TITLE
THE INFLUENCE OF AGE AND MATURATION ON SPRINT FORCE-POWER-VELOCITY CHARACTERISTICS IN BOYS

AUTHOR
Morris, Stephanie

DATE DEPOSITED
26 September 2017

THE INFLUENCE OF AGE AND MATURATION ON SPRINT FORCE-POWER-VELOCITY CHARACTERISTICS IN BOYS

by

Stephanie J. Morris

First Supervisor : Jon E. Goodwin

Second Supervisor : Dan J. Cleather

This Research Project is submitted as partial fulfilment of the requirements

for the

degree of Master of Science, St Mary's University

Table of Contents **Page Number**

List of Tables **Page Number**

List of Figures **Page Number**

List of Appendices **Page Number**

ACKNOWLEDGEMENTS

I would like to thank my dissertation supervisor's Dr Jon Goodwin and Dr Dan Cleather for their support and guidance throughout this research project.

ABSTRACT

The purpose of the study was to investigate the influence of age and maturation upon force-power-velocity (F-P-v) characteristics in a large cohort of boys. Three-hundred and sixty-two boys (9-14 years) volunteered to participate. Participants completed a series of anthropometric measurements including; standing height, seated height and body mass in addition to a 40m maximal sprint. Participants were grouped according to predicated years from peak height velocity (PHV) (pre-PHV and circum-PHV) and chronological age (U12, U13, U14, U15 and U16). From the split times, horizontal force-velocity and power-velocity relationships were derived using a previously validated method. Maximal theoretical horizontal force (F_0), relative maximal theoretical horizontal force (R. F_0), maximal theoretical velocity (V_0), maximum power (P_{max}), relative maximum power (R. P_{max}), velocity at peak power production (V_{opt}), force at peak power production (F_{opt}) and the decrease in the ratio of horizontal- to- resultant ground reaction force to the increase in velocity (D_{rf}) were determined from the force-velocity and power-velocity relationships. All variables, excluding D_{rf} (CV= 12.7 - 12.8, r= 0.328 - 0.362) (CV >10%; r=low correlation), were shown to exhibit acceptable levels of reliability. P_{max} was found to be significantly greater with increasing age ($p < 0.05$) Furthermore, F_0 was significantly ($p < 0.05$) greater with increasing age from U13. All F-P-v variables, excluding D_{rf}, were significantly greater ($p \leq 0.05$) in the circum-PHV group in comparison to the pre-PHV group. Additionally, from the pre-PHV to the circum-PHV group the difference in F_0 was of a higher magnitude than the difference in V_0. The study demonstrated that differences in the F-P-v profile may exist as a result of age and maturation. It appears that around the onset of puberty, boys show an increased reliance on the ability to generate high levels of force in addition to a reduction in the ability to apply such force at faster velocities.

KEY WORDS

Youth, Speed, Acceleration

CHAPTER ONE

INTRODUCTION

1.0 Introduction

Sprint speed has been shown to differentiate between elite and sub-elite athletes and is therefore often associated with team selection in youth (8). Furthermore, sprint performance is considered to be an essential physical quality that underpins youth physical development (15). Sprint efforts across field and court sports are typically short in duration (4,14,19,29), therefore the acceleration phase during sprint running, characterized by the ability to rapidly increase velocity over short distances (35), may be of primary concern within youth athlete development (15).

The natural development of speed throughout childhood and adolescence is a non-linear process, with evidence to suggest periods of accelerated development in sprint performance exist (28,31). Sprint speed performance in boys has been reported to improve markedly with age from 7 years until approximately 15 years of age, after which the rate of decease has been shown to lessen (31). Evidence further suggest a relationship between maturity related physical and physiological characteristics and speed development (31). Prior to the onset of puberty, boys show improvements in sprint speed performance which may be primarily attributed to increased neuromuscular function, with enhanced neuromuscular recruitment and motor co-ordination, coinciding with adaptations in the central nervous system (2). 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 prior to the onset of peak height velocity (PHV) (17). Later improvements in sprint speed performance are suggested to coincide with circa- and post- PHV (21,31). These improvements may be primarily attributed to endocrine-mediated development (8,28), with concomitant increases in muscle cross-sectional area (7), maximal strength, rate of force development (17) and leg stiffness (32) also occurring during this period. This is supported by research to suggest training modes targeting both neural and structural development (strength and plyometric) may elicit superior adaptations in adolescents (17,32).

Research has explored the effects of maturation on the kinematics and kinetics associated with maximum sprint velocity in boys, with findings to suggest spatiotemporal characteristics of maximal velocity sprinting also differ as maturation is experienced (21,31). Younger boys are shown to be more reliant on stride frequency (21,31). Adolescent boys, on the other hand, are shown to be more reliant on stride length (21). This increase in stride length evident around the time of PHV may be attributed to an increase in limb length (28). However, when stride length is normalised to leg length, significant differences still exists between boys of pre-and post-PHV (31). This indicates that other variables such as power may greater explain changes in step length throughout maturation, especially given that power has been shown to trend similarly to changes in step length among youth boys (31). In support, sprint performance has been shown to highly correlate to maximal power output (25,30).

Independent from power, the force-velocity (F-v) mechanical profile has recently been shown to influence sprint performance, with research suggesting that to maximize performance, an optimal F-v balance may exist for individuals (33). Information regarding any differences in this relationship at different stages of maturation would therefore provide a useful insight into the influence of maturation on mechanical outputs in sprint performance among youth athletes.

In comparison to maximal velocity sprinting, during acceleration, the orientation of the total force applied is deemed more important than the magnitude of total force (30). This is supported by positive correlations between sprint acceleration performance and maximal horizontal force (25,33). The overall mechanical capability to produce horizontal external force in sprint running can be well described by force-power-velocity (F-P-v) profiling, which provides a means identifying the forces that an individual can produce at given velocities, summarised by the following variables; maximal theoretical horizontal force (F_0), maximal theoretical horizontal velocity (V_0) and maximum horizontal power output (P_{max}). Force-velocity (F-v) relationships during running propulsion also integrate the ability to apply the external force effectively onto the ground (13, 33), quantified by the decrease in the ratio of horizontal- to- resultant ground reaction force to the increase in velocity (D_{rf}). While previous methods of such profiling have required the use of an instrumented treadmill or floor mounted force places over a sprint distance (26,32), the theoretical model recently validated by Samozino et al. (33) enables the F-v and power-velocity (P-v) relationships in sprint acceleration to be determined via simple field based measurements.

The interrelating determinants of the F-P-v profile in sprinting encompass many of the mechanical limits of neuromuscular function including; individual muscle mechanical properties such as the intrinsic F-v relationship, the length tension relationship and the rate of force development; muscle morphological factors such as muscle fibre composition, cross-sectional area, fascicle length, pennation angle and musculo-tendon properties; and neural mechanisms such as motor unit recruitment, firing frequency, motor unit synchronization and intermuscular co-ordination (3). Since adaptations to many of these factors are suggested to occur throughout maturation (2,7,17,31), and variance in spatiotemporal characteristics are apparent throughout maturation (21,31), differences in the way in which boys produce power during maximal sprinting appear likely. Prior to PHV, boys may show a deficit in force production, due to a poor ability to effectively apply force through the lower limbs, as suggested by an increased reliance on stride frequency at this stage of maturation (21,31). In contrast, during circa- and post- PHV, as a result of naturally occurring mechanical and morphological changes, an imbalanced F-v profile orientated towards force production may be evident.

It is clear from the research that identifying a single mechanism responsible for improved speed during childhood is unlikely, however exploring the effect age and maturation on the sprint F-v and P-v characteristics may help to provide a clearer picture of the mechanical variables accountable for change. The aim of the study was to investigate the influence of age and maturation upon F-P-v characteristics in a large cohort of boys. As a result of concomitant maturity-related adaptations (21,31), it was hypothesized that a more force-oriented profile would be evident around the onset of PHV and a more velocity-orientated profile would be evident throughout childhood. To the authors' knowledge, no data currently exists exploring the F-P-v relationships in sprint performance among youth athletes. Hence, there was a need to explore the reliability of these measurements to better to better inform interpretation. Therefore, the current study will also examine the reliability of F-P-v profiling in youth boys.

CHAPTER TWO

METHODS

2.1 Experimental Approach to the Problem

The study used a cross-sectional experimental design to determine the influence of age and maturation on the F-P-v characteristics in male youth. *Figure 1* details the data collection stages and flow of participants through the current study. From an existing dataset (Data collection 1), collected by Meyers et al., (23), anthropometric measures (standing height, sitting height, mass) and split times during a 40m maximal sprint were obtained for a large sample of school-aged boys. In order to accurately model the F-P-v relationships for this dataset, the time at which the initial force production occured, representative of the actual start of the sprint was required (33). However, the photo-electric timing method employed in data collection 1(23) included no measurement of the initial velocity prior to the trigger of the first gate. Since a large fraction of this cohort were either no longer available or had moved beyond the maturational group to which they were originally assigned, an additional sample of male youths were recruited (Data Collection 2) to determine the offset value, indicative of the time taken between the beginning of the force production and the trigger of the timing gate, that should to be applied to the dataset from data collection 1. Linear F-v and parabolic P-v profiles were then derived via sprint times corrected with the offset value.

