The Effect of Maturation on Relationships Between Physical Testing Variables in Youth Soccer Players

by

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Stephen Cooper

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Table 1. Participant Data.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Height</th>
<th>Leg Length</th>
<th>Mass</th>
<th>Maturation</th>
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<tbody>
<tr>
<td>Pre-PHV</td>
<td>11.4±0.9*</td>
<td>151±6.2*</td>
<td>73.6±4.4*</td>
<td>40.6±5.7*</td>
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<tr>
<td>Mid-PHV</td>
<td>13.4±0.7*</td>
<td>166.9±6*</td>
<td>81±4.3*</td>
<td>54.8±5.9*</td>
<td>-0.1±0.6*</td>
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<tr>
<td>Post-PHV</td>
<td>15.3±0.7*</td>
<td>176±5*</td>
<td>85.3±4.4*</td>
<td>64.7±7.28</td>
<td>1.5±0.5*</td>
</tr>
</tbody>
</table>

*Significantly different from all other maturation groups (P<0.05).

Table 2. Correlations between performance variable in the pre-PHV group.

<table>
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<th></th>
<th>10m</th>
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<th>R505</th>
<th>LAH</th>
<th>RAH</th>
<th>BCMJ</th>
<th>LCMJ</th>
<th>RCMJ</th>
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<tr>
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<td></td>
<td></td>
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<tr>
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<td>.652**</td>
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<tr>
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<tr>
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<td>.632**</td>
<td>.462**</td>
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</tr>
</tbody>
</table>

Note. * = p<0.05; ** = p<0.01. L 505 = 505 test to the left; R 505 = 505 test to the right; LAH = Left Arrowhead test; RAH = Right Arrowhead test; BCMJ = Bilateral Countermovement Jump; LCMJ = Left leg Countermovement Jump; RCMJ = Right leg Countermovement Jump.
Table 3. Correlations between performance variable in the mid-PHV group.

<table>
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<th>R505</th>
<th>LAH</th>
<th>RAH</th>
<th>BCMJ</th>
<th>LCMJ</th>
<th>RCMJ</th>
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<tbody>
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</table>

Note. * = p<0.05; ** = p<0.01. L 505 = 505 test to the left; R 505 = 505 test to the right; LAH = Left Arrowhead test: RAH = Right Arrowhead test; BCMJ = Bilateral Countermovement Jump; LCMJ = Left leg Countermovement Jump; RCMJ = Right leg Countermovement Jump.

Table 4. Correlations between performance variable in the post-PHV group.

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<th>RAH</th>
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<th>RCMJ</th>
</tr>
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<td>.778**</td>
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</tbody>
</table>

Note. * = p<0.05; ** = p<0.01. L 505 = 505 test to the left; R 505 = 505 test to the right; LAH = Left Arrowhead test: RAH = Right Arrowhead test; BCMJ = Bilateral Countermovement Jump; LCMJ = Left leg Countermovement Jump; RCMJ = Right leg Countermovement Jump.
### Table 5. Cohen's q for difference between correlations.

<table>
<thead>
<tr>
<th>Variable 1</th>
<th>Variable 2</th>
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<th>Pre-Post</th>
<th>Mid-Post</th>
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<td>0.14</td>
<td>0.14</td>
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</tr>
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<td>RAH</td>
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<td>LCMJ</td>
<td>RCMJ</td>
<td>-0.86</td>
<td>-0.54</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Note. > 0.1 = small effect; > 0.3 = medium effect; > 0.5 = large effect. L 505 = 505 test to the left; R 505 = 505 test to the right; LAH = Left Arrowhead test; RAH = Right Arrowhead test; BCMJ = Bilateral Countermovement Jump; LCMJ = Left leg Countermovement Jump; RCMJ = Right leg Countermovement Jump.
Abstract

Purpose: This study investigated the relationships between physical testing variables in youth soccer players and assessed the extent to which these relationships were affected by the maturation process. Method: 61 male youth soccer players, of which 34 categorised as pre-PHV, 16 mid-PHV and 11 post-PHV were tested for 10m and 30m speed, change of direction (COD) with the 505 and arrowhead tests and jumping ability using countermovement jumps (CMJ) performed bilaterally and unilaterally. Results: 10m and 30m sprint correlated closely across all three maturation groups ($r = 0.86 - 0.887; p < 0.05$ $q = -0.11 - 0.11$). CMJ significantly correlated with all 30m speed across all groups ($r = -0.607 - -0.922; p < 0.05$) but most strongly in the mid-PHV group ($q = -0.74 - 0.9$). Bilateral CMJ showed closer correlation to 505 COD test in the pre-PHV ($r = -0.607 - -0.46; p < 0.05$) and mid-PHV ($r = -0.676 - -0.579; p < 0.05$) in comparison to the post-PHV group ($r = -0.335 - -0.148; p > 0.05$; $q = -0.51 - -0.35$). Conclusion: correlations between some performance variables were shown to differ across the maturational stages suggesting changes in the underpinning physiology caused by maturation.

Introduction

Sprinting and jumping have been shown to be important actions in soccer with a goal often immediately proceeded by one of these actions (10). Stolen et al. (29) states that 96% of sprints in a game are less than 30m with 49% being under 10m. Sprint performance can differentiate players of varying levels and is improving in elite level players (11), demonstrating its importance in the game.

Little and Williams (15) analysed the relationship between acceleration and maximal speed in adult soccer players finding a significant relationship but a coefficient of determination of only 39% demonstrating that the abilities are not generic. Stronger correlations have been found in elite youth soccer players, with shared variance of 51-62% (4, 14).

Straight line speed has been consistently found to correlate to change of direction (COD) ability across a range of tests (3). There a strong correlation between sprint speed and COD ability in soccer players (15). In fact, both 10m
and flying 20m sprint times correlated to a multiple COD test, with the maximal speed test showing closer correlation. Koklu et al. (14) found a similar result in post pubescent youth soccer players, with 10m and 30m sprint times both correlated to a multiple COD test, again with the longer sprint showing a closer correlation. To the authors knowledge no studies have correlated sprint abilities with single COD tests in soccer but correlation between sprint speed and single COD tests have been found in adult Australian Rules football players (35), rugby players (30) and American football players (8).

