The influence of age, maturity and body size on the spatiotemporal
determinants of maximal sprint speed in boys

Sprint speed in Boys

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ABSTRACT

The aim of this study was to investigate the influence of age, maturity and body size on the spatiotemporal determinants of maximal sprint speed in boys. Three-hundred and seventy-five boys (age: 13.0 ± 1.3 yrs) completed a 30 m sprint test, during which maximal speed, step length, step frequency, contact time and flight time were recorded using an optical measurement system. Body mass, height, leg length and a maturity offset represented somatic variables. Step frequency accounted for the highest proportion of variance in speed (~58%) in the pre-PHV group, whilst step length explained the majority of the variance in speed (~54%) in the post-PHV group. In the pre-PHV group, mass was negatively related to speed, step length, step frequency and contact time; however measures of stature had a positive influence on speed and step length yet a negative influence on step frequency. Speed and step length were also negatively influence by mass in the post-PHV group, and leg length continued to positively effect step length.

The results highlighted that pre-PHV boys may be deemed step frequency reliant, whilst those post-PHV may be marginally step length reliant. Furthermore, the negative influence of body mass both pre- and post-PHV suggests that training to optimise sprint performance in youth should include methods such as plyometric and strength training, where a high neuromuscular focus and the development force production relative to body weight are key foci.

KEY WORDS

Youth; Somatic; Growth; Regression
INTRODUCTION

Sprint speed is defined as the product of step length and step frequency (9). Theoretically, both characteristics must increase in order to improve maximal sprint velocity; however, a negative interaction between step length and step frequency has been reported (7,10). Additionally, there is further suggestion that the optimal interaction between step length and step frequency may be best determined at a more individual level due to variation of these spatiotemporal variables in elite sprinters (31) and sprinters of different sex (4). Researchers have shown that, mechanistically, increased sprint performance may be obtained by applying greater ground reaction force (GRF) relative to body weight during brief periods of ground contact (34,35).

Furthermore, more recent data from adult sprinters has suggested that greater maximal speed is achieved by athletes who produce the greatest horizontal GRF relative to body weight (20).

Speed is known to develop in a non-linear fashion throughout childhood and adolescence, yet the exact impact of growth and maturation upon sprint performance and other measures of athletic performance remains unclear (14,17,23,33,36). Consequently, owing to their unique physiology, it is inappropriate to assume that the determinants of sprint performance in adult populations are necessarily transferable to youth populations. It has been suggested that changes in speed throughout childhood may be associated with changes in leg length (32). However, recent work highlighted that sprint performance is more closely associated with step frequency in pre-
pubertal boys, but primarily related to step length in post-pubertal boys (17). Furthermore, it has been suggested that increases in leg length and resultant step length, did not translate into improved sprint performance until around the period of PHV when maturity-related increases in ground contact time were stabilised (17). Moreover, growth throughout adolescence is also known to be non-linear, where rapid changes in leg length are observed during the early phases of the adolescent growth spurt, while rapid increases in body mass and muscle mass may not be be observed until after PHV (14). Such observations serve to highlight the possible interaction between somatic variables related to growth and maturation and sprint performance, yet data pertaining to the exact nature of these relationships remains unclear. Given the limited research examining the potential growth- and maturity-related determinants of sprint performance in youth, the aim of the study was to explore the influence of age, maturity and body size on the spatiotemporal determinants of maximal sprint speed in boys.

METHODS

Experimental approach to the problem

To determine the influence of somatic variables on sprint performance, anthropometric data (standing height, sitting height and mass) were collected for all participants in addition to measures of spatiotemporal characteristics of maximal sprint performance (speed, step length, step frequency, contact time and flight time) during a 30 m sprint test. A maturity offset was also calculated from anthropometric measures. Correlations and
multiple regression analyses were used in order to examine the relationships between somatic variables and spatiotemporal sprint variables.