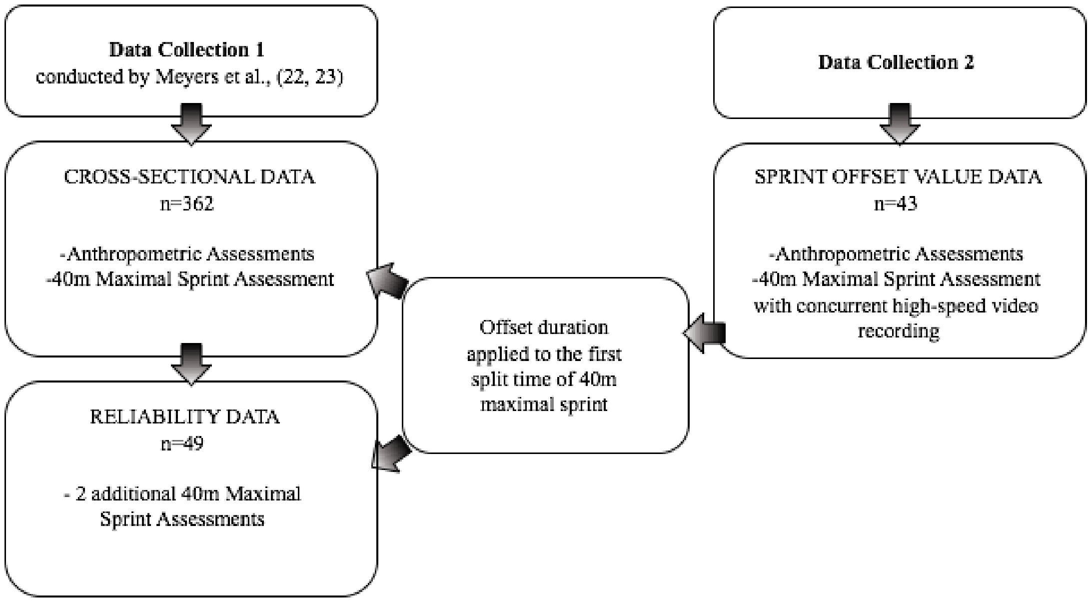

Figure 1. A schematic of the data collection stages and flow of participants.

A maturity offset, representative of the years a participant is estimated from PHV, was calculated for each participant via anthropometric measurements (standing height, sitting height, mass). To allow age and maturity related differences across all variables to be examined in the cross- sectional dataset, participants were grouped according to predicted years from PHV (24) and chronological age.

The reliability of F-P-v characteristics in youth boys was calculated by means of a sub-group from the cross-sectional dataset (22), see *Figure 1*. To better inform interpretations of the current study findings, linear F-v and parabolic P-v profiles from 40m maximal sprints on three separate occasions were derived for each participant allowing the test-retest reliability to be assessed.

2.2 Subjects

The cross-sectional dataset included three-hundred and sixty-two school boys (age 13.03 ± 1.28 years, age range = 11.08-16.05 years) who volunteered to participate in the study (23). Forty-nine of these participants volunteered to participate in the additional reliability data collection, identified as the reliability (Reli) sub-group (age = 14.14 ± 0.75 years, age range = 12.85-15.67 years) (22). While the participants were recruited, and tested during physical education classes, participation was voluntary and they were free to withdraw at any time. All subjects were injury free at the time of testing and were all regularly participating in bi-weekly physical education classes, lasting 60 minutes in duration. Information regarding the participants' habitual and sporting activities outside of the physical education curriculum was not obtained, however none of the participants were engaged in formal strength and conditioning programs as determined by questionnaire. All participants were instructed to wear the same clothing and footwear for each testing session and refrain from physical activity 24 hours prior to testing.

A similarly matched group of forty-three academy soccer players from Cardiff Metropolitan's Boys Junior Football programme, volunteered to participate in the additional data collection (Data collection 2) required for the current study (age = 10.90 ± 1.19 years, age range = 9.04-13.84 years). Descriptive details (mean ± standard deviation) for all anthropometric variables for each group are provided in *Table 1.* All participants were instructed to wear the same clothing and footwear for each testing session and refrain from physical activity 24 hours prior to testing.

Prior to any data collection, all participants were informed of the benefits and risks of the investigation and written parental consent and participant assent was obtained in addition to the completion of a physical activity questionnaire. Ethical approval for the data collection by Meyers et al (22,23) was granted by Cardiff Metropolitan University's research ethics committee. Further ethical consent was granted by Cardiff Metropolitan University's research ethics committee for the data to be used within the current study. St Marys University's research ethics committee granted ethical approval for the data collection 2.

Table 1. Mean (± SD) of all descriptive variables for the offset, reliability, chronological age and maturity groups.

Group	Age (yrs)	Standing height (cm)	Sitting height (cm)	Body mass (kg)	Maturity offset (yrs from PHV)
Offset (n=43)	10.90 ± 1.19	142.44 ± 16.17	75.63 ± 5.31	39.00 ± 9.59	-1.94 ± 1.08
Reli (n=49)	14.14 ± 0.75	163.34 ± 9.20	81.14 ± 5.1155	55.10 ± 13.45	-0.31 ± 0.90
U12 (n=88)	11.59 ± 0.29	146.69 ± 8.17	74.64 ± 4.02	42.78 ± 10.78	-2.26 ± 0.58
U13 (n=22)	12.47 ± 0.27 *	151.41 ± 8.73 *	75.30 ± 4.48	46.92 ± 12.82	-1.78 ± 0.64 *
U14 (n=59)	13.46 ± 0.27 *	158.56 ± 8.40 *	79.79 ± 4.62 *	52.98 ± 13.35 *	-0.78 ± 0.69 *
U15 (n=59)	14.46 ± 0.28 *	165.08 ± 8.42 *	82.85 ± 4.96 *	61.24 ± 14.60 *	0.13 ± 0.76 *
U16 (n=34)	15.55 ± 0.28 *	171.66 ± 8.39 *	86.36 ± 4.45 *	66.34 ± 13.99 ^	1.13 ± 0.71 *
Pre-PHV (n=115)	11.94 ± 0.55	143.34 ±5.65	71.93 ± 2.69	37.54 ± 6.14	-2.47 ± 0.33
Circum-PHV (n=112)	13.95 ± 0.92 #	163.64 ± 6.57 #	82.30 ± 3.20 #	59.20 ± 12.20 #	-0.20 ± 0.57 #

Reli= Reliability, PHV= Peak Height Velocity

* = Sig. greater than all younger age groups ($p \leq 0.05$), ^ = Sig. greater than U12, U13, U14 groups only ($p \leq 0.05$), # = Sig. greater than pre-pubertal ($p \leq 0.05$).

2.3 Procedures

Testing for the cross-sectional analysis took place over the course of a two-week period. All participants were required to complete an assessment of biological maturity and sprint test during a single testing session. Those who additionally provided reliability data were required to attend a further two testing sessions separated by a minimum of 24 hours during which they were required to perform a sprint test at each of the testing sessions. All testing for the offset group took place over a two-day period during which all participants were required to complete an assessment of biological maturity and sprint test during a single testing session. All assessments were conducted in an indoor sports hall, with the equipment standardised for each testing session. No wind was present during the indoor testing session and the very limited effect of air humidity on air density was not considered.

Assessment of Biological Maturity

All participants were required to take part in a series of anthropometric measurements including; standing height, seated height and body mass. Standing and seated height was measured using a portable stadiometer (SECA321, Vogel & Halke, Hamburg, Germany) and body mass was measured using portable scales (SECA770, Vogel & Halke, Hamburg, Germany). Participants were required to remove footwear for all anthropometric assessments. Maturity offset was then calculated using a previously validated, sex-specific regression equation [Equation 1(24)]. This non-invasive method calculates a maturity offset representative of the years a participant is estimated from PHV, with a standard error of estimate (SEE) of ± 0.592 years (24).

Maturity offset (boys)

= -9.236

+(0.0002708*(leg length*sitting height))

−(0.001663*(age*leg)) length))

+(0.007216*(age*sitting height)

+(0.02292*((Body mass/standing height)*100)

[Equation 1; (24)]

Sprint Test

Following a 15 minute standardised warm up, inclusive of a familiarisation sprint trial, participants were required to perform two maximal sprints over a 40m distance. Participants started in a split stance position, with the front foot on a tape line positioned 50cm behind the start timing gate (0 m gate). Participants were given the instructions ‘two’, ‘one’, ‘go’ and instructed to sprint maximally down the track. Split times were measured with pairs of photoelectric timing gates (Smartspeed, FushionSport, Brisbane, Australia) located at 0m, 5 m, 10m, 15m, 20 m, 25 m, 30 m and 35m. The finish line was marked at 40m and all participants received verbal encouragement throughout each trial to help ensure maximal speed throughout the sprint, devoid of deceleration. A minimum of 4 minutes passive rest was given between trials to ensure sufficient recovery. For each sprint, the photoelectric timing gate was triggered when the participants largest segment passed through the timing gate. Therefore, this timing method failed to obtain initial velocity prior to the trigger of the first gate. For all sprint trials completed by the offset group, the duration (s) from first movement, representative of force application, until the start of the largest body segment triggering the gate was determined using concurrent high- speed video recording (iPad Pro, Apple Inc., California, USA) (33). The mean (±SD) of this duration across the offset group was 0.624 ± 0.10. This value was then added to the first split time of the fastest trial for all participants in the cross-sectional and reliability groups.