Correlations have been identified between jumping and sprinting abilities in adults (19, 33) although research determining this link in youth athletes is less prevalent. Venturelli et al. (32) found a 20m sprint strongly correlated with both countermovement jump (CMJ) and a squat jump in preadolescent male soccer players. Amonette et al. (1) studied the physical determinants of sprint speed over 9.1m and 36.6m and similarly displayed strong correlations with CMJ height at both distances, although they did not assess for maturation state and their sample of youth soccer players aged 10-19 likely included individuals at pre, mid and post-pubertal stages of maturation. In contrast, although Koklu et al. (14) found a strong correlation between CMJ and 30m sprint no significant correlation existed between CMJ and time at 10m, when assessing relationships between physical performance variables in a group of likely post peak height velocity (PHV) youth soccer players (age 16.0±0.8 years). The strongest correlation was between CMJ and a zigzag COD test involving three ninety degree turns.

COD performance is also known to correlate with CMJ height in adult populations (5), although it is unclear, with Young et al. (35) finding no correlation between CMJ height and the mean of a single COD performed to the left and right. This may be due, at least in part, to a vertical jump test measuring net impulse (13), where COD may instead be more heavily influenced by rate of force development, as faster COD time is correlated with decreased ground reaction time of the contralateral leg (18) and reactive strength (35). This testing measure is rarely used in youth populations though, likely due to CMJ providing reliable results where reactive strength measured by reactive strength index did not in youth athletes (16).
Horizontal and vertical unilateral CMJ tests have been shown to correlate with sprint speed (19) but the relationship with COD performance is less clear. Hoffman et al. (12) found a 3 cone drill COD test performed to the dominant and non-dominant side demonstrated a moderate correlation with unilateral power on jumping in the non-dominant but not the dominant leg. Although Meylan et al. (21) found dominant leg vertical CMJ height correlated strongly with 10m time, with regard to COD it correlated only with a COD test involving 180 degree turns to the left and right as opposed to two 180 degree turns where the dominant leg was contralateral to the turn direction. They also found a dominant leg horizontal CMJ to more closely correlate to sprint and COD performance than the unilateral vertical CMJ.

Castillo-Rodriguez et al. (5) assessed the relationship between various CMJs and COD at 90 and 180 degrees in male, right leg dominant, undergraduate physical education students. Bilateral CMJ height significantly correlated with the 180 degree turn and the 90 degree turn to the left and right. Regarding unilateral jumps right CMJ height correlated to all COD tests but most strongly with the 90 degree COD to the left. Left CMJ only correlated moderately with the left 90 degree COD. The authors suggest that unilateral CMJ is more effective in predicting COD performance, but the bilateral CMJ was significantly correlated with all COD tests where a unilateral jump was not. To the authors knowledge no research currently exists detailing the relationships between unilateral jump performance variables and COD performance in youth athletes.

Chaouachi et al. (6) states that currently no gold standard test exists to assess COD ability in soccer players. This is shown to not just be the case in soccer, with a multitude of tests being used in research (3). These tests are rarely discrete often including multiple COD to the left and right with varying angles. Hoffman et al. (12) used a test that required five COD of various degrees including turns to both the left and right. Meylan et al. (21) used a test with only two 180 degree COD but the dominant and non-dominant tests varied as the non-dominant test still required one turn to be completed on the dominant leg. To make an accurate assessment a more discrete test is required that limits the effects of confounding variables. The 505 test only requires a single 180 degree COD and can be completed with a turn to the left or the right (28). This gives a more discrete measure of COD performance and allows left to right comparison.
Maturation is known to have wide-ranging effects on human physiology and is broadly split into three bands, pre-pubertal, mid-pubertal and post-pubertal with those predicted to be ±1 from PHV considered to be mid-pubertal (22). Pre-pubertal youths have been shown to have a higher proportion of type 1 muscle fibres (2) and their training related performance enhancements in strength are driven by neurological means (9). It seems reasonable to suggest therefore that at different maturational stages differing underlying physiology may underpin speed, COD and jumping abilities, especially when considering that different training methods have been found to be most effective for improving speed at the different stages of maturation (26). Jumping, sprinting and COD performance are known to increase throughout the maturation process with the greatest improvement concurrent with PHV (25), although little is known about the relationship between these variables at the different maturation stages.

The purpose of this study is to assess the relationships between physical testing variables in youth soccer players with consideration given to how these relationships are affected by the maturation process.

Methods

Participants

61 elite male youth soccer players from one English category 2 soccer academy were included in the study. 34 were categorised as Pre-PHV (age 11.4 ± 0.92 years, height 151 ± 6.16 cm, mass 40.6 ± 5.69 kg, maturity offset -2.1 ± 0.58 year from PHV), 16 were categorised as Mid-PHV (age 13.3 ± 0.68 years, height 166 ± 6.02 cm, mass 54.8 ± 5.93 kg, maturity offset -0.12 ± 0.56 years from PHV) and 11 were categorised as Post-PHV (age 15.3 ± 0.71 years, height 176 ± 4.99 cm, mass 64.7 ± 7.21 kg, maturity offset 1.53 ± 0.49 years from PHV). All participants regularly completed 3 training sessions per week plus one match and were free of injury at the time of testing. Goalkeepers were included as subjects as research has shown they do not differ physiologically from other players in youth soccer (34). Written assent/consent was given by all participants and their parent/guardian. Ethical clearance was granted by the Ethics Committee of Cardiff Metropolitan University.

Procedures
Testing took place over the course of one day. Firstly, subjects were measured for height, sitting height and body mass. From this they were placed into 3 groups based on their maturation status: pre-PHV (-3 years to -1 years from PHV), mid-PHV (-1 to +1 years from PHV) and post-PHV (+1 to +3 years from PHV) using the maturity offset equation of Mirwald et al (24) (22, 27). This assessment is a non-invasive and practical way of assessing maturity status with a standard error of estimate of 0.49 for males.

Subjects then followed a standardised warm up to prepare them for the physical tests consisting of jogging, mobility exercises and practice trials at sub-maximal intensity.

Jump tests. To assess bilateral and unilateral leg power CMJs were used. These test took place on a firm and level gym floor, jump height was calculated from flight time and measured using an Optojump (Microgate, Bolzano, Italy). Bilateral countermovement jump was assessed followed by unilateral countermovement jumps. For each test subjects were instructed to keep their hands on their hips to eliminate the effect of arm swing.

