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Maturation-related adaptations in running speed in response to sprint training in youth soccer players

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Abstract

Objectives: This study investigated the effects of a previously recommended dose of sprint training (ST) in young male soccer players of differing maturity status.

Design: Quasi-experimental design.

Methods: Male soccer players from two professional academies were divided into Pre-PHV (Training: n = 12; Control: n = 13) and Mid-PHV (Training: n = 7; Control = 10) groups. The training groups completed 16 sprints of 20 m with 90 seconds recovery, once per week.

Results: Between-group effect sizes (ES) were substantially larger in Pre-PHV (10m [1.54, CI: 0.74 to 2.23]; 20 m [1.49, CI: 0.75 to 2.23]; 5-10-5 [0.92, CI: 0.23 to 1.61]) than in Mid-PHV (10m [-0.00, CI: -0.81 to 0.81]; 20 m [-0.12, CI: -0.93 to 0.69]; 5-10-5 [-0.41, CI: -1.22 to 0.41]). Within-group effects demonstrated a similar, though less accentuated, trend which revealed ST to be effective in both Pre-PHV (10m [0.44, CI: -0.24 to 1.12]; 20 m [0.45, CI: -0.23 to 1.13]; 5-10-5 [0.69, CI: 0.00 to 1.38]) and Mid-PHV (10m [0.51, CI: -0.38 to 1.40]; 20 m [0.33, CI: -0.56 to 1.21]; 5-10-5 [0.43, CI: -0.46 to 1.32]).

Conclusions: ST, in the amount of 16 sprints over 20 m with a 90 s rest, may be more effective in Pre-PHV youths than in Mid-PHV youths.

Keywords: Trainability, speed, sprinting, youth, athletes, adolescent, children, sport

INTRODUCTION

The term 'speed' is defined as distance divided by time and in athletic terms refers to the movement of a body or part of a body over a given distance ¹. Depending on this distance, a differentiation can be made between 'acceleration speed' (5 to 20 m) and 'maximum speed' (30 to 60 m) ¹ with good performance over these distances being associated with greater sporting ability ². As sprinting is a common event in youth sport ³, its inclusion in a training programme is an important factor in the fitness of young athletes. This is reinforced by the potential existence of windows of trainability in youth. For example, it may be necessary to ingrain particular motor skills prior to the emergence of 'synaptic pruning' ⁴. This process, which cultivates higher-order cognitive processes, is affected by environmental stimuli which exert an influence over which synapses will, and will not, be required as a youth develops. Theoretically, this could result in impaired motor skill development if particular movements aren't ingrained prior to its onset in the first and second decades of life ^{5,6}.

The biological maturity of an individual is indicated by the degree to which they have progressed towards the adult state with a combination of sexual, somatic and skeletal factors denoting maturity status ⁷. Recent evidence suggests that youths of differing maturity status could respond to sprint training (ST) to different magnitudes with pubertal and post-pubertal individuals seeming more responsive than pre-pubertal to this type of exercise ⁸. This was demonstrated in a recent meta-analytical review which showed far larger effects in postpubertal ($d = 1.39$) and

pubertal ($d = 1.15$) athletes than in prepubertal ($d = -0.18$)⁸. This could be due to the variability of intertwined maturational factors relating to the development of muscle mass, the growth of limbs, changes to musculotendinous tissue, enhanced neural and motor development and greater neuromuscular coordination⁹. In support of this, Meyers et al.¹⁰ reported that maximal sprinting speed tends to develop at a quicker rate after the initiation of the growth spurt, highlighting increases in stride length, and stabilisation of stride frequency and ground contact times, as influencers of sprint speed in youth. The same research group showed that over a 21 month period, youths who entered their growth spurt demonstrated larger increases in sprint speed (10.4 vs. 5.6%) and relative vertical stiffness (12.1 vs. 5.6%) than a group which was yet to reach the growth spurt¹¹. Increases in growth hormone and testosterone could serve to reinforce these processes¹². Such factors could potentially be indicative of the presence of a maturational threshold which moderates adaptations to ST around peak height velocity (PHV)¹³. However, these factors are related to growth and maturation rather than training and the lack of ST studies carried out in prepubertal youths means that conclusions on trainability at this stage of maturation remain speculative.