Sprint Test Variables

In accordance with Samozino's method (33), the corrected split times at 0 m, 5 m, 10m, 15m, 20 m, 25 m, 30 m and 35 m along with the participants' height and body-mass were used to model the individual sprint- velocity time curves (V(t)) by a monoexponential function using least-square linear regression analysis:

$V(t) = V_{max}*(1-e^{-t/\tau})$

[Equation 2; (33)]

Where V_{max} is the maximal velocity reached at the end of the acceleration and τ is the acceleration time constant. Velocity over time was obtained by means of:

$a(t) = (Vmax/\tau)*e^{-t/\tau})$

[Equation 3; (33)]

From this, the net horizontal antero-posetrior ground reaction force (F_H) applied to the body centre of mass can be expressed as a function of time:

$F_H(t) = (m*a(t))+F_{aero}(t)$

[Equation 4; (33)]

Where m is the individual's body mass (kg) and F_{aero} (t) is the aerodynamic drag to overcome, calculated from sprint velocity and an estimated frontal area and aerodynamic friction coefficient (33). F-v relationships were extrapolated to obtain the theoretical maximal force the lower limbs can produce at null velocity (F_0) (N/kg) and the theoretical maximal velocity the lower limbs can extend under zero load (V_0)(m/s). As shown in *Figure 2,* F_0 and V_0 were identified as the intercepts of the F–v curve with the force and velocity axis, respectively. D_{rf} for each participant was computed as the slope of the linear F-v relationship, which represents the decrease in the ratio of horizontal- to- resultant ground reaction force to the increase in velocity, as shown in *Figure 2*. To remove the bias associated with modelling P_{max} as the apex of the parabolic P–v curve, P_{max} was calculated by means of:

$P_{max} = F_0 * V_0 / 4$

[Equation 5; (33)]

V_{opt} and F_{opt} were identified as the levels of each respective variable at which peak power production occurred, see *Figure 2*. Relative variables (relative F_0 and relative P_{max}) were determined by dividing the given absolute value by the participants' body mass (33). All variables were modelled over the whole sprint acceleration, thus correspond to step-averaged values, without considering intra-step changes.

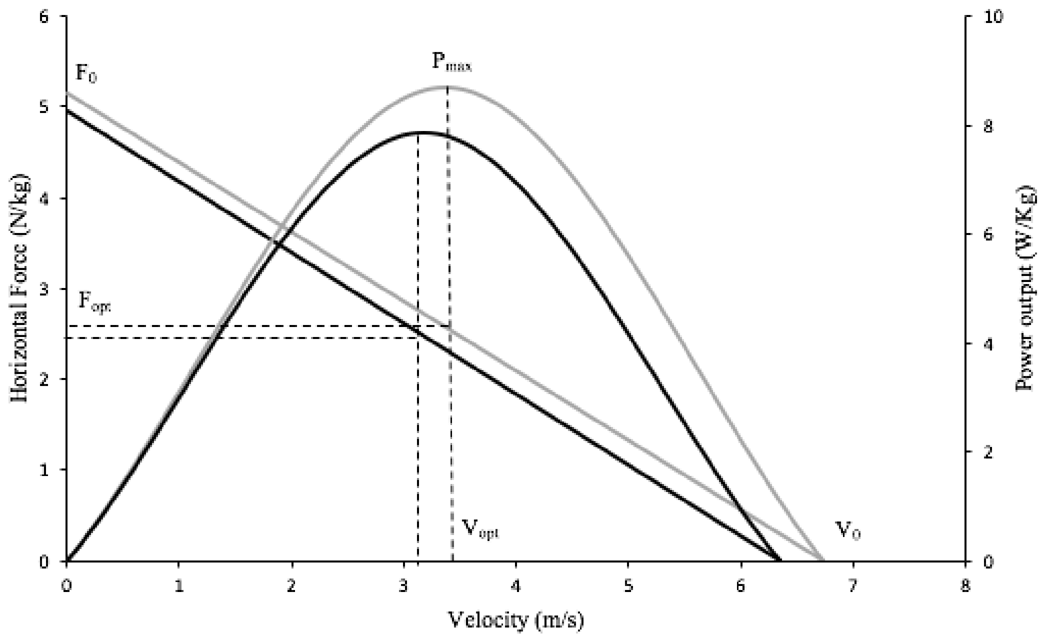

Figure 2. A graphical representation of the Force-Power-velocity profiles and associated optimal force and velocity values relative to power output for pre-PHV(black) and circum-PHV(grey) boys over a 40m over-ground sprint.

2.4 Statistical Analysis

Test-to-test reliability was assessed for all F-P-v variables through change-in-the-mean, coefficients of variation (CV) and intraclass correlation coefficients (ICC). These measures were calculated by means of a Microsoft Excel spreadsheet (version 15.24, Microsoft Excel for Mac) created by Hopkins (10). Ninety-five percent confidence intervals (95% CI) were reported for all test variables. ICC values were interpreted as 0.90–1.00 = very high correlation, 0.70–0.89 = high correlation, 0.50–0.69 = moderate correlation, 0.26–0.49 = low correlation and 0.00–0.25 = little, if any correlation (9). Smallest worthwhile effect was calculated as 0.2 of the between participant standard deviation either between trials or across all trials to provide an overall measure (9).

For the subsequent cross-sectional analysis, participants were separated into chronological age groups and maturity groups. Based on the participants' chronological ages, the age groups were U12, U13, U14, U15 and U16. As determined by the participants predicated years from PHV, the maturity groups were expressed as pre- PHV and circum-PHV. The pre-PHV group were defined as participants with a maturity offset greater than 2.0 years from PHV, while the circum- PHV group was inclusive of participants with a maturity offset range of 1.0 to -1.0 years from PHV. This process resulted in the exclusion of 140 participants. However, based on the reported measurement accuracy of the maturity offset regression equation applied (SEE ± 0.592 years), it may be suggested that such approach facilitated a valid application of the equation.

Descriptive statistics (mean $\pm$ SD) were produced for all F-P-v characteristics for each maturity and chronological group. A one-way analysis of variances (ANOVA) was used to examine for differences in F-P-v characteristics between groups. Homogeneity of variance was assessed via Levene's statistic and where violated, Welch's adjustment was used to correct the F-ratio. Significant difference between groups was specified by Bonferroni or Games- Howell post hoc analysis, where equal variances were and were not assumed, respectively. All data analysis was conducted through the Statistical Package for the Social

Sciences (SPSS for Mac (version 22.0, SPSS, Inc., Chicago, IL, USA)). For all statistical analysis, p value ≤ 0.05 was accepted as the level of statistical significance.

CHAPTER THREE

RESULTS

3.0 Results

Mean and standard deviations all of the F-P-v variables over the three testing sessions for the reliability group are presented in *Table 2*. There were no systematic changes observed in F_{0}, D_{rf} and F_{opt}, with no significant differences between tests 1,2 and 3. For relative F_0 (R. F_0), test 2 and 3 were significantly different. For V_0 and V_{opt}, tests 2 and 3 were significantly different ($p \leq 0.5$) to test 1. For P_{max} and for relative P_{max} (R. P_{max}), significant differences ($p \leq 0.5$) were noted between tests 1 and 2 and tests 2 and 3.

CV, ICC and smallest worthwhile change for all F-P-v variables can be observed in *Table 2*. The CV over the three tests was lowest for V_0 (4.5 - 3-8%) and V_{opt} (4.5 - 3.7%). However, all variables other than D_{rf} were below the 10% threshold often used to determine test reliability (11,22). Overall, P_{max} was found to be the most consistent variable, with a very high intra-class correlation (r= 0.952 - 0.945). High intra-class correlations were identified for F_0 (r= 0.892 - 0.874), V_0 (r= 0.865 - 0.900), R. P_{max} (r= 0.872 – 0.873), V_{opt} (r= 0.864 - 0.901) and F_{opt} (r= 0.891 - 0.875).

Table 2. Mean (± SD) of F-P-v characteristics in the reliability group over 3 trials.

	Mean ± Standard Deviation		
	Test 1	**Test 2**	**Test 3**
F_0 (N)	305.83 ± 79.59	295.28 ± 79.44	307.92 ± 80.63
R. F_0 (N/kg)	5.54 ± 0.45	5.37 ± 0.59	5.57 ± 0.39^
V_0 (m/s)	7.23 ± 0.80	7.05 ± 0.81*	7.12 ± 0.77*
P_{max} (W)	555.96 ± 168.55	524.54 ± 166.84*	552.75 ± 173.11^
R. P_{max} (W/kg)	10.04 ± 1.57	9.48 ± 1.64*	9.96 ± 1.56^
D_{rf}	-0.77 ± 0.08	-0.77 ± 0.11	-0.79 ± 0.07
V_{opt} (m/s)	3.62 ± 0.40	3.53 ± 0.40*	3.56 ± 0.39*
F_{opt} (N)	152.78 ± 36.67	147.66 ± 39.75	154.02 ± 40.31

* = Sig. different to test 1 ($p \leq 0.05$), ^ = Sig. different to test 2 ($p \leq 0.05$).

Table 3. Coefficients of variation, intra-class correlations (95% confidence intervals in brackets) and smallest worthwhile change for all F-P-v variables in the reliability group.