Sprint tests. The linear speed and COD tests were carried out on an indoor 3G artificial grass surface and participants wore soccer boots. Linear speed was assessed using a 30m sprint with a 10m split time. Electronic timing games (Brower Timing Systems, Utah, USA) were placed at the start, 10m and 30m. Participants started 0.3m behind the first gate and once readiness was indicated from the assessor the participant began when they felt ready. Two sprints were completed.

Change of direction tests. Multiple COD ability was assessed using the arrowhead (AH) agility test. The test consists of three COD, and covers 37.1m. The same starting protocol was used as for the sprint tests. Subjects completed the test 4 times, twice turning to their left and twice to their right. Single COD ability was assessed using the 505 agility test. Subjects started 10m away from the timing gates, from there they sprinted through the gates and to a line 5m beyond them, at the line they turned 180° and returned through the timing gates. An assessor was placed on the line to ensure participants planted their foot on or beyond the line, if the foot was planted before the line the test was repeated after a rest period. Subjects completed the test 4 times, twice turning to their left and twice to their right.
Test scoring. For all tests two trials were carried for each condition with the best result recorded as their score for that test condition. No encouragement was given to subjects during the tests. No coaching was given beyond the explanation of the tests. Tests were completed in the same order for all participants with standardised instructions given.

Statistical analysis

All data was analysed using Minitab 17th Edition (Minitab Inc., Pennsylvania, USA) and Microsoft Excel 2016 (Microsoft, Washington, USA). Between group differences were analysed using Anova tests with Tuckey’s post hoc analysis to assess difference between the individual groups. Correlations between all the anthropometric and physical variables were assessed using Pearson’s Correlation Coefficient. To allow for comparison between groups, correlations were transformed using a Fisher z-transformation and compared for size of difference between values using Cohen’s $q$, where $>0.1$ is considered a small effect, $>0.3$ is considered a medium effect and $>0.5$ is considered a large effect (7). Data were visually assessed for outliers and the test assumptions of normality, linearity and homoscedasticity. Alpha was set at 0.05.

Results

Anthropometric measures are shown in table 1, all measures were significantly different between the maturation groups ($t = 2.46-18.77$, $p < 0.05$). Maturation groups also differed in all of the physical tests ($t = -7.33 - 7.42$, all $p < 0.05$) with the exception that no significant difference was identified between the pre-PHV and mid-PHV groups for the 505 test to the left ($t = -1.52$, $p > 0.05$). Correlations between variables for each maturation group can be seen in tables 2-4. Effect sizes for differences between correlations can be seen in table 5. The full set of results were too large to publish but can be requested by contacting the lead author.

Discussion
The main finding of this study is that relationships exist between sprint, COD and jump tests in youth soccer players but importantly, some of these relationships differ at varying stages of the maturation process.

10m and 30m speed correlated strongly but not perfectly across all maturation groups. This supports previous studies in youth soccer and their conclusion that, while this shows that the two capabilities are specific, similar physiological abilities underpin performance at the different distances (4, 14). The strong correlations at each maturation stage showed little variance from each other, suggesting that maturation has little effect on this relationship and the anthropometric and physiological changes associated with this process do not cause any differentiation of the two abilities.

Sprint and COD tests displayed significant correlations for all tests in the pre-PHV and mid-PHV groups. No effects for difference between these two groups were found for many of the correlations, demonstrating that the early stages of maturation do not cause these abilities to become more or less distinct. These correlations are weaker though in the post-PHV group with fewer finding significance and effect sizes for correlation difference showing medium or large effects in three and four of the correlations with the pre-PHV and mid-PHV groups respectively.

It appears therefore that in the later stage of maturation that although speed and COD performance do still show some shared underpinning physiology they start to become more distinct. It is possible that technical or force production qualities have more of an effect at this stage, although further research is required to validate this.

Across all maturation groups 30m speed revealed stronger correlation with AH performance than 10m speed. This may demonstrate that in this test, where greater distances are covered and turns are not as acute as in the 505 test, speed is able to be maintained closer to top speed and acceleration is not required to the same extent. This again confirms and develops the work of Koklu et al. (14) who found a stronger relationship with a zigzag COD test, requiring multiple 100 degree COD, to correlate more closely with a 30m sprint than a 10m sprint. The present study progresses this by demonstrating that this relationship is not affected by maturation. Suggesting therefore that although more short sprints are recorded in a game (29) that a 30m sprint may be more predictive of in-game speed performance, due to the multiple COD required (29) and the constant nature of the game, where sprinting from a stationary start is unlikely.
It has been stated that a gold standard test does not currently exist to assess COD abilities in soccer players (6). Two COD tests were used in this study. The 505 test requires only a single COD over a relatively short distance and targets COD performance in a discrete manner where the AH test includes multiple COD at a range of angles. The more generic nature of the AH test is seen in the significant correlations between left and right at all age groups. This generic nature is not seen in the 505 test, where in the post-PHV group the turns to each side did not correlate with each other and a small effect size for difference was seen with the other two groups. This suggests that in more maturated youth soccer players turning abilities become more specific and a discrete test such as the 505 may be suitable for assessing differences in left and right COD ability. This is also seen in the correlations between the two tests. In the pre-PHV and mid-PHV groups strong correlations were found between most of the COD tests regardless of turning direction. This shows that COD performance is more of a generic quality in players of a lower maturity and is unaffected by the test used. In the post-PHV group fewer significant correlations were found and effect sizes show correlations are mostly weaker when compared to the pre-PHV group. This again suggests COD becomes less of a generic quality and shows greater specificity later in the maturation process. The differences seen may be due to the influence of leg dominance, which has been shown to have an effect on COD performance in adult athletes (5, 21).

