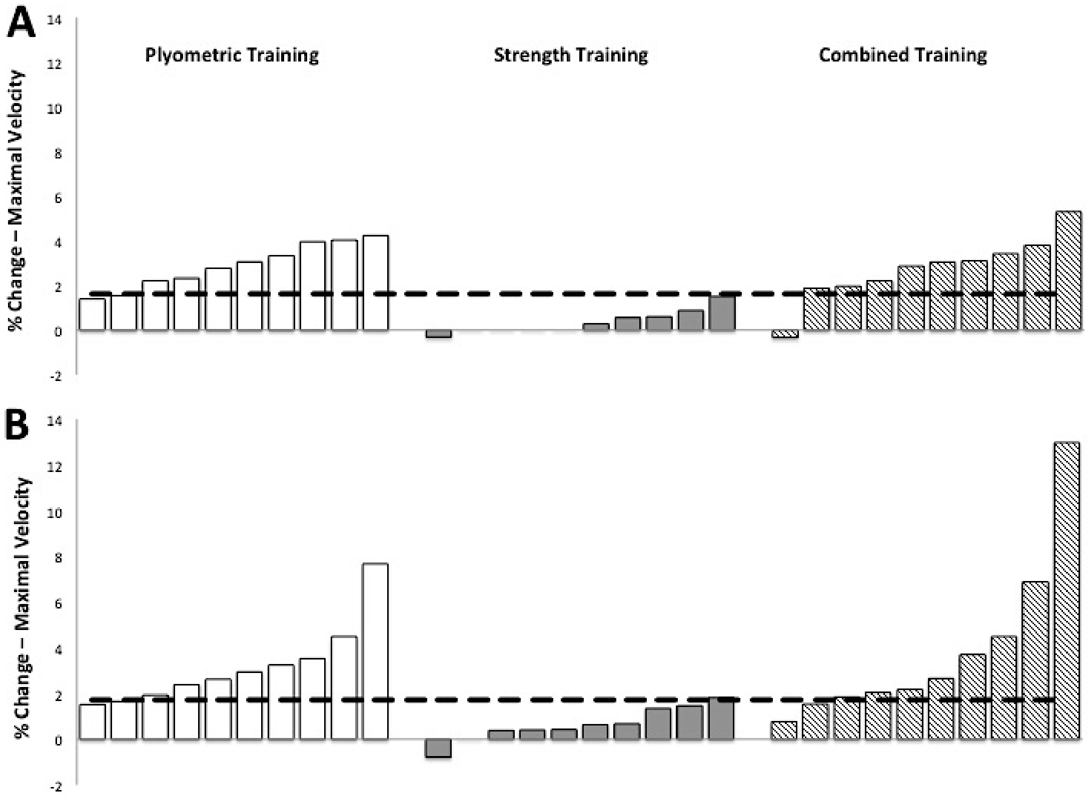

FIGURE 2 – Individual percentage change in maximal running velocity in response to plyometric, strength training and combined training for pre-PHV (A) and post-PHV (B) subjects. Horizontal line represents the smallest worthwhile change (SWC) for all training groups combined.