**Subjects**

Three-hundred and seventy-five school age boys agreed to participate in the study. Means ± standard deviations for all somatic variables are provided in Table 1. Upon enrolling into the study, participants reported no injuries and all regularly participated in bi-weekly physical education classes. All classes followed the national curriculum guidelines, and were 60 minutes in duration. None of the participants were engaged in formal strength and conditioning programmes. Participants were instructed to wear the same clothing and footwear to each testing session and to refrain from physical activity 24 hours prior to testing and to refrain from eating one hour prior to testing. Following the granting of ethics approval by the institutional research ethics committee, parental consent and participant assent were obtained.
### Table 1. Descriptive statistics for all variables collected from the whole sample, pre- and post-PHV groups (Mean ± SD).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Whole sample</th>
<th>Pre-PHV</th>
<th>Post-PHV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>13.0 ± 1.3</td>
<td>12.4 ± 0.8</td>
<td>15.1 ± 0.6*</td>
</tr>
<tr>
<td>Standing Height (m)</td>
<td>1.56 ± 0.12</td>
<td>1.50 ± 0.09</td>
<td>1.74 ± 0.06*</td>
</tr>
<tr>
<td>Leg length (m)</td>
<td>0.77 ± 0.07</td>
<td>0.75 ± 0.06</td>
<td>0.86 ± 0.04*</td>
</tr>
<tr>
<td>Sitting Height (m)</td>
<td>0.78 ± 0.06</td>
<td>0.75 ± 0.04</td>
<td>0.88 ± 0.03*</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>51.4 ± 15.7</td>
<td>45.4 ± 11.4</td>
<td>71.8 ± 15.8*</td>
</tr>
<tr>
<td>Maturity Offset (years)</td>
<td>-1.1 ± 1.3</td>
<td>-1.8 ± 0.7</td>
<td>1.2 ± 0.6*</td>
</tr>
<tr>
<td>Speed (m.s⁻¹)</td>
<td>6.54 ± 0.77</td>
<td>6.35 ± 0.64</td>
<td>7.16 ± 0.91*</td>
</tr>
<tr>
<td>Step length (m)</td>
<td>1.63 ± 0.18</td>
<td>1.57 ± 0.14</td>
<td>1.81 ± 0.18*</td>
</tr>
<tr>
<td>Step Frequency (Hz)</td>
<td>4.02 ± 0.33</td>
<td>4.05 ± 0.33</td>
<td>3.95 ± 0.34</td>
</tr>
<tr>
<td>Contact Time (s)</td>
<td>0.141 ± 0.021</td>
<td>0.138 ± 0.020</td>
<td>0.149 ± 0.023*</td>
</tr>
<tr>
<td>Flight time (s)</td>
<td>0.110 ± 0.016</td>
<td>0.110 ± 0.016</td>
<td>0.106 ± 0.016*</td>
</tr>
</tbody>
</table>

* Significantly different from pre-PHV group (p < 0.05).

### Procedures

All participants were required to complete a sprint test and an assessment of maturity. All tests were conducted in the same indoor facility, with equipment standardized for each testing session. All testing sessions occurred during scheduled physical education classes and all participants were provided the opportunity to familiarise themselves with the test procedures prior to commencing data collection.
Sprint Test

The assessment of the spatiotemporal characteristics of sprint performance required the participants to perform two trials of a maximal sprint over a 30 m track. Participants were instructed to begin their sprint in a split stance on a line 50 cm from the starting line. Participants were given the instructions “ready” and “go”, and asked to sprint maximally down the testing track. A finish line was placed at 35 m in order to encourage participants to sprint maximal throughout the 15-30 m section of the track where the spatiotemporal data were collected. All participants completed their trials one at a time and verbal encouragement was provided throughout each trial. A minimum of four minutes passive rest was given between trials to ensure sufficient recovery (25).

Sprint Test Variables

The assessment of spatiotemporal sprint characteristics was performed via an optical measurement system (Optojump, Microgate, Italy) positioned at floor level in the 15-30 m section of the sprint track. Data for the sprint characteristics were instantaneously collected to an accuracy of 1/1000 s using a Windows XP laptop via specialist software (Optojump, Microgate, Italy), and subsequently exported to Microsoft Excel for data processing. Good levels of reliability have been reported from the assessment of spatiotemporal sprint characteristics in boys (CV: 3.8-5.0%) utilising this methodology (18). Data obtained from the optical measurement system automatically calculated the following variables:
• **Speed**: Calculated by dividing the distance (m) between alternate foot contacts (step length) and the time taken (s) between these contacts (flight time + contact time). Units are expressed as distance per unit time (m.s\(^{-1}\)).