Current literature is undermined by a number of limitations. The authors of a recent meta-analysis⁸ on ST in youth athletes were unable to find any qualifying studies which measured the biological maturity status of youths with one of the most commonly used methods in sport: the maturity offset¹⁴. The results of that study suggested that ST in prepubertal youth athletes was ineffective, and though this was in line with other studies in youth training^{15,16}, a lack of data prevented definitive conclusions being made⁸. Moreover, researchers have thus far failed to include comparison groups of disparate maturity status in ST intervention studies making it difficult to compare adaptations at different stages of development. Also, recommendations on the optimal load of ST in youth are scarce. It has been recommended that an effective training session load for increasing sprinting speed across the spectrum of maturation is 16 sprints of approximately 20 m distance, with a recovery

period of 90 seconds or greater (or work to rest ratio of 1:25)⁸. On that basis, the aim of this study was to assess the effects of such a dose of ST on sprint speed before (Pre-PHV) and during (Mid-PHV) the growth spurt in youth soccer players. To date, no intervention has described adaptations to an evidence-based dose of ST in youths of differing maturity status.

METHODS

The study was approved by the university's ethics committee and participants and their parents granted consent to partake. The study was undertaken in accordance with the Declaration of Helsinki. The experimental cohort comprised of youth soccer players from an English professional category three academy (n = 19). To prevent cross-group contamination, the control group were members of a nearby category three academy (n = 23). English soccer academies are divided into four categories by independent audit with category 1 being the highest and category 4 the lowest. Participants were further divided into Pre-PHV (Experimental: n = 12; Control = 13) and Mid-PHV (Experimental: n = 7; Control = 10) groups for analysis, as recommended by Mirwald et al.¹⁴ (Pre-PHV = ≥ -4.0 and < -1 years from PHV; Mid-PHV = ≥ -1.0 and $< +0.99$ years from PHV). There was 1.4 years between the maturity offset of the most mature member of the Pre-PHV group and the least mature member of the Mid-PHV group, reducing the chances of participants being allocated to the wrong group based on error of measurement (approx. ± 6 months) associated with the utilised method¹⁴. The characteristics of the participants are in Table 1.

Testing was carried out by the soccer clubs' sports science staff and was in accordance with the English Premier League's Elite Player Performance Plan. To estimate participant maturity status, anthropometric measurements (height, sitting height, body mass) were entered into an equation to predict maturity offset¹⁴: $\text{Maturity Offset} = -9.236 + (0.0002708 \times \text{leg length and sitting height interaction}) + (-0.001663 \times \text{age}$

and leg length interaction) + (0.007216 x age and sitting height interaction) + (0.02292 x weight by height ratio). The equation can measure maturity offset within an error of ± 1 year, 95% of the time ¹⁴.

To measure linear sprint (10 m and 20 m) and multidirectional change of direction (COD [5-10-5 test]) speed, electronic timing gates were used (Brower Timing Systems, Draper, Utah, United States). This equipment has shown excellent test-retest reliability (ICC = 0.91 to 0.99) in the measurement of linear sprint speed in adult athletes ¹⁷. For the utilised performance measures, our reliability testing showed consistently high Cronbach's alpha values ranging from 0.93 to 0.97.

Subjects began each sprint in a front-facing, crouched, standing 'two-point position' behind the start line. They were instructed to sprint straight through each timing gate line (10 m, 20 m) maximally until they were past target markers placed 5m after the final line. There was 3 minutes of recovery between trials and the best of 3 was recorded for each distance and used in the analysis. For COD, the pro agility (5-10-5) test was used with the aforementioned start protocol. The test mirrored that of a previous investigation ¹⁸. A 10 m distance was measured and bisected to indicate the timing gate's start point. Timing started when the participant initiated movement to his left or right and he was required to run to the end of the 10 m line before changing course to run to the opposite end. Changing direction once more, the test concluded when the participant crossed the middle line for a second time, culminating in a total run distance of 20 m. There was 3 minutes of recovery between trials and the best of 3 was used in the analysis.