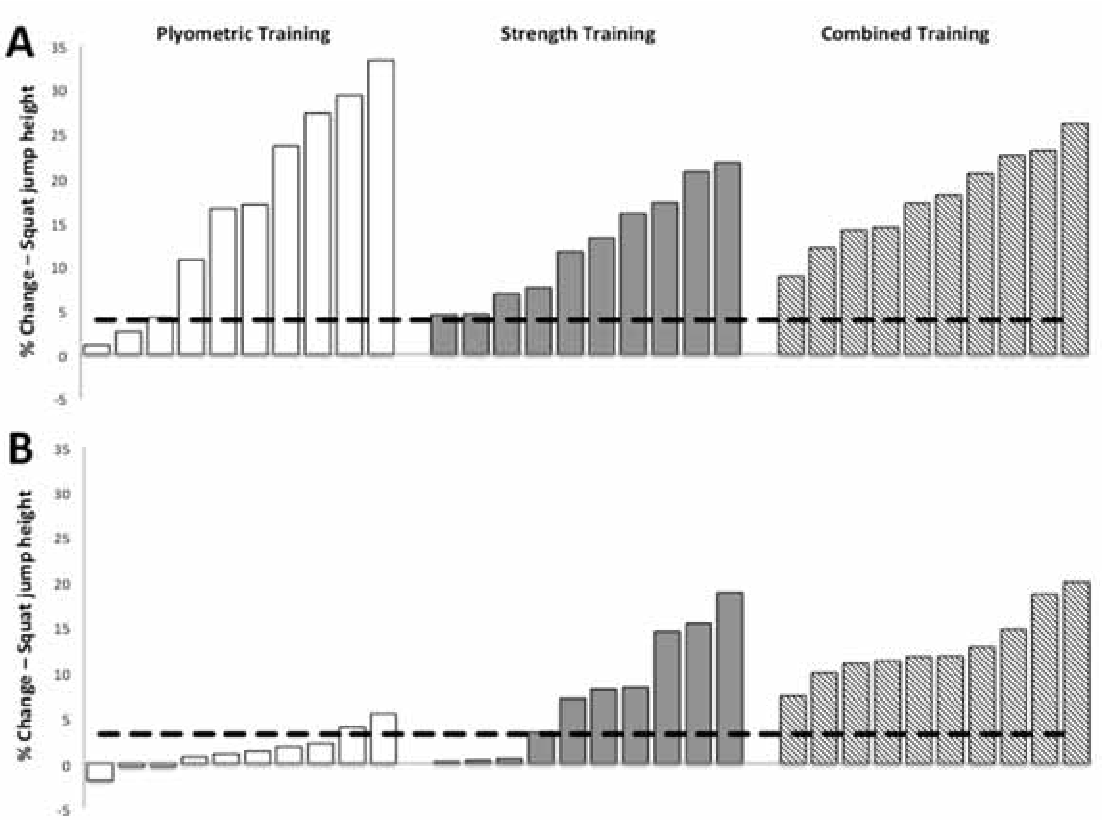

FIGURE 3 – Individual percentage change in squat jump height in response to plyometric, strength training and combined training for pre-PHV (A) and post-PHV (B) subjects. Horizontal line represents the smallest worthwhile change (SWC) for all training groups combined.