Correlations were seen between jump and sprint variables in all maturation groups. All groups showed significant correlation between CMJ and 30m sprint time, with the strongest correlation found in the mid-PHV showing a large difference from both the pre-PHV and post-PHV groups. Similar differences were also seen for the effect of CMJ on 10m performance. The strongest correlation was found in the mid-PHV group demonstrating a large difference from the non-significant post-PHV correlation and a medium difference from the significant correlation of the pre-PHV group. This again supports the work of Koklu et al. (14) who also found CMJ to correlate with 30m sprint time but not with time over 10m in a group of likely post-PHV youth soccer players. This additionally supports the work of Amonette et al. (1) who found vertical jump height to correlate with 9.1m and 36.6m sprint time in youth soccer players.
From these correlations it is possible to suggest physiological factors underpin both jump and sprint abilities in the earlier stages of maturation and especially around the time of PHV. Therefore, methods that improve one of these factors is likely to cause changes in the other. This suggestion is further supported by research into plyometric training, which utilises jumping exercises, being found to be an effective method for improving sprint speed in pre-PHV and mid-PHV subjects (17, 20, 23, 26) but not in older youth players (31).

The role of horizontal force production in the sprint performance of youth soccer players has recently been evaluated by Buchheit et al (4). They concluded that horizontal force production correlated most closely with acceleration while maximal horizontal power correlated more closely with maximal speed in a radar gun measured sprint test. The results of this study show some agreement with their results, demonstrating that power production in a vertical direction also correlates more closely with the 30m sprint across all stages of maturation. Further research would be required to assess the influence of vertical and horizontal force and power production on the various speed abilities of youth soccer players across maturation, this could provide further evidence as to how best to improve these abilities.

Bilateral CMJ seems a more relevant measure than unilateral jumps to predict sprint ability over a 30m distance in elite youth soccer players. This was revealed in the greater correlations between bilateral jump performances in all maturation groups at this distance, although this same difference is not as apparent for the 10m sprint, where no consistent differences were found.

The correlations between CMJ and COD performance seems to be maturation dependent with CMJ height correlated with left and right 505 tests in the pre-PHV and mid-PHV groups but not in the post-PHV group. This is supported by effect sizes showing differences between the post-PHV group and the pre-PVH (small effects) and mid-PHV (medium and large effects). These differences were again clear in the multiple COD AH test. Significant correlations were observed between CMJ and AH to the left and right in the pre-PHV and mid-PHV groups only and effect sizes for difference with the post-PHV group were medium and large respectively. This demonstrates that in the later stages of maturation vertical jump ability is not closely correlated with COD performance and other factors may have more of an effect. These results are in contrast to the findings of Koklu et al. (14) who
found a significant correlation between CMJ and a multiple COD test in a group of likely post-PHV elite youth soccer players. Biomechanical factors such as pelvic lateral tilt and thorax lateral rotation have been shown to be determinants of COD ability in adults (18), it may be that in post-PHV players that technical ability starts to have a greater role in performance. Although no correlations between CMJ height and COD performance were found for post-PHV players in this study it seems that a shared underpinning physiology may still exist as CMJ training has been shown to improve performance in the 505 test in likely post-PHV (age 17.3±0.4 year) elite youth soccer players (31).

As seen with previous research the ability of single leg jumps to predict COD performance shows an unclear picture. This study utilised a discrete single COD test and a more general test to allow closer analysis into the relationship than previous studies, which have used tests that include multiple COD often to the left and right (12, 21). Castillo-Rodriguez (5) found a greater correlation for a 90 degree left turn with right leg CMJ than a bilateral CMJ although the bilateral CMJ still correlated significantly. In the turn to the right, again, both the right leg and bilateral CMJ correlated with the result where the left CMJ did not.

No clear pattern was identified in this study linking a jump score on one leg to a turn to the other side, likely requiring more work from the contralateral leg. The 505 test to the left did not correlate with right CMJ in any of the maturation groups. The 505 to the right only significantly correlated to the left CMJ in the mid-PHV group but did not show a stronger correlation than with the right CMJ. The results of this study do not confirm the conclusions of Castillo-Rodriguez et al (5) for adult subjects and show that in elite youth soccer bilateral CMJ is a more relevant test for assessing potential in COD performance regardless of type of COD test in pre-PHV and mid-PHV youth soccer players. Further study in this area may warrant use of other types of jumps that have shown closer correlation with COD performance in adults such as a unilateral horizontal CMJ (21) or bilateral drop jumps (35).

Training studies in youth soccer players have consistently shown that programmes utilising plyometric and jump based training protocols improve speed and change of direction performance (17, 20, 23, 26, 31). This supports
the conclusion that shared physiology underpins these two physical abilities and indicates that training programmes of this nature are a valid way to improve on field performance in youth soccer players.

Most of the correlations between physical capacities were found to be strongest in the mid-PHV group. It is known that jump, sprint and COD abilities see their greatest natural development around PHV (25) and therefore it is plausible to suggest that the physiological changes, such as an increase in testosterone levels and changing of muscle fibre type distribution (2) that occur throughout adolescence drive the changes in all of these abilities causing the strong correlations. This could also be considered a limitation of studies that assess correlations in youth athletes especially around the time of PHV. In this study although athletes were banded by maturation stage players within a group could still demonstrate a biological age difference of up to two years with the more mature players likely to show increases in all physical abilities leading to stronger correlations.

The results show a significant difference between the maturational groups for all anthropometric and physiological measures. This clearly demonstrates that when carrying out assessments on the physical abilities of children and adolescents that assessment of maturation is crucial. Analysis involving subjects of various maturation states may give unreliable results due to the apparent differences in anthropometry and physiology leading to variations in correlation strengths. This limits any conclusions drawn by papers where correlations between physical abilities are identified but no measure of maturation is used (1, 4, 14).

**Conclusion**

Close but non-perfect correlations across maturation stages show acceleration and maximal speed are closely related but not generic and that the maturational process does not affect this relationship. Longer sprints correlate more closely with multiple COD performance across all maturational stages. COD performance shows greater specificity in more maturated players. CMJ correlates with speed performance across all groups and with the pre-PHV and mid-PHV groups for COD performance, this suggests a shared underpinning physiology and supports studies showing jump based protocols are effective for improving speed and COD performance in youth soccer players. Bilateral CMJ is a more relevant measure than unilateral for assessing speed and COD potential at all stages of maturation.
References


26. Rumpf MC, Cronin JB, Oliver J, Hughes M. Effect of different training methods on running sprint times in male youth. Pediatric exercise science. 2012 May 1;24(2):1


Appendices

Appendix 1.

When undertaking a research or enterprise project, Cardiff Met staff and students are obliged to complete this form in order that the ethics implications of that project may be considered.