The ST intervention was based on the findings of a meta-analysis ⁸ which suggested that effective speed development programmes for youth athletes consisted of 16 sprints over a distance of 20 m with 90 seconds recovery time between each effort. We adopted this protocol, exposing experimental groups to 1 ST session per week. All experimental groups trained under the supervision of a qualified sport scientist. We

deliberately did not periodise the weekly training sessions with a view to establishing a base session dose for the improvement of sprint speed. We did this to provide maturation-specific recommendations to coaches which could then be periodised around athletic competition, with coaches increasing or decreasing the base dose of sixteen 20 m sprints per session when and where appropriate. All participants were engaged in a comprehensive programme of athletic development which included complementary strength and plyometric training. The control groups continued with their usual training schedule but did not carry out any specific ST during the course of the period of observation.

Magnitude-based inferences were used to calculate effect sizes which were interpreted using previously outlined ranges (<0.2 = trivial; 0.2-0.6 = small, 0.6-1.2 = moderate, 1.2-2.0 = large, 2.0-4.0 = very large, >4.0 = extremely large) ¹⁹. An effect size of 0.2 was considered to be the 'smallest worthwhile change' ²⁰. The estimates were considered unclear when the chance of a beneficial effect was high enough to justify use of the intervention, but the risk of impairment was unacceptable. An odds ratio of benefit to impairment of <66 was representative of such unclear effects ¹⁵. This odds ratio corresponds to an effect that is borderline possibly beneficial (25% chance of benefit) and borderline most unlikely detrimental (0.5% risk of harm). This was calculated using an available spreadsheet ²¹. Otherwise, the effect was considered as clear and was reported as the magnitude of the observed value, with the qualitative probability that the true value was at least of this magnitude ¹⁵. The scale for interpreting the probabilities was as follows: possible = 25–75%; likely = 75–95%; very likely = 95–99.5%; most likely > 99.5% ¹⁹. Uncertainty in the effect sizes was represented by 90% confidence limits. Effects were considered unclear if the confidence interval overlapped thresholds for substantial positive and negative values. Otherwise, the effect was clear and reported as the magnitude of the observed value with a qualitative probability ^{15,19}. The utilised confidence limits of 90% are important in intervention studies in which one is presented with an inexpensive intervention that is most unlikely to be harmful, but likely to be at least trivially beneficial ²¹.

RESULTS

Effect sizes and their descriptors and likelihood estimates of beneficial effects are shown in Tables 2 and 3.

Between-group effect sizes (ES) were substantially larger in Pre-PHV (10m [1.54, CI: 0.74 to 2.23]; 20 m [1.49, CI: 0.75 to 2.23]; 5-10-5 [0.92, CI: 0.23 to 1.61]) than in Mid-PHV (10m [-0.00, CI: -0.81 to 0.81]; 20 m [-0.12, CI: -0.93 to 0.69]; 5-10-5 [-0.41, CI: -1.22 to 0.41]). Within-group effects demonstrated a similar, though less accentuated, trend which revealed ST to be effective in both Pre-PHV (10m [0.44, CI: -0.24 to 1.12]; 20 m [0.45, CI: -0.23 to 1.13]; 5-10-5 [0.69, CI: 0.00 to 1.38]) and Mid-PHV (10m [0.51, CI: -0.38 to 1.40]; 20 m [0.33, CI: -0.56 to 1.21]; 5-10-5 [0.43, CI: -0.46 to 1.32]). Effect sizes were generally larger in Pre-PHV. Effect sizes were smaller in the control groups than they were in the experimental groups in all but one test, the exception being the Mid-PHV control group which demonstrated greater changes than the Mid-PHV training group.

DISCUSSION

This study compared the effects of a ST program in male soccer players of differing biological maturation status. We sought to address limitations of previous research by including a measure of biological maturity status and comparable maturity groups within the same ST intervention. This has not previously been achieved and would go some way to clarifying previous suggestions that youth of differing maturity status adapt to ST to different magnitudes⁸. Based on our analyses, the primary finding was that the applied dose of ST was more effective in the Pre-PHV group than in the Mid-PHV group.