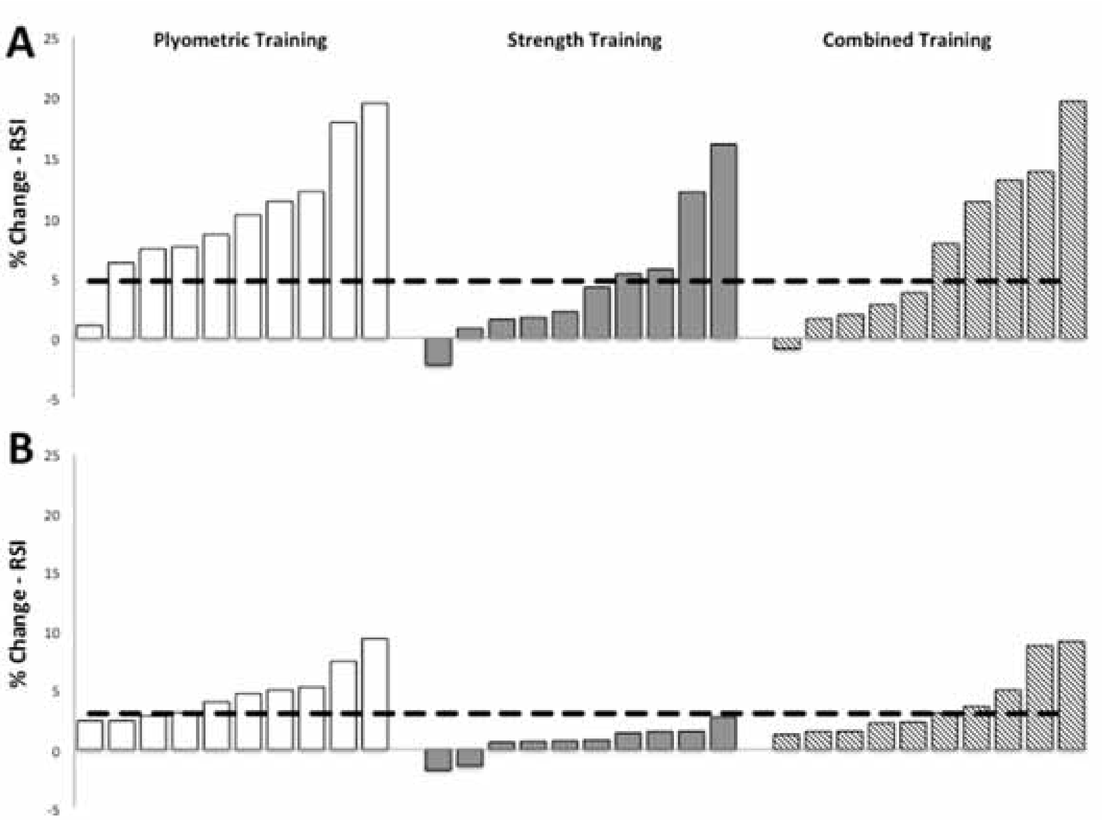

FIGURE 4 – Individual percentage change in reactive strength index (RSI) in response to plyometric, strength training and combined training for pre-PHV (A) and post-PHV (B) subjects. Horizontal line represents the smallest worthwhile change (SWC) for all training groups combined.

Table 1. Descriptive statistics for anthropometrics per group (Mean ± SD)*

Maturation Stage	Group	Number	Age	Height (cm)	Body Mass	PHV
Pre-PHV	PT	10	12.67 ± 0.27	159.64 ± 8.85	56.00 ± 11.02	-1.5 ± 0.4
	~~R~~TST	10	12.61 ± 0.25	156.87 ± 6.30	50.28 ± 14.38	-1.4 ± 0.6
	CT	10	12.73 ± 0.29	158.34 ± 7.60	53.47 ± 10.65	-1.5 ± 0.7
	Control	10	12.78 ± 0.21	156.95 ± 9.22	54.90 ± 10.61	-1.5 ± 0.6
Post-PHV	PT	10	16.36 ± 0.24	179.54 ± 5.67	67.78 ± 6.13	1.3 ± 0.3
	~~R~~TST	10	16.27 ± 0.31	177.49 ± 5.28	64.85 ± 5.29	1.3 ± 0.3
	CT	10	16.23 ± 0.27	178.32 ± 5.39	65.34 ± 7.18	1.3 ± 0.6
	Control	10	16.24 ± 0.32	179.04 ± 5.23	67.18 ± 8.43	1.2 ± 0.4

* PHV = peak height velocity; PT = plyometric training; TST = traditional strength Training; CT = combined training; CON = control group

Table 2. Overview of the plyometric training program

Week	Exercise	Sets	Reps
1	Drop Lands (20 cm box)	3	6
	Vertical Jump in place (stick landings)	3	6
	Broad Jump (stick landings)	3	6
	SL (Single Leg) Hop in place (stick landings)	2	10
2	Drop Lands (20 cm box)	3	6
	SL Forward hop (stick landings)	2	10
	Split Squat drop lands (20 cm box)	3	6
	SL Lateral hop and stick	2	10
3	Box Jumps	3	6
	Pogo Hopping	3	8
	Multiple bilateral bounds (low intensity)	4	3
	Ankling	3	8
4	Power Skipping	3	10
	Unilateral pogo hops	2	10
	Multiple bilateral bounds	5	3
	Multiple bilateral bounds (w/hurdles)	5	3
5	Unilateral pogo hops	2	10
	Alternate leg bounds	3	8
	Multiple Unilateral bounds	3	8
	Multiple bilateral bounds (w/hurdles)	5	3
6	Drop Jumps (20 cm box)	4	4
	Alternate leg bounds	3	8
	Power Skipping (w/hurdles)	3	8
	Multiple Unilateral bounds	3	8

Table 3. Overview of the resistance training program

Week	Exercise	Sets	Reps	Load
1-6	Back Squat Barbell Lunge DB (Dumbbell) Step Up Leg Press	3	10	Increased each week by 5%