If the project requires ethics approval from an external agency (e.g., NHS), you will not need to seek additional ethics approval from Cardiff Met. You should however complete Part One of this form and attach a copy of your ethics application and letter(s) of approval in order that your School has a record of the project.

The document Guidelines for obtaining ethics approval will help you complete this form. It is available from the Cardiff Met website. The School or Unit in which you are based may also have produced some guidance documents, please consult your supervisor or School Ethics Coordinator.

Once you have completed the form, sign the declaration and forward to the appropriate person(s) in your School or Unit.

PLEASE NOTE:
Participant recruitment or data collection MUST NOT commence until ethics approval has been obtained.

PART ONE

<table>
<thead>
<tr>
<th>Name of applicant:</th>
<th>Stephen Cooper</th>
</tr>
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<tbody>
<tr>
<td>Supervisor (if student project):</td>
<td>Dr Jeremy Moody</td>
</tr>
<tr>
<td>School / Unit:</td>
<td>Cardiff Metropolitan University</td>
</tr>
<tr>
<td>Student number (if applicable):</td>
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<tr>
<td>Programme enrolled on (if applicable):</td>
<td>MSc Strength and Conditioning</td>
</tr>
<tr>
<td>Project Title:</td>
<td>Assessment of Relationships Between Physical Testing Measures in Academy Football Players.</td>
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<tr>
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<tr>
<td>Approximate duration of data collection:</td>
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<tr>
<td>Funding Body (if applicable):</td>
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</tr>
<tr>
<td>Other researcher(s) working on the project:</td>
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</tr>
<tr>
<td>Will the study involve NHS patients or staff?</td>
<td>No</td>
</tr>
<tr>
<td>Will the study involve taking samples of human origin from participants?</td>
<td>No</td>
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Does your project fall entirely within one of the following categories:

| Paper based, involving only documents in the public domain | No |
Laboratory based, not involving human participants or human tissue samples | No  
---|---  
Practice based not involving human participants (eg curatorial, practice audit) | No  
---|---  
Compulsory projects in professional practice (eg Initial Teacher Education) | No  
---|---  
A project for which external approval is required (e.g., NHS) | No  
---|---  
If you have answered YES to any of these questions, make this clear in the non-technical summary. No further information regarding your project is required.  
If you have answered NO to all of these questions, you must complete Part 2 of this form  
---|---  
In no more than 150 words, give a non-technical summary of the project  
The study will use testing data already collected as part of the usual testing battery of an elite youth football academy with players aged between 8 and 16. The data will be analysed to assess for relationships between the various tests. Players will be grouped by age to see if differences in the relationships of testing variables exist at certain ages. The tests are measures of jumping, sprinting and change of direction ability. Evidence of relationships already exist in adults (Loturco et al., 2015) and older youths (Koklu et al., 2014) but not children. Consequently, the results of the study will develop a better understanding for strength and conditioning practitioners to more effectively train young athletes of various ages and allow for further research into training protocols to take place.  
---|---  
DECLARATION:  
I confirm that this project conforms with the Cardiff Met Research Governance Framework  
Signature of the applicant:  
Stephen Cooper  
Date: 19th May 2015.  
---|---  
FOR STUDENT PROJECTS ONLY  
Name of supervisor:  
Dr Jeremy Moody  
Date:  
19th May 2015  
---|---  
Signature of supervisor:
**Research Ethics Committee use only**

<table>
<thead>
<tr>
<th>Decision reached:</th>
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<td>Project not approved</td>
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Project reference number: 15/5/06P

Name: Dr. Brendan Cropley  
Date: 27/05/2015

Signature: [Signature]

Details of any conditions upon which approval is dependant:

A valid DBS form is to be presented to the CSSREC prior to the research taking place.

---

**PART TWO**

**A RESEARCH DESIGN**

<table>
<thead>
<tr>
<th>A1 Will you be using an approved protocol in your project?</th>
<th>No</th>
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</thead>
</table>

A2 If yes, please state the name and code of the approved protocol to be used¹

Click here to enter text.

A3 Describe the research design to be used in your project

All data has been previously collected as part of the organisation's usual player testing battery. The data includes: age, height, weight, bilateral countermovement jump, unilateral countermovement jump, ten metre sprint, thirty metre sprint, arrowhead agility test and 505 agility test. Permission will therefore be sought from the organisation to gain access to the data for the purposes of this research, as well as from the players (participants) and their guardians (the director of the organisation will be asked to act in *loco parentis* in the first instance).

---

¹ An Approved Protocol is one which has been approved by Cardiff Met to be used under supervision of designated members of staff; a list of approved protocols can be found on the Cardiff Met website here
The data will be statistically analysed to assess for relationships that may exist within it. Relationships will be looked at between tests as a whole and the players will also be grouped by age to assess if different relationships exist at different ages. Suitable correlation and regression statistical tests will be used to assess the data. The findings will be presented anonymously to the coaching staff only.

A4 Will the project involve deceptive or covert research? No

A5 If yes, give a rationale for the use of deceptive or covert research

Click here to enter text.

A6 Will the project have security sensitive implications? No

A7 If yes, please explain what they are and the measures that are proposed to address them N/a

B PREVIOUS EXPERIENCE

B1 What previous experience of research involving human participants relevant to this project do you have?

Undergraduate dissertation assessing the effect of a hip strengthening programme on limb alignment during a landing exercise. Analysis of data for that study and also as part of my career as a strength and conditioning coach, analysing athlete testing data – which adopted similar procedures to those being proposed in this study.

B2 Student project only

What previous experience of research involving human participants relevant to this project does your supervisor have?

Dr Jeremy Moody has a number of years of experience of conducting research with human participants and working with NGBs of sport in a research and professional practice capacity. Some selected peer-reviewed publications to support this are presented below:


### C POTENTIAL RISKS

**C1 What potential risks do you foresee?**

As this study will only perform analysis on an already collected data set no physical risks to the participants exist. Risks that may exist involving the participants are: (a) the maintenance of confidentiality; (b) the maintenance of participant anonymity; and (c) the potential impact of the results on the way in which the participants are seen within the organisation. There is also the risk that not all players in the organisation agree to participate, reducing the reliability and validity of the study and thus potentially wasting the participants’ and researcher's time.