Though mechanistic factors were not assessed, there exists some evidence to potentially explain this finding. The lower trainability in the Mid-PHV stage could be attributed to the phenomenon of adolescent awkwardness whereby a youths' motor coordination is temporarily disrupted due to rapid growth of the limbs and trunk ²². Associated increases in body dimensions can heighten the centre of mass making it more challenging to control the trunk during fast movements and this can be compounded by rapid increases in body mass ²³. If an increase in body mass is not concurrently offset by a rise in relative strength, an athlete may find himself relatively less capable of producing the requisite force to propel the body forward during sprinting movements ^{12,24}. If indeed this is the case, it could indicate that performing relatively high volumes of ST during the Mid-PHV period may not be optimal, given the higher susceptibility to injury during this period ²⁵ and the possibility that adaptations to applied stimuli may be temporarily reduced. This would seem to suggest that training risks could be greater than rewards and is exemplified by the disproportionate ratio of benefit to harm in Table 3. On the contrary, this finding does not suggest that Mid-PHV are not responsive to ST, only that adaptations could be lower than those observed in Pre-PHV for the reasons stated.

It was previously reported that maximal sprinting velocity may develop more rapidly during and after the interval of maximal growth in males with maturation-related increases in stride length, better stabilisation of stride frequency and ground contact times serving as mediators of this quality around PHV ¹⁰. Greater leg length has also been positively associated with sprinting velocity in youth ²⁶ and it seems that sprinting performance during and after PHV may be further enhanced by increases in muscular strength ¹⁰. With all of these concurrently occurring positive and negative factors being considered in what is a time of dynamic physical change for the young male, it may be prudent to decrease the volume of ST and increase the volume of resistance training to optimise development during Mid-PHV. This could be particularly appropriate given that biological maturation may result in increases in sprinting speed regardless of training stimuli ^{11,27}, whilst other training

methods may continue to drive adaptations. Indeed, recent research ²⁸ identified the Mid-PHV period as the time during which adaptations to resistance training are maximised in youth which potentially validates this as an important strategy to develop relative strength at a time when the trainability of sprint speed could be temporarily impeded. The above points do, however, remain somewhat speculative and more research, that assesses the effectiveness of ST relative to that of resistance training, is required to provide further clarity.

In light of the above points, it is important to differentiate between increases in sprint speed that can be attributed to growth and maturation and those which can be attributed to ST. The Mid-PHV period may well be the time at which sprint speed is maximally developed through biological processes but it may not necessarily be the time at which ST is most effective. This is evidenced by the faster sprint times in the Mid-PHV group, as compared to the Pre-PHV group, in all tests despite lower effect sizes.

In relation to the Pre-PHV group our study was much needed given the lack of data relating to ST in youths of this maturity status ⁸. Previous literature has suggested that there exists a prepubertal critical training period for speed development which is facilitated by the maturation of the central nervous system through increased myelination of nerve cell axons and enhanced inter- and intramuscular coordination ^{4,29,30}. This could mean that the Pre-PHV period is the optimal time at which to develop sprint speed, a stance strengthened by the suggestion that bouts of activity that exceed 15 seconds duration are difficult for prepubertal youths to sustain owing to low energy delivery due to an immature glycolytic capacity ³¹. Accordingly, it may be more beneficial for Pre-PHV youth to carry out training that is more suited to their physiological profiles thus lending credence to the concept of 'synergistic adaptation' ³².

It is also notable that 5-10-5 performance may not have been impacted by the applied ST stimulus in the Mid-PHV group. Indeed, in this test the Mid-PHV control group achieved a substantially larger effect than the group which performed ST. It is possible that these changes in 5-10-5

performance could have occurred due to soccer-specific training rather than the linear ST programme which may have had less of an impact on the multi-directional 5-10-5 test owing to the specificity of motor abilities³³. This could again be indicative of reduced trainability in the Mid-PHV cohort but could also be due to their soccer training schedule with typical game-based training exercises also being effective for the improvement of agility performance³⁴. Because the control groups continued with their usual soccer training activities, it is plausible that general sport training continued to exert a positive effect on multidirectional performance in the absence of a linear ST stimulus. Nevertheless, important 'moderate' changes were still seen in the 5-10-5 test in the Pre-PHV cohort indicating potentially larger trainability at that stage of maturation.