	Coefficients of Variation (%)		Intra-class Correlation		Smallest Worthwhile Change		
	T2-1	T3-2	T2-1	T3-2	T2-1	T3-2	Overall
F_0 (N)	9.3 (7.7:11.7)	9.8 (8.1:12.4)	0.89 (0.82:0.94)	0.87 (0.79:0.93)	5.669	5.611	5.640
R. F_0 (N/kg)	9.3 (7.7:11.7)	9.8 (8.1:12.4)	0.45 (0.19:0.65)	0.36 (0.09:058)	0.080	0.079	0.080
V_0 (m/s)	4.5 (3.7:5.7)	3.8 (3.1:4.7)	0.87 (0.77:0.92)	0.90 (0.83:0.94)	0.053	0.054	0.054
P_{max} (W)	7.7 (6.4:9.7)	8.0 (6.6:10.0)	0.95 (0.92:0.97)	0.95 (0.91:0.97)	7.986	7.912	7.949
R. P_{max} (W/kg)	7.7 (6.4:9.7)	8.0 (6.6:10.0)	0.87 (0.78:0.93)	0.87 (0.79: 0.93)	0.117	0.117	0.117
D_{rf}	12.7 (10.4:16.1)	12.8 (10.5-16.2)	0.36 (0.09:0.05)	0.33 (0.05:0.56)	0.016	0.016	0.016
V_{opt} (m/s)	4.5 (3.7:5.7)	3.7 (3.1:4.7)	0.86 (0.77:0.92)	0.90 (0.83:0.94)	0.026	0.027	0.027
F_{opt} (N)	9.3 (7.7:11.8)	9.8(8.1:12.3)	0.89 (0.82:0.94)	0.88 (0.79:0.93)	2.827	2.801	2.814

The age-group comparisons in F-P-v variables are presented in *Table 4.* The results show P_{max} was shown to be significantly greater ($p \leq 0.05$) over increasing age. Likewise, such relationship was evident when P_{max} was relative to the participants' body mass, however not all changes were found to be significant. The U16 age group was shown to have a significantly higher ($p \leq 0.05$) R. P_{max} than all other groups. Additionally, R. P_{max} in the U14 age group was significantly higher ($p \leq 0.05$) than the U12s and R. P_{max} in the U15 group was significantly higher ($p \leq 0.05$) than the U12 and U13 age groups.

A similar pattern exists for F_0, with the U14, U15 and U16 age groups all producing significantly greater ($p \leq 0.05$) F_0 than all younger counterparts. Such relationship was not consistent when F_0 was relative to the participants' body mass, only the U15 age group having a significantly higher R. F_0 ($p \leq 0.05$) than all younger age groups (U12, U13 and U14). F_{opt} was found to be greater with increasing age, although not all differences were significant. V_0 typically was typically greater with increasing age, however this was not true in the U15 age group who had a lower V_0 when compared to the U14 age group. Similarly, V_{opt} typically was found to be greater with increasing age, however, this was again not true in the U15 age group who show no change in V_{opt} in comparison to the U14 group. As previous, significant differences were not evident across all age groups; specifically, the U14 and U15 age groups show significantly higher ($p \leq 0.05$) V_{opt} than the U12 age group, while V_{opt} in the U16s was found to be significantly higher ($p \leq 0.05$) than all other age groups. D_{rf} was shown to vary across the age groups; the D_{rf} in the U16s was found to be significantly lower than the U12, U13 and U15 age groups and the D_{rf} in the U14s was found to be significantly lower than the U12 age group.

The maturity group comparison in F-P-v variables are presented in *Table 5*. Significant differences ($p \leq 0.05$) were observed between pre-PHV and circum-PHV subgroups for all F-P-v variables with the exception of D_{rf}, which was found to be only marginally lower in the circum-PHV group. Specifically, all F-P-v variables, excluding D_{rf}, were found to be significantly greater in the circum-pubertal group in comparison to the pre-pubertal group.

Table 4. Chronological age group analysis of F-P-v variables.

Group	F_0 (N)	R. F_0 (N/kg)	V_0 (m/s)	P_{max} (W)	R. P_{max} (W/kg)	D_{rf}	V_{opt} (m/s)	F_{opt} (N)
U12	210.08 ± 54.15	4.95 ± 0.51	6.15 ± 0.65	321.16 ± 80.25	7.62 ± 1.22	-0.81 ± 0.11	3.08 ± 0.32	105.08 ± 27.10
U13	228.91 ± 66.86	4.90 ± 0.47	6.29 ± 0.70	355.60 ± 91.54 ^{e}	7.71 ± 1.18	-0.79 ± 0.12	3.14 ± 0.35	114.46 ± 33.43
U14	262.28 ± 71.20 ^{e}	4.96 ± 0.43	6.69 ± 0.85 ^{e}	437.31 ± 128.06 ^{e}	8.32 ± 1.45 ^{a}	-0.75 ± 0.10 ^{a}	3.34 ± 0.43 ^{a}	131.13 ± 35.56 ^{e}
U15	324.34 ± 89.17 ^{e}	5.31 ± 0.57 ^{e}	6.68± 1.03 ^{a}	536.96 ± 141.24 ^{e}	8.88 ± 1.67 ^{ab}	-0.82 ± 0.18	3.34 ± 0.52 ^{a}	162.13 ± 44.65 ^{e}
U16	346.21 ± 74.11 ^{e}	5.17 ± 0.48 ^{b}	7.64 ± 0.92 ^{e}	662.42 ± 158.85 ^{e}	9.92 ± 1.65 ^{e}	-0.68 ± 0.09 ^{abd}	3.82 ± 0.46 ^{e}	173.01 ± 37.03 ^{abc}

^{a} = Sig. greater than U12 only ($p \leq 0.05$); ^{b} = Sig. greater than U13 only ($p \leq 0.05$); ^{c} = Sig. greater than U14 only ($p \leq 0.05$); ^{d} = Sig. greater than U15 only ($p \leq 0.05$), ^{e} = Sig. greater than all younger age groups ($p \leq 0.05$).

Table 5. Maturity group analysis of F-P-v variables.

Group	F_0 (N)	R. F_0 (N/kg)	V_0 (m/s)	P_{max} (W)	R. P_{max} (W/kg)	D_{rf}	V_{opt} (m/s)	F_{opt} (N)
Pre-Pubertal	185.34 ± 35.59	4.95 ± 0.45	6.34 ± 0.58	293.28 ± 56.75	7.85 ± 1.07	-0.79 ± 0.10	3.17 ± 0.29	92.67 ± 17.77
Circum-Pubertal	304.31 ± 71.92^{a}	5.14 ± 0.54^{a}	6.74 ± 1.00^{a}	508.44 ± 117.55^{a}	8.68 ± 1.67^{a}	-0.78 ± 0.16	3.37 ± 0.50^{a}	152.13 ± 35.96^{a}

^{a} = Sig. greater than pre-pubertal ($p \leq 0.05$).

CHAPTER FOUR
DISCUSSION

4.1 Reliability Analysis

Measurement errors across all F-P-v variables appear higher than those seen in adult populations tested via the same method (SEE <5%) (33), however such findings may be expected due to the higher variability typically found in youth performance measures in comparison to adults (6). Nevertheless, it would seem from the results of this study that the F-P-v determinants in sprint running obtained via a simple field method proposed by Samozino et al. (33) may exhibit acceptable levels of reliability, with all variables except the decrease in ratio of force possessing coefficients of variation below the 10% threshold, which may be recommended as the upper limit to determine test reliability (11,22). The decrease in ratio of force may be deemed an unreliable measurement, owing to coefficients of variation above the recommended threshold of 10% (CV= 12.7 - 12.8%) in addition to moderate intra-class correlations (r= 0.328 - 0.362). Based on the findings, use of the decrease in ratio of force to establish inter and/or intra-individual variation in F-P-v profiles in maximal sprinting in youth boys is discouraged. It may be suggested that maximal theoretical velocity and the velocity at which peak power production occurred are the most reliable variables, with high levels of retest correlation and low levels of random variation (r= 0.865 - 0.900, CV= 3.8 – 4.5% and r= 0.864 - 0.901, CV= 3.7 – 4.5%, respectively).

Significant changes in the mean between testing occasions, indicative of random change or systematic bias (9), were evident for several variables including: maximal theoretical velocity, maximum power, relative maximum power and velocity at peak power. Such systematic bias is difficult to rationalize due to its multifactorial nature (9); however, it may suggest the need for more than one familiarisation sprint trial to reduce the potential effect of learning, or the use of a mean value across more sprint trials to reduce between trial variation (11), although further research is required to warrant such recommendations.

Such findings are important owing to the lack of published data related to the measurement errors of this method to evaluate mechanical properties of sprint running in youth populations. The reliability measures reported in the current study would be most applicable to researchers and/or practitioners using similar equipment and data collection methods to those used in the current study. The smallest worthwhile change presented in *Table 3* may provide an additional useful insight into the use of F-P-v variables for monitoring changes in athletic performance in youth populations. When observed changes in F-P-v variables exceed the relevant minimal values (as shown in Table 3), they may be considered as a meaningful change (9).

4.2 Age Group Analysis

The main aim of the current study was to explore the influence of age and maturity of F-P-v characteristics during maximal sprinting in boys. In the current study, all F-P-v variables, other than maximum power, were similar between the two younger age groups (U12 and U13's). Since body mass was found to be higher in the U12 gorup in comparison to the U13s, the mechanisms of higher power production in the U13 age group may appear to be associated with enhanced neuromuscular recruitment and motor co-ordination rather than an increase body mass, often associated with changes in muscle cross-sectional area (7,27).

Higher maximal theoretical force, relative maximal theoretical force, maximal theoretical velocity, maximum power, relative maximum power, velocity at peak power and force at peak power and decrease in ratio of force was typically observed with advancing age. However, in the U15 age group in comparison to U14, theoretical maximal velocity was higher, the ratio of horizontal- to- resultant ground reaction force to the increase in velocity was higher and the velocity at peak power was the same. Additionally, the largest difference in force between the age groups was evident from the U14 to U15s, showing a 23.7% increase in theoretical maximal force and 7.1% when relative to body mass. These findings suggest this group shows an imbalanced F-v profile during maximal sprinting orientated towards force production, showing a deficit in velocity in comparison. Based on the descriptive statistics, which suggest this age group is in the cirum-pubertal stage of maturation, it may be speculated that this shift in orientation of the F-v profile coincides with a period deemed ‘adolescent awkwardness’ (28), during which individuals may be subject to a temporary reduction in co-ordination primarily due to alterations in limb length (28).