• **Step length**: The distance (m) between the foot tip of alternate foot contacts (i.e. the distance between left and right foot contacts).

• **Step frequency**: The rate (Hz) of lower limbs movements as defined by the number of steps taken per second.

• **Contact time**: The amount of time (s) the participant spends during the stance phase of the sprint, where the foot is in contact with the floor.

• **Flight time**: The amount of time (s) between alternate foot contacts, where the participant is not in contact with the floor.

**Sprint Test Data Processing**

Data for all steps completed within the 15-30 m data collection zone were instantaneously recorded for each participant over their two sprint trials. Subsequently all data corresponding to the fastest two consecutive steps from either trial were extracted and averaged for analysis. This process has been shown to have acceptable levels of reliability for the described methodology (18).

**Assessment of Maturity**

Biological maturity was assessed using anthropometric variables including body mass, standing height, and sitting height using a previously validated regression equation (19). This method calculates a maturity offset.
that represents the years a participant is estimated from peak height velocity (PHV). This method was chosen owing to its non-invasive nature and acceptable level of measurement accuracy ($\pm 0.592$ years).

**Statistical Analyses**

For the purpose of analysis the data were analysed as a whole sample and also divided into pre- and post-PHV sub-groups. The pre-PHV group were defined as those with a maturity offset less than -0.5 years from PHV, whilst the post-PHV group had a maturity offset greater than 0.5 years from PHV. This process resulted in the removal of 52 participants who were deemed circa-pubertal; however this approach facilitated a valid application of the maturity offset regression equation based on the reported measurement accuracy. Descriptive statistics (mean ± standard deviation) were calculated for all descriptive and spatiotemporal sprint characteristics for the whole sample, pre- and post-PHV groups using Microsoft Excel for Mac. The strength of relationships between pairs of variables in the whole sample and sub-groups was quantified via Pearson’s correlation coefficients.

Subsequently, step-wise multiple regression analyses were employed to establish the spatiotemporal determinants of speed, and the role of somatic variables as determinants of speed and its spatiotemporal components across the whole sample and sub-groups. The assumption of independent errors was tested via a Durbin-Watson test, whilst multi-collinearity was tested using variance inflation factor (VIF) and tolerance (6). All correlation and multiple regression analyses were conducted in SPSS Statistics v. 20 for Mac. Statistical significance was accepted as $p < 0.05$, whilst all correlation...
coefficients greater than 0.7 were classified as “strong”, 0.45-0.7 were “moderate”, 0.2-0.45 “weak”, and less than 0.2 representing “no relationship” (21).

RESULTS

The descriptive data relating to the spatiotemporal characteristics of sprint performance are shown in Table 1. Significant differences ($p < 0.05$) were observed between pre- and post-PHV sub-groups for all somatic and spatiotemporal sprint variables, with the exception of step frequency.

For the whole sample pre- and post-PHV sub-groups, speed had strong-moderate positive relationships with step length ($r = 0.74, p < 0.05; r = 0.65, p < 0.05; r = 0.74, p < 0.05$, respectively) but weak-moderate positive correlations with step frequency ($r = 0.44, p < 0.05; r = 0.53, p < 0.05; r = 0.67, p < 0.05$, respectively). Moderate to strong relationships were evident between speed and contact time for the whole sample, pre- and post-PHV groups ($r = -0.59, p < 0.05; r = -0.71, p < 0.05; r = -0.79, p < 0.05$, respectively), whilst no relationship was evident between speed and flight time in the whole sample or sub-groups ($p > 0.05$).

The relationships between somatic and spatiotemporal sprint characteristics are shown in table 2. For the whole sample and pre-PHV group, all somatic variables displayed positive moderate-weak relationships with step length ($p < 0.05$) and moderate-weak negative relationships with step frequency ($p < 0.05$), with the exception of age. Furthermore, results indicated that body mass was not significantly related with speed for the whole sample ($p > 0.05$) but negatively related to speed in both sub-groups ($p$...
All other somatic variables showed weak, positive relationships with speed ($p < 0.05$) for the whole sample, whilst only age demonstrated a positive relationship ($p < 0.05$) with speed in both sub-groups.