A strength of this study is that it is the first to compare adaptations to ST in youth athletes of differing maturity status. By extension, it also provides the first experimental evidence of an appropriate base dose of ST in youth athletes. The study also has some limitations. Due to resource constraints, the groups performed only 1 ST session per week, in addition to their other training activities. Moran *et al.*⁸ have previously recommended 2 per week, though they did not provide maturation specific-doses. A similar study could assess the effect of two or three ST sessions per week, whilst also assessing the effects of a periodised programme. The method by which biological maturity status was assessed, though reliable, can lack accuracy³⁵ and may be reinforced if used in conjunction with predictions of full adult height³⁶. Lastly, though the measures of sprint speed showed important differences between the Pre- and Mid-PHV groups, they do not necessarily describe the underlying mechanisms of adaptation, necessitating the need for more in-depth investigations.

CONCLUSION

Based on the results of this study, ST, in the amount of 16 sprints over 20 m with a 90 s rest, may be more effective in Pre-PHV youths than in Mid-PHV youths. On the basis of these findings, Pre-PHV youths can carry out 1 ST session per week which could be reduced during Mid-PHV when injury susceptibility could be higher and adaptations potentially lower. Youths in the Mid-PHV stage can still carry out ST but coaches must judge their ability to do so and should base programming decisions on the movement competency of the individual. If coaches decide to reduce ST in Mid-PHV, it may be beneficial to replace it with resistance training with a view to reducing injury risk and developing the requisite relative strength to overcome the rapid changes in body mass and dimensions which may temporarily impair performance during the growth spurt ^{12,24}. Regardless of the configuration of training, coaches should administer multidimensional programmes that address all physical capabilities in youth athletes.

PRACTICAL IMPLICATIONS

- Sixteen 20 m sprints, with a 90 s rest between each, seems an effective base dose of ST to improve running speed in youth soccer players.
- One session per week seems adequate to achieve positive adaptations, though coaches could split the dose over two sessions.
- Less mature athletes, who have not yet entered the growth spurt, may be more responsive to ST.
- If ST volume is reduced during Mid-PHV, other forms of exercise, such as resistance training, could be increased in volume to offset deconditioning and maintain athletic development.

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Table 1 Descriptive data for participants

Pre-PHV Group	Training (n = 12)	Control (n = 13)
Age (years)	10.4 ± 0.8	10.0 ± 1.0
Age range (years)	9.4 to 11.8	8.7 to 11.3
Maturity offset (years)	-3.4 ± 0.4	-3.2 ± 0.6
Height (cm)	139.0 ± 5.6	139.7 ± 6.7
Mass (kg)	31.3 ± 3.8	34.4 ± 4.4
Mid-PHV Group	Training (n = 7)	Control (n = 10)
Age (years)	13.6 ± 0.7	14.5 ± 1.0
Age range (years)	12.9 to 14.9	12.8 to 15.5
Maturity offset (years)	-0.3 ± 0.5	0.0 ± 0.6
Height (cm)	166.9 ± 5.5	163.5 ± 5.6
Mass (kg)	55.4 ± 9.2	53.2 ± 5.7

Variable	Group	Mean difference (s)*	Effect size	Confidence limits	Likelihood effect is beneficial	Likelihood effect is harmful	Effect descriptor	Odds ratio of benefit to harm
10 m sprint	Pre-PHV	0.18 ± 0.05*	1.54	0.74 to 2.23	92.5%	3.3%	Likely beneficial	368
	Pre-PHV (Control)							
	Mid-PHV	-0.00 ± 0.05	0.00	-0.81 to 0.81	0.0%	0.0%	Most likely trivial	1
	Mid-PHV (Control)							
20 m sprint	Pre-PHV	0.28 ± 0.08*	1.49	0.75 to 2.23	92.4%	3.3%	Likely beneficial	368
	Pre-PHV (Control)							
	Mid-PHV	-0.03 ± 0.09	-0.12	-0.93 to 0.69	0.0%	14.7%	Likely trivial	0
	Mid-PHV (Control)							
5-10-5 COD	Pre-PHV	0.3 ± 0.13*	0.92	0.23 to 1.61	90.3%	2.4%	Likely beneficial	380
	Pre-PHV (Control)							
	Mid-PHV	-0.10 ± 0.10	-0.41	-1.22 to 0.41	1.0%	80.6%	Possibly harmful	0
	Mid-PHV (Control)							

Table 3 Baseline and follow-up scores, between-group effect sizes, confidence limits, likelihood effects and odds ratios for performance data

*mean difference favours training group