4.3 Maturity Group Analysis

The results of the study revealed all somatic measures (standing height, sitting height, body mass) in the circum-PHV group were significantly higher than the pre-PHV which would be expected as the child experiences maturation (18). The consistent difference in somatic measures evident between the maturity groups supports the prediction of maturity status and subsequent grouping in the current study.

Novel results show that maximal theoretical force, relative maximal theoretical force, maximal theoretical velocity, maximum power, relative maximum power, velocity at peak power and force at peak power were all significantly greater in the circum-pubertal group in comparison to the pre-pubertal group. Such findings support existing research that has observed maturity-related improvements in strength and power around the time of PHV (1,5) and provide evidence that such improvements are apparent in the dynamic mechanical capabilities of the lower limbs during sprint performance. It may be postulated that these significant changes from pre-pubertal to circum-pubertal are partially due to natural development changes in somatic variables (23), in addition to increases in muscle cross-sectional area (7), maximal strength, rate of force development (17) and leg stiffness (32).

In previous research exploring youth populations similarly matched to those in the current study, a concurrent increase in mass over increasing age was shown to be negatively associated with sprint performance, with additional mass failing to elicit positive increases in relative force production (23). In contrast, in the current study, the circum-pubertal group had a significantly higher mass accompanied by higher relative force output in comparison to the pre- pubertal group. It may be postulated that the negative influence of mass and difference in findings seen in the study by Meyers et al.,(23) was due to an increase in non- lean body mass. However, because body composition was not assessed an accurate conclusion on the mechanism of body mass change is difficult.

Although theoretical maximal force, theoretical maximal velocity and maximum power were significantly higher in the circum-PHV group in comparison to the pre-PHV group, the magnitude of the change in both theoretical maximal force and maximum power was substantially higher (64.2% and 73.4% increase, respectively) than the magnitude of change in theoretical maximal velocity (6.2%). Such findings give some support the study hypothesis that a more velocity-orientated profile would be evident prior to puberty and a more force-oriented profile would be evident around the onset of PHV. The low magnitude of change in theoretical maximal velocity between the groups may suggest the development and reliance on the ability to generate higher amounts of force at slower velocities around the onset of puberty.

From the current study, it is evident that the decrease in ratio of forces over the duration of the acceleration does not show a significant change with maturation. Importantly however, such findings must be interpreted with caution due to the lack of reliability in this measure, as demonstrated in the reliability analysis. The ratio of horizontal- to- resultant ground reaction force to the increase in velocity may be used to quantify the technical ability of force application over the entire acceleration phase (33). Hence, changes in absolute theoretical force, absent from changes in the ability to maintain a greater net horizontal force over the sprint observed in the circum-pubertal group may suggest the need improve the ability to apply force at faster velocities. This may be best achieved by improving the individual's physical capacity to produce force at faster velocities, via velocity specific strength training, or improvements in technical ability of force application. Existing research on adult populations advocates training with heavy sled drags, with the forward orientation position decreasing the vertical impulse production and teaching athletes to better direct GRF impulse more horizontally (13). Additionally, given suggestions that hamstring function is highly related to horizontal force production during sprinting (20) it could be recommended that training to elicit improvements in hamstring strength in circum-pubertal boys may reduce the apparent decrease in the ratio of force evident throughout acceleration.

The findings presented should be viewed in the context of the limitations in the study design. While the current study utilised a large cohort, the cross-sectional nature of the analysis allows only a comparison between participants of differing ages and maturity status' rather than measuring the change in youth participants as they age and mature. This may result in different interpretations regarding the influence of age and maturation on the F-P-v profile compared to longitudinal studies (34).

CHAPTER FIVE

PRACTICAL APPLICATIONS

5.0 Practical Applications

The results of this study indicate that the time around PHV may be a key period in the improvement in sprint speed in boys. Research suggests an optimal F-P-v profile exists in ballistic movements and training to work on athlete's weakness in comparison to strengths in relation to the optimal profile elicits superior training results in comparison to training on existing strengths (12). Hence on this basis, as a result of the current findings, it may be recommended that training during the pre-pubertal stage of maturation should aim to develop force producing capabilities. Training at the circum-pubertal stage however should focus on improving velocity capabilities, in addition to technical capability over increasing velocity.

On the contrary, youth physical development literature suggests the training approach should target characteristics that are experiencing rapid natural development (17). Hence in contrast, based on current findings it may be recommended that training during the pre-pubertal stage of maturation should focus primarily on developing the ability to produce force at higher velocities, while training during the circum-pubertal stage of maturation should focus on the development of the both force and velocity, improving the ability to generate high levels of force at high velocities. Such recommendations are in accordance with existing research, which suggests training pre-PHV should focus on developing technique and co-ordination (31).

With such ambiguity in training recommendations, future studies employing training interventions based on F-P-v profiling in sprinting for youth populations are recommended. This would help to determine the most advantageous training approach and better establish the interaction of maturation with training.

REFERENCES

1. Beunen, G, and Malina, RM. Growth and physical performance relative to the timing of the adolescent spurt. *Exercise and Sport Sciences Reviews* 16(1): 503-540, 1988.
2. Cliff, DP, Okely, AD, Smith, L, and McKeen, K. Relationships between fundamental movement skills and objectively measured physical activity in pre-school children. *Pediatric Exercise Science* 21(4): 436-439, 2009.
3. Cormie, P, McGuigan, MR, and Newton, RU. Developing maximal neuromuscular power. *Sports Medicine* 41(1): 17-38, 2011.
4. Davidson, A, and Trewartha, G. Understanding the Physiological Demands of Netball: a time-motion investigation. *International Journal of Performance Analysis in Sport* 8(3): 1-17, 2008.
5. Forbes, H, Bullers, A, Lovell, A, McNaughton, LR, Polman, RC, and Siegler, JC. Relative torque profiles of elite male youth footballers: effects of age and pubertal development. *International Journal of Sports Medicine* 30(8): 592-597, 2009.
6. Gerodimos, V, Zafeiridis, A, Perkos, S, Dipla, K, Manou, V, and Kellis, S. The contribution of stretch-shortening cycle and arm-swing to vertical jumping performance in children, adolescents, and adult basketball players. *Pediatric Exercise Science* 20(4): 379-389, 2008.
7. Granacher, U, Goesele, A, Roggo, K, Wischer, T, Fischer, S, Zuerny, C, Gollhofer, A, and Kriemler, S. Effects and mechanisms of strength training in children. *International Journal of Sports Medicine* 32(5): 357-364, 2011.
8. Gravina, L, Gil, SM, Ruiz, F, Zubero, J, Gil, J, and Irazusta, J. Anthropometric and physiological differences between first team and reserve soccer players aged 10-14 years at the beginning and end of the season. *The Journal of Strength & Conditioning Research 22(4):* 1308-1314, 2008.

9. Hopkins, WG. Measures of reliability in sports medicine and science. *Sports Medicine* 30(1): 1-15, 2000.
10. Hopkins, WG. Reliability from consecutive pairs of trials (Excel spreadsheet). *A new view of statistics*. Internet, 2000.
11. Hunter, JP, Marshall, RN, and McNair, P. Reliability of biomechanical variables of sprint running. *Medicine and Science in Sports and Exercise* 36(5): 850-861, 2004.
12. Jiménez-Reyes, P, Samozino, P, Brughelli, M, and Morin, JB. Effectiveness of an individualized training based on force-velocity profiling during jumping. *Frontiers in Physiology* 7(1):677, 2017.
13. Kawamori, N, Newton, RU, Hori, N, and Nosaka, K. Effects of weighted sled towing with heavy versus light load on sprint acceleration ability. *The Journal of Strength & Conditioning Research* 28(10): 2738-2745, 2014.
14. Keogh, JW, Weber, CL, and Dalton, CT. Evaluation of anthropometric, physiological, and skill-related tests for talent identification in female field hockey. *Canadian Journal of Applied Physiology 28*(3): 397-409, 2003.
15. Lloyd, RS, and Oliver, JL. The youth physical development model: A new approach to long-term athletic development. *Strength & Conditioning Journal 34(3*): 61-72, 2012.
16. Lloyd, RS, Oliver, JL, Hughes, MG, and Williams, CA. Age-related differences in the neural regulation of stretch–shortening cycle activities in male youths during maximal and sub-maximal hopping. *Journal of Electromyography and Kinesiology* 22(1): 37-43, 2012.
17. Lloyd, RS, Radnor, JM, Croix, MB, Cronin, JB, and Oliver, JL. Changes in sprint and jump performances after traditional, plyometric, and combined resistance training in male youth pre- and post-peak height velocity. *Journal of Strength and Conditioning Research* 30(5): 1239-1247, 2016.

18. Malina, RM, Bouchard, C, and Bar-Or, O. Growth, Maturation, and Physical Activity (2nd ed.). Champaign, IL: Human Kinetics, 2004.

19. Meir, R, Newton, R, Curtis, E, Fardell, M, and Butler, B. Physical fitness qualities of professional rugby league football players: determination of positional differences. *The Journal of Strength & Conditioning Research* 15(4): 450-458, 2001.