Table 2. Pearson’s correlations ($r$) between age, somatic variables and spatiotemporal sprint characteristics for whole sample, pre- and PHV groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Variable</th>
<th>Speed</th>
<th>Step length</th>
<th>Step frequency</th>
<th>Contact time</th>
<th>Flight time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole sample</td>
<td>Age</td>
<td>0.42*</td>
<td>0.56*</td>
<td>-0.15*</td>
<td>0.20*</td>
<td>-0.04</td>
</tr>
<tr>
<td></td>
<td>Maturity offset</td>
<td>0.35*</td>
<td>0.56*</td>
<td>-0.28*</td>
<td>0.34*</td>
<td>-0.06</td>
</tr>
<tr>
<td>(n = 375)</td>
<td>Mass</td>
<td>-0.03</td>
<td>0.21*</td>
<td>-0.35*</td>
<td>0.57*</td>
<td>-0.24*</td>
</tr>
<tr>
<td></td>
<td>Standing height</td>
<td>0.32*</td>
<td>0.61*</td>
<td>-0.38*</td>
<td>0.41*</td>
<td>-0.00</td>
</tr>
<tr>
<td></td>
<td>Sitting height</td>
<td>0.32*</td>
<td>0.56*</td>
<td>-0.32*</td>
<td>0.33*</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Leg length</td>
<td>0.28*</td>
<td>0.58*</td>
<td>-0.39*</td>
<td>0.42*</td>
<td>-0.01</td>
</tr>
<tr>
<td>Pre-PHV</td>
<td>Age</td>
<td>0.18*</td>
<td>0.35*</td>
<td>-0.17*</td>
<td>0.16*</td>
<td>0.07</td>
</tr>
<tr>
<td>(n = 271)</td>
<td>Maturity offset</td>
<td>0.01</td>
<td>0.40*</td>
<td>-0.44*</td>
<td>0.44*</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>-0.35*</td>
<td>0.22</td>
<td>-0.48*</td>
<td>0.67*</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Standing height</td>
<td>0.05</td>
<td>0.45*</td>
<td>-0.51*</td>
<td>0.50*</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Sitting height</td>
<td>0.05</td>
<td>0.38*</td>
<td>-0.43*</td>
<td>0.38*</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Leg length</td>
<td>-0.01</td>
<td>0.41*</td>
<td>-0.47*</td>
<td>0.50*</td>
<td>0.01</td>
</tr>
<tr>
<td>Post-PHV</td>
<td>Age</td>
<td>0.29*</td>
<td>0.29*</td>
<td>0.14</td>
<td>-0.16</td>
<td>0.07</td>
</tr>
<tr>
<td>(n = 52)</td>
<td>Maturity offset</td>
<td>-0.11</td>
<td>-0.11</td>
<td>-0.05</td>
<td>0.10</td>
<td>-0.05</td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>-0.47*</td>
<td>-0.54*</td>
<td>-0.13</td>
<td>0.40*</td>
<td>-0.40*</td>
</tr>
<tr>
<td></td>
<td>Standing height</td>
<td>0.01</td>
<td>0.17</td>
<td>-0.19</td>
<td>0.20</td>
<td>-0.01</td>
</tr>
<tr>
<td></td>
<td>Sitting height</td>
<td>-0.13*</td>
<td>-0.09</td>
<td>-0.11</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Leg length</td>
<td>0.13</td>
<td>0.30*</td>
<td>-0.15</td>
<td>0.19</td>
<td>-0.07</td>
</tr>
</tbody>
</table>

* Significant relationship between characteristics ($p < 0.05$).
Multiple regression analysis of the spatiotemporal determinants of speed in the whole sample and post-PHV group revealed that step length was the strongest predictor of speed (54.7% and 54.0% total variance, respectively), with step frequency accounting for the remaining total variance. Step frequency accounted for the majority of the total variance in speed in the pre-PHV group (57.6% total variance), with step length accounting for the remaining total variance. In turn, contact time and flight time were the strongest predictors of step frequency in all groups (95.3%, 94.9% and 98.9% total variance in whole sample, pre- and post-PHV groups, respectively).