**C2 How will you deal with the potential risks?**

In order to deal with the potential, but unlikely, risks a number of measures will be taken:

(a) all data will be anonymised to prevent identification of the participants being possible. This means that when the findings are presented to the organisation individual players’ data will not be identifiable and thus the participants will be protected from any impact on the perception the organisation has of individuals;

(b) participants will be asked to provide written assent prior to participation. This will be informed through a participant information sheet that will detail the research and how the findings will be used. It will also detail the rights of the participants (e.g., right to withdraw their participation at any time). It is thought that such information will help to recruit the participants and therefore reduce the risk of them not wishing to volunteer;

(c) parental consent (or consent from the organisation’s director in *locus parentis*) will also be sought prior to gaining assent from the participants.

When submitting your application you **MUST** attach a copy of the following:

- All information sheets
- Consent/assent form(s)

An exemplar information sheet and participant consent form are available from the Research section of the Cardiff Met website.
Appendix 2.

Participant Information Sheet

Project:
Title: Assessment of Relationships between Physical Testing Measures in Academy Football Players.
Purpose: The project will be completed as the dissertation for my M.Sc. in Strength and Conditioning.

Parent:
I would like to use the results from the physical tests that your child completes throughout the season for a research project. Your child will not have to take part in any extra tests, all I need is your permission to use the results that have already been obtained for a research project.

The project will aim to assess whether, and to what level, relationships between the physical tests exist. This will allow further insight into the physical test results and therefore how to best train young athletes to improve their physical capacities. All of the data will be completely anonymised so no-one outside of the club will see any of the player names. In addition, the analysis that occurs as part of my research project will also be anonymised so that individual players cannot be recognised in the final project. As a result, I do not foresee any further risks to your child regarding their participation in this study.

Importantly, the data will be used for a university postgraduate dissertation project and might be published in an academic journal. As a result, you do not have to agree to the data being used and you can ask for the data to stop being used at any point. If you have any questions feel free to ask using the contact information below.

If you and your child are willing to consent to my use of the testing data then you both need to fill out the relevant sections of the consent form.

Player:
I would like to use the scores from the physical testing that you have completed this year in order to conduct a research project.

Why?
I would like to use the information to work out if there are any similarities between the tests. This will help to then work out which tests we should be using and how we can train you to help you get better at them.

Who will see the findings?
Your name will be removed from the scores sheet so no-one will know that they are your scores. The information will then be used for the research project and possibly also be published, but you will not be identified in any of the outcomes of the research.

What do I have to do?
You won’t need to do any more tests, you will only need to say it is ok for me to use the scores from the tests you have already done.

Do I have to?
No, it’s up to you. You can also ask at any point for me to not use your data if you change your mind.

Do have any questions?
If you have any questions then just ask. You can ask yourself or get your parent or guardian to ask.

If you are happy for me to use the data then please sign your part on the form that comes with this sheet.
I would like to thank you for taking the time to consider your (or your child’s) participation in this research project and look forward to answering any questions that you may have. If you are happy to proceed please complete the consent form and return it to me (Stephen Cooper) as soon as possible.

Best wishes,

Stephen Cooper.
MSc Strength and Conditioning student
Cardiff Metropolitan University

Dr Jeremy Moody.
Dissertation Supervisor
JMoody@cardiffmet.ac.uk
Appendix 3.

Informed Consent/Assent Form

Parent:

I have read and understood the information provided about the research project and have had time to consider all the information, ask any questions and am satisfied with the answered provided.

I understand that my child's data may be withdrawn from the research project at any point.

I consent to my child's data being used for the research project.

Parent Name:_______________________

Signature:__________________________

Date:_________

Child:

I have read the information provided about the research project. I have thought about it, have asked any questions and am happy with the answers.

I understand that I can ask for my data to be removed from the research project at any time.

I give my permission for my data to be used for a research project.

Child Name:________________________

Signature:__________________________

Date:_______
Appendix 4.

Acute Effects of Sled Towing on Sprint Time in Male Youth of Different Maturity Status

Michael Clemens Rumpf and John Barry Cronin
Auckland University of Technology

Ikhwan Nur Mohamad
Sultan Idris Education University

Sharil Mohamad
National Sport Institute Malaysia

Jonathan Oliver and Michael Hughes
University of Wales Institute Cardiff

The purpose of this study was to investigate the effect of 2.5, 5, 7.5, and 10% body mass load on resisted sled towing 30 meter sprint times in male youth athletes of different maturity status. A total of 35 athletes (19 prepeak-height-velocity (PHV) and 16 mid/post-PHV) sprinted three times in an unloaded and each of the loaded conditions. The pre-PHV athletes were significantly slower (-33%; p < .05) than the more mature athletes across all loads (unloaded, 2.5, 5, 7.5, 10% body mass). Each incremental load (i.e., 2.5% body mass) was found to reduce 30 m sprint times by 3.70% (± 2.59) and 2.45% (± 1.48) for the pre- and mid/post-PHV respectively. The slopes of the pre- (β = 0.09 x + 5.71) and mid/post (β = 0.04 x + 4.38) regression equations were compared and found to be statistically different (p = .004) suggesting that athletes of different maturity status responded differently to the same relative resisted sprint load. Ten percent body mass load resulted in a reduced sprint time of -15.8 and -9.8% for the pre- and mid/post-PHV group, respectively. These results enable predictive equations to be formulated and appropriate resisted sprint loading, based on the intended focus of a session.

Running is a fundamental movement for human beings and its fastest form, sprinting, is prerequisite to success in many sports. Given the importance of sprint speed, a number of training methods have been used to develop this motor quality. One such method is resisted sled towing, which has been used in the training of adult populations (3,8,11,13,25,27) with trivial (3) to very large (27) effect sizes observed in these studies. However, the utilization of this type of training in youth populations has not been documented to the knowledge of these authors.

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Before using resisted sled towing in training, it is necessary to understand how the load may affect sprint kinematics. For example, sled towing has been shown to change stride kinematics (14,15,17) significantly (15,17) in adults. The loads used in these studies were characterized as absolute (e.g., 2.5 kg) or relative (e.g., 10% of body mass). Loads of 2.5, 5, and 10 kg, decreased sprint time by 8.6, 12.6, and 23.4% respectively in female sprinters (14). A relative load of 10, 12, 6, 20, and 32% decreased sprint speed significantly (p < .05) by 7.8, 12 and 22.8% respectively (15,17). Whether such decrements are similar in youth athletes and similar across athletes of different maturity status, is unknown.