20. Mendiguchia, J, Samozino, P, Martinez-Ruiz, E, Brughelli, M, Schmikli, S, Morin, JB, and Mendez-Villanueva, A. Progression of mechanical properties during on-field sprint running after returning to sports from a hamstring muscle injury in soccer players. *International Journal of Sports Medicine* 35(8): 690-695, 2014.

21. Meyers, RW, Oliver, JL, Hughes, MG, Cronin, JB, and Lloyd, RS. Maximal sprint speed in boys of increasing maturity. *Pediatric Exercise Science 27*(1): 85-94, 2015.

22. Meyers, RW, Oliver, JL, Hughes, MG, Lloyd, RS, and Cronin, JB. Reliability of the spatiotemporal determinants of maximal sprint speed in adolescent boys over single and multiple steps. *Pediatric Exercise Science* 27(3): 419-426, 2015.

23. Meyers, RW, Oliver, JL, Hughes, MG, Lloyd, RS, and Cronin, JB. Influence of age, maturity, and body size on the spatiotemporal determinants of maximal sprint speed in boys. *The Journal of Strength & Conditioning Research* 31(4): 1009-1016, 2017.

24. Mirwald, RL, Baxter-Jones, AD, Bailey, DA, and Beunen, GP. An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports and Exercise 34*(4): 689-694, 2002.

25. Morin, JB, Bourdin, M, Edouard, P, Peyrot, N, Samozino, P, and Lacour, JR. Mechanical determinants of 100-m sprint running performance. *European Journal of Applied Physiology 112*(11): 3921-3930, 2012.

26. Morin, JB, Edouard, P, and Samozino, P. Technical ability of force application as a determinant factor of sprint performance. *Medicine and Science in Sports and Exercise* *43*(9): 1680-1688, 2011.

27. Ozmun, JC, Mikesky, AE, and Surburg, PR. Neuromuscular adaptations following prepubescent strength training. *Medicine and Science in Sports and Exercise* 26(4): 510-514, 1994.

28. Philippaerts, RM, Vaeyens, R, Janssens, M, Van Renterghem, B, Matthys, D, Craen, R, Bourgois, J, Vrijens, J, Beunen, G, and Malina, RM. The relationship between peak height velocity and physical performance in youth soccer players. *Journal of Sports Sciences* 24(3): 221-230, 2006.

29. Reilly, T, Williams, AM, Nevill, A, and Franks, A. A multidisciplinary approach to talent identification in soccer. *Journal of Sports Sciences* 18(9): 695-702, 2000.

30. Rabita, G, Dorel, S, Slawinski, J, Sàez-de-Villarreal, E, Couturier, A, Samozino, P, and Morin, JB. Sprint mechanics in world-class athletes: a new insight into the limits of human locomotion. *Scandinavian Journal of Medicine & Science in Sports 25*(5): 583-594, 2015.

31. Rumpf, MC, Cronin, JB, Oliver, JL, and Hughes, M. Kinematics and Kinetics of Maximum Running Speed in Youth Across Maturity. *Pediatric Exercise Science* 27(2): 277-284, 2015.

32. Rumpf, MC, Cronin, JB, Pinder, SD, Oliver, JL, and Hughes, M. Effect of different training methods on running sprint times in male youth. *Pediatric Exercise Science* 24(2): 170-186, 2012.

33. Samozino, P, Rabita, G, Dorel, S, Slawinski, J, Peyrot, N, Saez de Villarreal, E, and Morin, JB. A simple method for measuring power, force, velocity properties, and

mechanical effectiveness in sprint running. *Scandinavian Journal of Medicine & Science in Sports* 26(6): 648-658, 2015.

34. Viru, A, Loko, J, Harro, M., Volver, A, Laaneots, L, and Viru, M. Critical periods in the development of performance capacity during childhood and adolescence. *European Journal of Physical Education* 4(1): 75-119, 1999.
35. Volkov, NI, and Lapin, VI. Analysis of the velocity curve in sprint running. *Medicine and Science in Sports* 11(4): 332-337, 1978.

APPENDICIES

Appendix A - Information Sheets

Force-velocity-power profiling during sprint performance in 10-16 year old boys.
Investigators: Oisín Geary-Cuddy, Dr Robert Meyers, Dr. Jon Oliver, Dr Ian Bezodis, Dr Izzy Moore, Robert Condliffe and Steph Morris.

Parent/ Guardian Information Sheet

Background
Force-velocity-power profiling is a relatively new concept, which may have the potential to provide coaches and support staff with simple, cheap, yet accurate method for a more individualised monitoring and training of sprint performance. However, to date this form of profiling has only been tested in an adult population and its transfer to children and adolescents has yet to be determined. On this basis, staff and students within the Cardiff School of Sport at Cardiff Metropolitan University are conducting a project with the following aim:
Examine the force-velocity-power profiles of a large cohort of 11-16 year old boys.

What your child is being asked to do?
Your child is being asked take part in the project and if you and they are willing, they will be asked to perform two assessments. Firstly, your child will be asked to perform a sprint test over 30m whilst being measured simultaneously by a series of timing gates, a radar gun (similar to those used by traffic police to determine speed) and a high-speed video. With all these sources of data we will be able to establish the validity/ usefulness of each of these methods.

What would happen if you agree for your child to participate in the study?
If you agree for your child to join the study, your child will be asked to attend a single testing session. These sessions will be conducted during the football academy training camp, dates TBC. The start of the testing session will involve taking some anthropometric measurements (standing height, sitting height and weight), which will be used to predict their stage of maturity. Following a comprehensive warm up, your child will be asked to perform two maximal effort sprints over 40m from a stationary start. Timing gates will be placed at regular intervals along the sprint track along with high-speed video recordings and a radar gun system. This will allow us to compare the data using these different approaches.

Is participation mandatory?
No. While the tests will occur during academy time, participation in this study is completely voluntary and will in no way reflect on your child's academy performance/ standing. You and/or your child also have the opportunity to withdraw from the study at any point, with no explanation required. Furthermore, you will also be permitted to complete the testing and not have your data entered into the research project if you or your child so wishes.

Are there any risks?
As with any form of exercise there is the risk of incurring an injury such as cramp, joint sprains, or muscle strains. While the risk of injury is low, every effort will be made to reduce this risk. Thorough warm ups will be conducted prior to sprint tests and your child will have

the opportunity to familiarise themselves with the equipment and protocol as part of the warm up protocol. Any participant carrying a lower-limb injury will not be allowed to participate in the testing for his own safety.

Are there any benefits from taking part?

From the testing, your child will be given his height and weight results along with his 40m sprint time, which will also include the time splits from the other timing gates. This will be provided free of charge.

What happens to the results of the testing?

All the data will be stored securely on password-protected computers and only accessed by the researchers named on this form. All data will be coded so that we can remove names, but we will keep a record of the codes so that we can give individuals their own results, before these records will be deleted. The data gathered from all the participants during the sprint test will be used to examine the different methods of testing the force-velocity-power profiles in male youth, as well as examine the influence of age and maturity in the measures obtained. You or your child will not be identifiable from this part of the work. The aim will be for this research to be included as part of a Masters Dissertation and in academic publications such as the Journal of Strength and Conditioning Research and Paediatric Exercise Science. No names or personal information will be given as part of these works. All data, including video material, will be held for a period of 5 years in accordance with Cardiff Metropolitan University policy, and disposed of thereafter.

What happens next?

With this letter you'll also find an information sheet for your child, an assent form for them to sign if they are happy to participate, and a consent form for you to sign as the parent/ guardian if you are happy for your child to participate. If you are willing for your child to participate, and he is too, these forms should be completed and handed to the researcher on the first day of the training camp.

How will we protect your privacy?

We have taken very careful steps to make sure that you cannot be identified from any of the information that we have about you. All the information about you and your child will be stored securely. All electronic information such as the collected sprint data and video footage will be password protected and accessible only to those conducting the study. We will only keep the consent and assent forms with you and your child's name. We keep these for ten years because we are required to do so by the University.

Further information

If you have any questions about the research or how we intend to conduct the study, please contact us.

Oisín Geary-Cuddy (MSc Student)
Email: st20092654@outlook.cardiffmet.ac.uk
Steph Morris (MSc Student)
Email: Smorris@cardiffmet.ac.uk
Dr Robert Meyers (Supervisor and project lead)
Email: rwmeyers@cardiffmet.ac.uk

Force-velocity-power profiling during sprint performance in 10-16 year old boys.
Investigators: Oisín Geary-Cuddy, Dr Robert Meyers, Dr. Jon Oliver, Dr Ian Bezodis, Dr Izzy Moore, Robert Condliffe and Steph Morris.

Child Participant Information Sheet

Background
Force-velocity-power profiling is a new way for researchers and coaches to look at sprint performance and what makes people run fast. However, it has only tested on adults and we want to look at this concept in children and teenagers.

What am I being asked to do?
You are being asked to take part in a study to help the researchers understand which way is best to look at force-velocity-power profiling and how age and maturity influence this profile. You will have some simple measurements taken (standing height, sitting height and weight) and also asked to perform a sprint test twice whilst we record you using some timing gates, a radar gun (similar to the traffic police use for recording the speed of cars) and a high-speed video camera.

What happens if I agree?
If you agree to join the study, you will be asked to attend a single testing sessions during your football training camp. At the start of the session we will take some simple measurements (standing height, sitting height and weight), which will be used to predict your stage of maturity. Following a warm up, you will be asked to run two sprints as fast as you can over 40 metres. Timing gates will be placed at regular intervals along the sprint track along with high-speed video recordings and a radar gun system. This will allow us to compare the data using these different approaches.