When specifically exploring the somatic variables in the whole sample and pre-PHV group, (Tables 3 and 4), mass had a negative influence on speed, step length, step frequency, contact time and flight time, whereas height or leg length had a positive influence on speed and step length but a negative influence on step frequency. For the post-PHV group (Table 5) mass still had a negative effect on speed and step length, and leg length maintained a positive effect on step length; however no variables could explain step frequency. For all multiple regression models there was no evidence of multi-collinearity, with acceptable values for tolerance (> 0.1) and variance inflation factor (<10).
Table 3. Stepwise multiple regression equations explaining the somatic variables that significantly ($p < 0.05$) contributed to spatiotemporal characteristics of sprint performance for the whole sample.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Independent variables</th>
<th>Regression equation</th>
<th>Adjusted $R^2$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>Constant</td>
<td>7.455</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>-0.043</td>
<td>0.274</td>
</tr>
<tr>
<td></td>
<td>Maturity offset</td>
<td>0.519</td>
<td>0.367</td>
</tr>
<tr>
<td></td>
<td>Leg Length</td>
<td>2.396</td>
<td>0.382</td>
</tr>
<tr>
<td>Step length</td>
<td>Constant</td>
<td>0.155</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standing height</td>
<td>1.278</td>
<td>0.373</td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>-0.009</td>
<td>0.550</td>
</tr>
<tr>
<td></td>
<td>Maturity offset</td>
<td>0.056</td>
<td>0.573</td>
</tr>
<tr>
<td>Step frequency</td>
<td>Constant</td>
<td>5.069</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leg length</td>
<td>-2.006</td>
<td>0.151</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.056</td>
<td>0.167</td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>-0.004</td>
<td>0.186</td>
</tr>
<tr>
<td>Contact time</td>
<td>Constant</td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>0.001</td>
<td>0.319</td>
</tr>
<tr>
<td></td>
<td>Maturity offset</td>
<td>-0.007</td>
<td>0.347</td>
</tr>
<tr>
<td></td>
<td>Leg length</td>
<td>0.075</td>
<td>0.368</td>
</tr>
<tr>
<td>Flight time</td>
<td>Constant</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>-0.001</td>
<td>0.054</td>
</tr>
<tr>
<td></td>
<td>Standing height</td>
<td>0.102</td>
<td>0.139</td>
</tr>
<tr>
<td></td>
<td>Leg length</td>
<td>0.037</td>
<td>0.146</td>
</tr>
</tbody>
</table>
Table 4. Stepwise multiple regression equations explaining the somatic variables that significantly \((p < 0.05)\) contributed to spatiotemporal characteristics of sprint performance in the pre-PHV group.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Independent variables</th>
<th>Regression equation</th>
<th>Adjusted (R^2) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>Constant</td>
<td>5.431</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>-0.042</td>
<td>0.122</td>
</tr>
<tr>
<td></td>
<td>Standing height</td>
<td>2.175</td>
<td>0.243</td>
</tr>
<tr>
<td></td>
<td>Maturity</td>
<td>0.252</td>
<td>0.261</td>
</tr>
<tr>
<td>Step length</td>
<td>Constant</td>
<td>0.352</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standing height</td>
<td>1.103</td>
<td>0.200</td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>-0.008</td>
<td>0.363</td>
</tr>
<tr>
<td></td>
<td>Maturity</td>
<td>0.050</td>
<td>0.378</td>
</tr>
<tr>
<td>Step frequency</td>
<td>Constant</td>
<td>6.319</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Standing height</td>
<td>-1.296</td>
<td>0.257</td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>-0.007</td>
<td>0.286</td>
</tr>
<tr>
<td>Contact time</td>
<td>Constant</td>
<td>0.086</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>0.001</td>
<td>0.430</td>
</tr>
<tr>
<td></td>
<td>Leg length</td>
<td>0.132</td>
<td>0.444</td>
</tr>
<tr>
<td></td>
<td>Standing height</td>
<td>-0.064</td>
<td>0.452</td>
</tr>
<tr>
<td>Flight time</td>
<td>Constant</td>
<td>0.031</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mass</td>
<td>-0.001</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>Sitting height</td>
<td>0.139</td>
<td>0.114</td>
</tr>
</tbody>
</table>
The aim of the present study was to explore the influence of age, maturity and body size on the spatiotemporal determinants of maximal sprint speed in boys. The results of this study revealed that speed is best predicted by step frequency in a pre-PHV group of boys, and by step length for those who are post-PHV. In the pre-PHV group, mass had a negative influence upon speed, step length, step frequency and contact time, whilst height or leg length had a positive influence upon speed and step length yet a negative
influence upon step frequency and contact time. In the post-PHV group, mass
also negatively influenced speed, step length and contact time, but only leg
length continued to positively influence step length.