Due to the rise of hormone levels (testosterone and growth hormones) associated with puberty (5,6,12,20,22) around peak height velocity (PHV), it could be hypothesized that improvements in strength (18) and consequently power output (1,2,5,10,18) may affect force production and therefore running speed. Hence it may be that the kinetics and kinematics of running may differ in participants of contrasting maturity status and there-
fore affect possible loading of the athletes. However, to the knowledge of these authors, there is no scientific evidence on how age and maturation influence the sensitivity of sled-towing performance and further more spine running performance. The purpose of this study therefore, is to investigate the acute effects of different sled towing loads on sprint times of youth athletes of different maturity status. Furthermore, to provide coaches with possible loading schemes the secondary purpose is to provide a regression equation for each maturity status.

Methods

Participants

A total of 35 male children participated in the study. Nineteen participants were categorized as prepeak height velocity (PHV) age 10.5 ± 1.12 years, height 141 ± 9.54 cm, mass 38.4 ± 14.0 kg, maturity offset -3.01 ± 0.96 years from PHV) and the remaining 16 classified as mid/post-PHV (age 15.2 ± 1.14 years, height 172 ± 4.52 cm, mass 60.9 ± 6.15 kg, maturity offset 1.22 ± 0.93 years from PHV). All participants were physically active and trained a minimum of two times per week in track and field events in which sprinting was considered a major component of performance (e.g., 100 m, 200 m, 110 m hurdles, pole vault, long jump). All participants represented their school at a state and national level and all participants and their parents/legal guardians were informed about the potential risk involved with the study and gave written consent to participate. The investigation was approved by the AUT University ethics committee.

Study Design

A total of 35 developmental athletes were used to determine the effect of different load (2.5, 5, 7.5, and 10% body mass) sled towing on 30 m sprint times. To achieve this, participants sprinted three times in unloaded and in each of the loaded conditions and results were compared across each condition. In addition, a linear regression analysis was used to describe the effect of load on sprint times across respective populations.

Procedures

Participants were assessed on two separate occasions, with two days between assessments. On the first day of testing, anthropometric measurements were taken before the warm-up session. The height (cm), sitting height (cm), weight (kg) were measured and the body mass index (BMI) calculated. The maturity status of participants, a maturity index (i.e., timing of maturity) was calculated using the following equation: Maturity Offset = -9.236 + (0.0002708 x leg length x sitting height) + (-0.01563 x age x leg length) + (0.077216 x age x sitting height) + (0.0292 x weight by height ratio); 19. This technique is a noninvasive and practical method of predicting years from PHV as a measure of maturity offset using anthropometric variables. Negative values were interpreted as pre-PHV and positive values as post-PHV. Generally, athletes can be categorized into 3 groups as followed (23): pre-PHV velocity (–3 years to –1 years from PHV), around PHV (–1 to +1 years from PHV) and post-PHV (+1 to +3 years from PHV); 23. However, as the number of participants was too small in the mid-PHV group, the mid-PHV and post-PHV participants were grouped together. The standard error of estimate for peak height velocity (PHV) is 0.49 years for boys (19).

Immediately after a warm-up, consisting of jogging, stretching and warm-up accelerations runs, the participants sprinted for 30 m outdoors on a natural dry grass surface for three times to determine their average unloaded sprint time over 30 m, measured with Swift double beam timing gates (SWIFT Performance Equipment, Wacol, Australia). Thereafter, using a randomized approach, participants sprinted with an additional 2.5, 5, 7.5, and 10% of their body mass utilizing custom made sleds, attached to harnesses from SPEEDY sled equipment (Sport Pawlik, Unterkirch, Germany). On the first day of testing and after the unloaded sprints, two sets of loaded sprints occurred and the remaining two sets occurred on the second testing day after participants received the identical standardized warm-up. A total of three sprints were performed at each load with a recovery of at 180 s between each sprint for all testing conditions and occasions. Average values of three runs in the unloaded and each of the loaded conditions were used for further data analysis.

Statistical Analysis

Three trials for each load condition were averaged for an individual participant mean, and participants' means for each load condition were averaged to provide a group mean. A two factor (group x load) repeated measures ANOVA (SPSS, IBM, NY, USA) was performed. Post hoc contrasts was used to determine whether there was a significant difference in sprint times. Data were checked for outliers and assumptions regarding normality, linearity and homoscedasticity were checked using scatter and Normal P-P plots. Linear regression equations (load vs sprint time) were calculated for each participant, and thereafter averaged for both the pre- and mid/post-PHV group. Goodness of fit (R²) scores were generated using Microsoft Excel 2007 (Microsoft Corporation). An independent t-test was used to determine if the slopes of the regression equations differed significantly. To assess criterion validity, the Bland-Altman limits of agreement and the standard error of estimate were employed by utilizing an independent t-test for each load in both groups were also calculated from the regression equations. An alpha level of $p < 0.05$ was chosen as the criterion for significance.

Results

Averaged sprint data for the two groups for unloaded and all loaded conditions can be observed in Table 1. Thirty-meter sprint times ranged from 5.69 to 6.59 s for
Table 1  Thirty Meter Sprint Times While Unloaded and at Different Sled Weights (2.5–10% Body Mass; Mean ± SD) for Pre-PHV and Mid/Post-PHV Groups

<table>
<thead>
<tr>
<th></th>
<th>Unloaded Time (s)</th>
<th>2.5% Time (s)</th>
<th>5% Time (s)</th>
<th>7.5% Time (s)</th>
<th>10% Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-PHV</td>
<td>5.69* ± 0.34</td>
<td>5.97*** ± 0.35</td>
<td>6.18*** ± 0.41</td>
<td>6.37*** ± 0.41</td>
<td>6.59*** ± 0.54</td>
</tr>
<tr>
<td>Mid/Post-PHV</td>
<td>4.33* ± 0.17</td>
<td>4.52** ± 0.20</td>
<td>4.61** ± 0.21</td>
<td>4.67** ± 0.24</td>
<td>4.76*** ± 0.25</td>
</tr>
</tbody>
</table>

*Significant difference from unloaded conditions p < 0.05.
**Significant difference from 10% load p < 0.05.
***Significant difference from unloaded and 2.5% conditions p < 0.05.

pre-PHV and 4.33–4.76 s for mid/post-PHV athletes across the 0–10% body mass loads. The older athletes were significantly (p < 0.05) faster across all loads (average of 33% ranging from 31 to 39%). In terms of the within group comparison the pre-PHV participants were slower by 3.70% (± 2.59%) on average with each 2.5% incremental load while the mid/post-PHV participants were less affected and increased sprint time by 2.45% (± 1.48%) on average with each load. However, a 2.5% load is not enough to change sprint time significantly in both groups. A load greater than 5% changed sprint times significantly compared with the unloaded conditions and no changes were observed between loads of 2.5 and 7.5% in both groups. The 10% load was significantly different from unloaded and 2.5% load in both groups.