Do I have to?
No. Doing this study is completely voluntary and won't effect on what you do as part of the academy. If you agree to join the study but then change your mind, you can leave at any time, without giving a reason. You can also do the testing but decide to not have your data included in the research project if you like.

Are there any risks?
While it its quite unlikely, you may pick up an injury like you might get during sprinting in football. These injuries might include cramp, a joint sprain, or muscle strains. While the risk you getting injured is low, the researchers will try and lower your risk by doing a warm up as well showing you the equipment and giving you some practice runs so you know what you're doing. If you have injuries to your legs then you will not be allowed to do the testing for your own safety.

Are there any benefits from taking part?
From the testing, you will be given your height and weight results along with your sprint time so you can see how fast you are,

What happens to the results of the testing?

Your measurements, sprint times and video footage will be stored on a computer that will be protected by a password. They will also be coded so that we can remove your name to ensure that no one outside the research team will be able to identify your data. We will look at the result and see what is the best way to look at the force-velocity-power profiles during sprinting and also see how your age and maturity influence the result you get. At the end of the project we would like to try and publish the result in an academic journal or at an academic conference, but your name or personal information will not be used at any time. All your information, including video material, will be held for of 5 years as that is the rules at our University.

What happens next?

With this information sheet is an assent form for you to complete if you want to take part. As you are under 18, there is another information sheet that your parent /guardian must read and then a consent form for them to sign as well. If you would like to be a part of this study, the forms from you and your parent/ guardian should be signed and handed to one of the researchers on the first day of the training camp.

How we protect your privacy?

We have taken very careful steps to make sure that you cannot be identified from any of the information that we have about you. All the information about you will be stored securely. All electronic information such as the collected sprint data and video footage will be password protected and accessible only to those conducting the study. We will only keep the consent and assent forms with your name. We keep these for ten years because that's the rules at our University.

Further information

If you have any questions about the research or how we intend to conduct the study, please contact us.

Oisín Geary-Cuddy (MSc Student)
Email: st20092654@outlook.cardiffmet.ac.uk
Steph Morris (MSc Student)
Email: Smorris@cardiffmet.ac.uk
Dr Robert Meyers (Supervisor and project lead)
Email: rwmeyers@cardiffmet.ac.uk

Appendix B- Parental Consent Forms

PARENTAL CONSENT FORM

Reference Number:	
Participant name or Study ID Number:	
Title of Project	Force-velocity-power profiling during sprint performance in 10-16 year old boys.
Name of Researchers:	Oisín Geary-Cuddy, Steph Morris & Dr Robert Meyers

Parent/ Guardian to complete this section: Please initial each box.

I confirm that I have read and understand the information sheet for the above study.	
I am aware that video footage will be collected as part of this study	
I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
I have been made aware of the risks and benefits to my child.	
I understand that my child's participation is voluntary and that I am free to withdraw him at any time, without giving any reason.	
I agree for my child to take part in the above study	

Name of Parent/ Guardian:	
Date:	
Signature of Parent/ Guardian:	

Appendix C - Participant Assent form

PARTICIPANT ASSENT FORM

Reference Number:	
Participant name or Study ID Number:	
Title of Project	Force-velocity-power profiling during sprint performance in 10-16 year old boys.
Name of Researchers:	Oisín Geary-Cuddy, Steph Morris & Dr Robert Meyers

Participant to complete this section: Please initial each box.

I have read and understand the information sheet for the above study.	
I am aware that video footage will be collected as part of this study	
I understand information and have been able to ask questions about the study	
I have been made aware of the risks and benefits.	
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.	
I agree for to take part in the above study	

Name of Participant:	
Date:	
Signature of Participant:	

Appendix D- Signed Ethical Approval

St Mary's University Twickenham London

7 February 2017 Unique Ref: SMEC_2016-17_067

Stephanie Morris (SHAS): 'The influence of age and maturation on the force-velocity characteristics during sprinting in male youth'

Dear Stephanie
University Ethics Sub-Committee
Thank you for submitting your ethics application for the above research.
I can confirm that your application has been considered by the Ethics Sub-Committee and that ethical approval is granted.
Yours sincerely

Prof Conor Gissane
Chair, Ethics Sub-Committee

Cc Jon Goodwin, Dan Cleather

Appendix E- Journal of Strength and Conditioning Research Submission Format

The Journal of Strength and Conditioning Research (JSCR) is the official research journal of the National Strength and Conditioning Association (NSCA). The JSCR is now published monthly. Membership in the NSCA is not a requirement for publication in the journal. JSCR publishes original investigations, reviews, symposia, research notes, and technical and methodological reports contributing to the knowledge about strength and conditioning in sport and exercise. All manuscripts must be original works and present practical applications to the strength and conditioning professional or provide the basis for further applied research in the area. Manuscripts are subjected to a ‘‘double blind’’ peer review by at least two reviewers who are experts in the field. Editorial decisions will be based on the quality, clarity, style, and importance of the submission relative to the goals and objectives of the NSCA and the journal. Tips for writing a manuscript for the JSCR can be found at http://edmgr.ovid.com/jscr/accounts/Tips_for_Writing.pdf.

Please read this document carefully prior to preparation of a manuscript. Manuscripts can be rejected on impact alone as it relates to how the findings impact evidence based practice for strength and conditioning professionals, end users, and clinicians. Thus, it is important authors realize this when submitting manuscripts to the journal.

The JSCR will now administratively REJECT a paper before review if it is deemed to have very low impact on practice, poor experimental design, and/or poorly written. Additionally, upon any revision the manuscript can be REJECTED if experimental issues and impact are not adequately addressed. The formatting of the paper is also of importance and manuscripts will be sent back if not PROPERLY formatted.

EDITORIAL MISSION STATEMENT

The editorial mission of the JSCR, formerly the Journal of Applied Sport Science Research (JASSR), is to advance the knowledge about strength and conditioning through research. Since 1978 the NSCA has attempted to ‘‘bridge the gap’’ from the scientific laboratory to the field practitioner. A unique aspect of this journal is the inclusion of recommendations for the practical use of research findings. While the journal name identifies strength and conditioning as separate entities, strength is considered a part of conditioning. This journal wishes to promote the publication of peer-reviewed manuscripts that add to our understanding of conditioning and sport through applied exercise and sport science. The conditioning process and proper exercise prescription impact a wide range of populations from children to older adults, from youth sport to professional athletes.

Understanding the conditioning process and how other practices such as such as nutrition, technology, exercise techniques, and biomechanics support it is important for the practitioner to know.

Original Research

JSCR publishes research on the effects of training programs on physical performance and function to the underlying biological basis for exercise performance as well as research from a number of disciplines attempting to gain insights about sport, sport demands, sport profiles, conditioning, and exercise such as biomechanics, exercise physiology, motor learning, nutrition, and psychology. A primary goal of JSCR is to provide an improved scientific basis for conditioning practices.

Article Types

JSCR publishes symposia, brief reviews, technical reports and research notes that are related to the journal's mission. A symposium is a group of articles by different authors that address an issue from various perspectives. The brief reviews should provide a critical examination of the literature and integrate the results of previous research in an attempt to educate the reader as to the basic and applied aspects of the topic. We are especially interested in applied aspects of the reviewed literature. In addition, the author(s) should have experience and research background in the topic area they are writing about in order to claim expertise in this area of study and give credibility to their recommendations.

The JSCR strongly encourages the submission of manuscripts detailing methodologies that help to advance the study of strength and conditioning.

Manuscript Clarifications

Manuscript Clarifications will be considered and will be published online if accepted. Not all requests for manuscript clarifications will be published due to costs or content importance. Each will be reviewed by a specific sub-committee of Associate Editors to determine if it merits publication. A written review with needed revisions will be provided if it merits consideration. Clarifications questions are limited to 400 words and should only pose professional questions to the authors and not editorial comments (as of 19.2). If accepted, a copy will be sent to the author of the original article with an invitation to submit answers to the questions in the same manner again with a 400 word limit.

Submissions should be sent to the JSCR Editorial Office via email:

Editorial Office

kraemer.45@osu.edu

MANUSCRIPT SUBMISSION GUIDELINES

Manuscripts should be submitted online at http://www.editorialmanager.com/JSCR or by email following the instructions below. If email is used to submit the paper (we encourage on-line submission), only one copy is required of each document including a copyright form.

1. If by email, authors should submit a MicrosoftWord (.doc) file.
2. A cover letter must accompany the manuscript and state the following: ''This manuscript is original and not previously published, nor is it being considered elsewhere until a decision is made as to its acceptability by the JSCR Editorial Review Board.'' Please include the corresponding author's full contact information, including address, email, and phone number.
3. All authors should be aware of the publication and be able to defend the paper and its findings and should have signed off on the final version that is submitted. For additional details related to authorship, see ''Uniform Requirements for Manuscripts Submitted to Biomedical Journals'' at http://www.icmje.org/.
4. The NSCA and the Editorial Board of the JSCR have endorsed the American College of Sports Medicine's policies with regards to animal and human experimentation. Their guidelines can be found online at http://www.editorialmanager.com/msse/. Please read these policies carefully. Each manuscript must show that they have had Institutional Board approval for their research and appropriate consent has been obtained pursuant to law. All manuscripts must have this clearly stated in the methods section of the paper or the manuscript will not be considered for publication.
5. All manuscripts must be double-spaced with an additional space between paragraphs. The paper should include a minimum of 1-inch margins and page numbers in the upper right corner next to the running head. Authors must use terminology based upon the International System of Units (SI). A full list of SI units can be accessed online at http://physics.nist.gov/.
6. The JSCR endorses the same policies as the American College of Sports Medicine in that the language is English for the publication. ''Authors who speak English as a second language are encouraged to seek the assistance of a colleague experienced in writing for English language journals. Authors are encouraged to use nonsexist language as defined in the American Psychologist 30:682- 684, 1975, and to be sensitive to the semantic description of persons with chronic diseases and disabilities, as outlined in an editorial in Medicine & Science in Sports & Exercise_, 23(11), 1991. As a general rule, only standardized

abbreviations and symbols should be used. If unfamiliar abbreviations are employed, they should be defined when they first appear in the text. Authors should follow Webster's Tenth Collegiate Dictionary for spelling, compounding, and division of words. Trademark names should be capitalized and the spelling verified. Chemical or generic names should precede the trade name or abbreviation of a drug the first time it is used in the text.''