Despite the untrained nature of the current sample, the sprint
speed data are comparable with those previously reported for over-ground
sprint performance that covered similar distances in a sample of trained youth
games players (15). The data from the present study were considerably faster
than those reported for studies utilizing a non-motorized treadmill (2.64 m.s⁻¹)
(28); however the methodological constraints associated with the treadmill
inertia, influence of body mass and elasticity of tethers may explain the
reduced sprint speed attained (26). Significant improvements in all the
spatiotemporal components of sprint performance were shown between pre-
and post-PHV groups with the exception of step frequency. The lack of
change in step frequency could be explained by the increased contact time
and decreased flight time in the post-PHV group compared to the pre-PHV
group, and may suggest that children and adolescents self-regulate step
frequency through the manipulation of contact time and flight time.

The strong influence of step length and step frequency upon sprint
performance is consistent with adult literature (10); however, notably a higher
variance of speed was accounted for by step length in the post-PHV
compared to the pre-PHV group (~54% vs ~42%). This finding is consistent
with previous paediatric literature, with researchers suggesting that changes
in speed with advancing age were proportional to changes in step length
(15,16,23,32), yet may also support the suggestion that pre-PHV boys may be
more step-frequency-reliant (17), with this variable explaining ~58% of the
total variance in speed in the pre-PHV sub-group. In the present study, measures of stature (standing height or leg length) positively influenced step length in the both pre- and post PHV groups. This relationship may be explained by increases in contact length (distance the centre of mass travels during ground contact) and step length that would occur naturally as a result of changes in leg length. Furthermore, the moderate relationships between maturity and stature with step length in both the whole sample ($r = 0.56-0.61$), along with the level of explained variance in step length that these variables may account for (~57%), may further highlight the role of natural growth- and maturity-related characteristics that are not influenced by training.

Negative relationships between step frequency and all somatic variables were observed in the whole sample and pre-PHV group, however, somatic variables were not related to step frequency post-PHV, suggesting other factors may influence step frequency in more mature youth. Furthermore, multiple regression analyses highlighted that mass had a negative influence upon not only step frequency but also step length and speed in pre- and post-PHV sub-groups. A novel finding within the current study was that additional mass did not seem to result in positive increases in relative force production, which is different to that typically associated with improved sprint performance in adults (35). Although body composition was not assessed in the present study, it is postulated that those participants with increased mass may have possessed greater absolute levels of fat-mass, which may not positively contribute to force production during explosive tasks. It has also been suggested that pre-pubertal children do not experience changes in muscle cross sectional area or mass despite improved force-
generating capability (8). Intuitively, the mechanisms of increased force production in pre-pubertal youth would appear to be associated with enhanced neuromuscular recruitment and motor co-ordination rather than increased mass (22,24). Previous literature has suggested that improvements in sprint speed are seen just prior to the time of PHV (17,23), and therefore it may be postulated that in the whole sample, and particularly in the pre-PHV sub-group, improved sprint performance may be associated with increased neuromuscular function. This notion is reinforced by the observation that training inclusive of a high neuromuscular focus (i.e. plyometric training), may be the most effective method of speed development in boys who are prior to and circa-PHV (13,30). As mass was negatively associated with sprint performance in the current sample, it could be suggested that supplementary strength training may play a important role in enhancing maximal sprint speed. Previous studies in youth have reported increased neuromuscular function and force production whilst also improving body composition (5), all of which would act favourably to offset the negative influence of increased mass seen in this study, and consequently may lead to enhanced maximal sprint performance.