The percent decrease in sprint times as a function of load in percent of body mass as well as the regression equations for the lines of best fit can be observed in Figure 1. With regards to the between group analysis, it needs to be stated that there was no significant Group × Load interaction observed (p = .056) from the ANOVA. However, given the interaction was approaching significance the slopes of the regression equations for pre- (0.09 ± 0.04) x + 5.71 ± 0.33, R² = .94 (± 0.07) vs. mid/post-PHV participants (0.04 ± 0.01) x + 4.38 ± 0.17, R² = .90 (± 0.09) were compared and they were found to be statistically different (p = .004). For pre-PHV the raw (%) standard error of estimate (SEE) for loads of 2.5, 5 and 7.5% were quite consistent with values of 0.15 (2.5%), 0.19 (3.1%) and 0.14 (2.2%) respectively, but more variable at a load of 10% with a SEE of 0.33 (9.9%). This was also reflected in limits of agreement (LoA) with values of 0.04 ± 0.29 s for a load of 2.5%, -0.02 ± 0.37 s for a load of 5%, 0.09 ± 0.26 s for a load of 7.5% and 0.10 ± 0.62 s for a load of 10%. The mid/post-PHV participants data revealed raw (%) SEE of 0.07 (1.5%), 0.10 (2.2%), 0.10 (2.1%) and 0.11 (2.3%) for loads of 2.5, 5, 7.5 and 10% respectively. LoA were -0.08 ± 0.14, -0.08 ± 0.20 s, -0.04 ± 0.25 s and -0.02 ± 0.28 s for a loads of 2.5, 5, 7.5 and 10% respectively.

**Discussion**

The primary purpose of this study was to investigate the acute effects of different sled loads on sprint times in different maturation status. Not surprisingly, the between

![Figure 1](image-url) — Decrease in sprint time (%) as a function of load body mass (%) for pre-PHV (•) and mid/post-PHV participants (○).
group comparison of sprint times at different loads revealed that post-PHV participants were significantly faster (~33% on average) over 30 m in all conditions compared with the pre-PHV participants. In both groups, a load of 2.5% was not sufficient to change sprint time over 30 m significantly. Furthermore, no differences were seen for loads between 2.5 and 7.5%. Ten percent load was significantly different compared with unloaded and 2.5% load for both groups. Comparisons with other research is difficult given all subjects are adults. Locke et al. (15) reported velocity decrements of 8.7% and 22.8% over a 1.5 m distance for 12.6% and 32.2% body mass loads respectively. Mauder et al. (17) used loads of 10 and 20% of body mass over a 10 m distance from a block start and reported an increase in sprint time of 8 and 14% respectively, as compared with the unloaded condition.

Of interest was whether athletes of different maturational status responded the same to resisted sprint loads. Each incremental load (i.e., 2.5% body mass) was found to reduce 30 m sprint times by ~4% and ~2.5% for the pre- and mid/post-PHV participants respectively. It would seem that the older and mature athletes were less affected by the same relative load. In addition, the post-PHV seemed to be less variable across all loads, as seen in the SEE and LoA. Given the Group X Load interaction was approaching significance (p = .056) and a comparison of the slopes of the regression equations was found to be significantly different, this contention seems somewhat supported.

The regression equations generated enable the prediction of the effects of load on the sprint performance of youth athletes. The equations are maturational specific, the differences in the effect of load magnified at heavier relative loads. For example, a 5% body mass load resulted in ~8% increase in sprint time for pre-PHV athletes, whereas ~8% body mass load was needed to produce the same increase in sprint time in mid/post-PHV participants.

One possible explanation for the different response to equal body mass load might be the greater body mass, and therefore, greater muscle mass and relative strength and power in mid/post-PHV participants due to increased hormonal outflow that is known to occur during puberty (21). For example, Viitsinen et al. (26) stated that peak muscle mass spurt occurred one year later than peak weight spurt as fat mass was reduced due to rapid growth and increased testosterone secretion at the same time as muscle mass was increasing, which could explain some variance in the performance between the participants in our study. However, relative strength changed significantly across age groups after adjusting for body mass in other studies (4,7,16,24) suggesting that other factors than body mass, and as a result muscle mass, influences performance. Increases of 67% and 91% in adjusted peak power to body mass was reported from preadolescence (10-year-olds) to adolescence (15-year-olds) and adults (2-year-olds) in a force-velocity cycling test suggesting a maturation effect (24). However, as we did not measure neither muscle mass nor hormonal status of the participants, we are only able to speculate on the effect of these parameters on the resisted sled towing performance across maturation.

Despite the difference in loading schemes for youth athletes in different maturation status, the efficacy of resisted sled towing in youth athletes in different maturation status is yet to be proven and would require a longitudinal design. Furthermore, it would be very useful to quantify joint kinematics to disentangle the effect of different loads on the running technique and possible safety issues.

Conclusion

Resisted sprint towing is a common form of sprint training used to increase track and sport speed. The loading parameters for the most part have been generated from research with adult athletes. Given that speed development can occur in the youth athlete it would make sense to ensure that resisted loading parameters are specific to the maturing athlete. In this regard, this study found that sprint performance decreased on average by ~1.5% and 1% for each additional percent of body mass load, for pre- and mid/post-PHV participants respectively. It seems that athletes of different maturity status respond differently to the same relative resisted sprint load. It is recommended that different regression equations are generated for different maturational groups as these equations can be used to understand the effect of load on speed and design resisted sprint programs to better effect.

References

Effects of Sled Towing on Sprint Time