Table 4. Overview of the combined training program

Week	Exercise	Sets	Reps
1	Back Squat	3	10
	Drop Lands (20 cm box)	3	6
	Barbell Lunge	3	10
	Broad Jump (Stick Landing)	3	6
2	Back Squat	3	10
	SL (Single Leg) Forward Hop and stick	2	10
	Barbell Lunge	3	10
	Split Squat Drop Lands (20 cm box)	3	6
3	Back Squat	3	10
	Pogo Hopping	3	8
	Barbell Lunge	3	10
	Multiple Bilateral bounds (low intensity)	4	4
4	Back Squat	3	10
	Multiple Bilateral bounds (w/hurdles)	5	3
	Barbell Lunge	3	10
	Power Skipping	3	10
5	Back Squat	3	10
	Alternate leg bounds	3	8
	Barbell Lunge	3	10
	Unilateral pogo hopping	2	10
6	Back Squat	3	10
	Drop Jumps (20 cm box)	4	4
	Barbell Lunge	3	10
	Power Skipping (w/hurdles)	3	8

Table 5. Percentage changes in running speed and jump performance for both maturity groups.

Pre-PHV	Acceleration		Maximal Velocity		SJ		RSI	
	Group % Change	n > SWC	Group % Change~~% Change~~	n > SWC	Group % Change~~% Change~~	n > SWC	Group % Change~~% Change~~	n > SWC
Plyometric Training (PT)	3.10 ± 2.30[a]	7[ac]~~[$+]~~	2.88 ± 1.02[ac]	8[ac]~~[$+]~~	16.56 ± 11.70[a123]	8[a]~~[+]~~	10.21 ± 5.43[a12]	9[a]~~[+]~~
Traditional Strength Training (TST)	1.12 ± 1.33	2	0.35 ± 0.54	0	12.42 ± 6.44[a123]	10[a]~~[+]~~	4.76 ± 5.53[2]	4
Combined Training (CT)	3.34 ± 1.83[ac]	9*[ac]~~[$+]~~	2.72 ± 1.47[ac]	9*[ac]~~[$+]~~	17.70 ± 5.42[a123]	10[a]~~[+]~~	7.50 ± 6.71[2]	5
Control Group (CON)	-0.06 ± 0.26	0	0.12 ± 0.74	0	0.86 ± 2.85	1	1.10 ± 2.77	2
Post-PHV	Acceleration		Maximal Velocity		SJ		RSI	
	Group % Change~~% Change~~	n > SWC	Group % Change~~% Change~~	n > SWC	Group % Change~~% Change~~	n > SWC	Group % Change~~% Change~~	n > SWC
Plyometric Training	0.37 ± 0.43	2	3.20 ± 1.81[a1]	8[ac]~~[$+]~~	1.41 ± 2.15	2	4.64 ± 2.25[ac1]	7*[ac]~~[$+]~~
Traditional Strength Training	1.78 ± 1.50[ab]	8[b]~~[△a+]~~	0.63 ± 0.76	1	7.68 ± 6.76[ab123]	7[ab]~~[△+]~~	0.67 ± 1.35	0
Combined Training	2.68 ± 1.10[ab]	10[ba]~~[△+]~~	3.91 ± 3.64[ac]	8[ac]~~[$+]~~	12.93 ± 3.89[abc123]	10*[ab]~~[△+]~~	3.84 ± 2.90[a,c]	5[ac]~~[$+]~~
Control Group	0.15 ± 0.76	1	-0.17 ± 0.72	0	-0.01 ± 1.42	0	0.19 ± 1.56	2

[a] significantly greater than CON (p <0.05)

[b] significantly greater than PT (p <0.05)

[c] significantly greater than TST (p <0.05)

*significantly greater than expected count

[1]significantly greater than acceleration (p <0.05)

[2]significantly greater than maximal running velocity (p <0.05)

[3]significantly greater than RSI (p <0.05)

~~[3]significantly greater than RSI (p <0.05)~~

~~*significantly greater than expected count (p <0.05)~~

~~△ significantly greater than PT (p <0.05)~~

~~$ significantly greater than TST (p <0.05)~~

~~+ significantly greater than CON (p <0.05)~~

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