It was also noted in the results that contact time was negatively influenced by maturity and all other somatic variables in the whole sample and pre-PHV group. Such an observation is consistent with previous research that has suggested contact time may increase prior to PHV and it may not be not until this variable is stabilized around the time of PHV that improvements in speed may be realized (17). Furthermore, the fact that all somatic variables were related (p < 0.05) to increased contact time pre-PHV, yet only mass was
related to increased contact time in the post-PHV group may serve to highlight
the influence of maturity on the performance in the sub-groups respectively.
Such observations may reinforce the need for specific training to offset the
increases in contact time seen with growth and maturation. It may therefore
be postulated that practitioners and youth athletes may wish to exploit the
untrainable aspects of maturation that naturally improve speed (e.g. leg length
and associated change in step length) whilst focusing upon factors that are
negatively influenced by maturity such as contact time and step frequency.
This approach to youth speed development is different to the philosophy of
some long term development models (1), whereby it is suggested the training
should target characteristics that are experiencing rapid natural development,
rather than those where decrements in performance are observed.
It is important to note that the somatic variables are only able to
explain a small proportion of the total variance in the spatiotemporal
characteristics of speed (11% - 57%). This level of explained variance
suggests that whilst the somatic variables play a role in aspects of youth
sprint performance, other more trainable characteristics, independent of the
somatic variables assessed in this study, may be able to better explain
maximal sprint performance in youth. For example, factors including
developmental changes in muscle fascicle length (11), pennation angle (2),
muscle-tendon junction size (12), musculo-tendon stiffness (27), and neural
firing rates (22) seen throughout childhood and adolescence may act
favorably to enhance sprint performance, but were not assessed in this study
and may warrant further research.
In conclusion, the results of this study suggest that it may be important for practitioners to use an integrated approach to developing speed, inclusive of training modes that are focused on enhancing neuromuscular function to synergistically complement (5) the growth-related changes in youth sprint performance observed in this study.

**PRACTICAL APPLICATIONS**

The results of the present study serve to highlight the contribution of somatic variables to spatiotemporal sprint characteristics in youth. The results indicated that boys who are pre-PHV may be deemed more step frequency reliant, whilst those post-PHV may be more step length reliant. Thus, practitioners with a pre-PHV population should focus on the development of neuromuscular qualities that may enhance movement efficiency, and lead to positive changes in step frequency, whilst those post-PHV may wish to try an optimise the production of GRF to facilitate optimal step length. Practically it is suggested that for those aiming to enhance the development of speed, modalities such as technical drills, plyometric training and strength development should be used; training modes that are proven to be safe and effective in youth of all stages of maturation (5,30). Furthermore, boys seeking to optimise speed development may wish to enhance their relative strength via resisted strength training. This focus may also serve to offset the negative influence of increased body mass (29), which in turn may also result in beneficial synergistic adaptations (5) derived from growth- and maturity-related changes in stature. Whilst further longitudinal research is needed to verify these claims, it could be suggested that such an approach
may facilitate the development of neuromuscular qualities to cope with
growth-related changes in somatic variables that would not only enhance
acute sprint performance, but also serve as a stable platform to enhance the
long-term development of maximal sprint speed.

The regression equations presented in this study can also be used
to predict expected gains in sprint performance due to changes in body size.
For example, the mean stature (1.56 m), leg length (0.77 m) and mass (51.4
kg) in the present study represent values approximately aligned with the 50th
percentile for an average 13 year old boy (3,14). Based on the expected
change in the somatic variables over a two-year period (3), the regression
equations indicate a 0.6 m.s^{-1} improvement in sprint speed. Whilst the level of
explained variance is quite low (~38%), this change in performance is derived
in-part from growth-related changes, and therefore practitioners could utilise
these data to anticipate changes in maximal sprint performance in boys with
advancing age.

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