7. There is no word limitation but authors are instructed to be concise and accurate in their presentation and length will be evaluated by the Editor and reviewers for appropriateness.

Please Note

- Make sure you have put in your text under the "Subjects" section in the METHODS that your study was approved by an Institutional Review Board (IRB) or Ethics Board and that your subjects were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study. Additionally, if you include anyone who is under the age of 18 years of age, it should also be noted that parental or guardian signed consent was also obtained. Please give the age range if your mean and SD suggest the subjects may have been under the age of 18 years.
- Make SURE you have all your tables and figures attached and noted in the text of paper as well as below a paragraph of where it should be placed.
- Very IMPORTANT---Table files must be MADE in Word NOT copied into Word.

MANUSCRIPT PREPARATION

1. Title Page

The title page should include the manuscript title, brief running head, laboratory(s) where the research was conducted, authors' full name(s) spelled out with middle initials, department(s), institution(s), full mailing address of corresponding author including telephone and fax numbers, and email address, and disclosure of funding received for this work from any of the following organizations: National Institutes of Health (NIH); Wellcome Trust; Howard Hughes Medical Institute (HHMI); and other(s).

2. Blind Title Page

A second title page should be included that contains only the manuscript title. This will be used to send to the reviewers in our double blind process of review. Do not place identifying information in the Acknowledgement portion of the paper or anywhere else in the manuscript.

3. Abstract and Key Words

On a separate sheet of paper, the manuscript must have an abstract with a limit of 250 words followed by 3 – 6 key words not used in the title. The abstract should have sentences (no headings) related to the purpose of the study, brief methods, results, conclusions and practical applications.

4. Text

The text must contain the following sections with titles in ALL CAPS in this exact order:

A. Introduction. This section is a careful development of the hypotheses of the study leading to the purpose of the investigation. In most cases use no subheadings in this section and try to limit it to 4 – 6 concisely written paragraphs.

B. Methods. Within the METHODS section, the following subheadings are required in the following order: ‘‘Experimental Approach to the Problem,’’ where the author(s) show how their study design will be able to test the hypotheses developed in the introduction and give some basic rationales for the choices made for the independent and dependent variables used in the study; ‘‘Subjects,’’ where the authors include the Institutional Review Board or Ethics Committee approval of their project and appropriate informed consent has been gained. All subject characteristics that are not dependent variables of the study should be included in this section and not in the RESULTS; ‘‘Procedures,’’ in this section the methods used are presented with the concept of ‘‘replication of the study’’ kept in mind. ‘‘Statistical Analyses,’’ here is where you clearly state your statistical approach to the analysis of the data set(s). It is important that you include your alpha level for significance (e.g., P # 0.05). Please place your statistical power in the manuscript for the n size used and reliability of the dependent measures with intra-class correlations (ICC Rs). Additional subheadings can be used but should be limited.

C. Results. Present the results of your study in this section. Put the most important findings in Figure or Table format and less important findings in the text.Do not include data that is not part of the experimental design or that has been published before.

D. Discussion. Discuss the meaning of the results of your study in this section. Relate them to the literature that currently exists and make sure you bring the paper to completion with each of your hypotheses. Limit obvious statements like, ‘‘more research is needed.’’

E. Practical Applications. In this section, tell the ‘‘coach’’ or practitioner how your data can be applied and used. It is the distinctive characteristic of the JSCR and supports the mission of ‘‘Bridging the Gap’’ for the NSCA between the laboratory and the field practitioner.

5. References

All references must be alphabetized by surname of first author and numbered. References are cited in the text by numbers [e.g., (4,9)]. All references listed must be cited in the manuscript and referred to by number therein. For original investigations, please limit the number of references to fewer than 45 or explain why more are necessary. The Editorial Office reserves the right to ask authors to reduce the number of references in the manuscript. Please check references carefully for accuracy. Changes to references at the proof stage, especially changes affecting the numerical order in which they appear, will result in author revision fees. End Note Users:

The Journal of Strength

& Conditioning Research reference style,

ftp://support.isiresearchsoft.com/pub/pc/styles/endnote4/J%20Strength%20Condition%20Res.ens may be downloaded for use in the End Note application: ftp://

support.isiresearchsoft.com/pub/pc/styles/endnote4/J%20Strength%20Condition%20Res.ens.

Below are several examples of references:

Journal Article

Hartung, GH, Blancq, RJ, Lally, DA, and Krock, LP. Estimation of aerobic capacity from submaximal cycle ergometry in women. Med Sci Sports Exerc 27: 452–457, 1995.

Book

Lohman, TG. Advances in Body Composition Assessment. Champaign, IL: Human Kinetics, 1992.

Chapter in an edited book

Yahara, ML. The shoulder. In: Clinical Orthopedic Physical Therapy. J.K. Richardson and Z.A. Iglarsh, eds. Philadelphia: Saunders, 1994. pp. 159–199.

Software

Howard, A. Moments ½software_. University of Queensland, 1992.

Proceedings

Viru, A, Viru, M, Harris, R, Oopik, V, Nurmekivi, A, Medijainen, L, and Timpmann, S. Performance capacity in middle-distance runners after enrichment of diet by creatine and creatine action on protein synthesis rate. In: Proceedings of the 2nd Maccabiah-Wingate International Congress of Sport and Coaching Sciences. G. Tenenbaum and T. Raz-Liebermann, eds. Netanya, Israel, Wingate Institute, 1993. pp. 22–30.

Dissertation/Thesis

Bartholmew, SA. Plyometric and vertical jump training.Master's thesis, University of North Carolina, Chapel Hill, 1985.

6. Acknowledgments

In this section you can place the information related to Identification of funding sources; Current contact information of corresponding author; and gratitude to other people involved with the conduct of the experiment. In this part of the paper the conflict of interest information must be included. In particular, authors should: 1) Disclose professional relationships with companies or manufacturers who will benefit from the results of the present study, 2) Cite the specific grant support for the study and 3) State that the results of the present study do not constitute endorsement of the product by the authors or the NSCA. Failure to disclose such information could result in the rejection of the submitted manuscript.

7. Figures

Figure legends should appear on a separate page, with each figure appearing on its own separate page. One set of figures should accompany each manuscript. Use only clearly delineated symbols and bars. Please do not mask the facial features of subjects in figures. Permission of the subject to use his/her likeness in the Journal should be included in each submission.

Electronic photographs copied and pasted into Word and PowerPoint will not be accepted. Images should be scanned at a minimum of 300 pixels per inch (ppi). Line art should be scanned at 1200 ppi. Please indicate the file format of the graphics.We accept TIFF or EPS format for both Macintosh and PC platforms.We also accept image files in the following Native Application File Formats:

_ Adobe Photoshop (.psd)

_ Illustrator (.ai)

_ PowerPoint (.ppt)

_ QuarkXPress (.qxd)

If you will be using a digital camera to capture images for print production, you must use the highest resolution setting option with the least amount of compression. Digital camera manufacturers use many different terms and file formats when capturing high-resolution images, so please refer to your camera's manual for more information.

Placement:. Make sure that you have cited each figure and table in the text of the manuscript. Also show where it is to be place by noting this between paragraphs, such as Figure 1 about here or Table 1 about here.

Color figures: The journal accepts color figures for publication that will enhance an article. Authors who submit color figures will receive an estimate of the cost for color reproduction in print. If they decide not to pay for color reproduction in print, they can request that the figures be converted to black and white at no charge. All color figures can appear in color in the online version of the journal at no charge (Note: this includes the online version on the journal website and Ovid, but not the iPad edition currently)

8. Tables

Tables must be double-spaced on separate sheets and include a brief title. Provide generous spacing within tables and use as few line rules as possible. When tables are necessary, the information should not duplicate data in the text. All figures and tables must include standard deviations or standard errors.

9. Supplemental Digital Content (SDC)

Authors may submit SDC via Editorial Manager to LWW journals that enhance their article's text to be considered for online posting. SDC may include standard media such as text documents, graphs, audio, video, etc. On the Attach Files page of the submission process, please select Supplemental Audio, Video, or Data for your uploaded file as the Submission Item. If an article with SDC is accepted, our production staff will create a URL with the SDC file. The URLwill be placed in the call-out within the article. SDC files are not copy-edited by LWW staff, they will be presented digitally as submitted. For a list of all available file types and detailed instructions, please visit http://links.lww.com/A142.

SDC Call-outs

Supplemental Digital Content must be cited consecutively in the text of the submitted manuscript. Citations should include the type of material submitted (Audio, Figure, Table, etc.), be clearly labeled as ''Supplemental Digital Content,'' include the sequential list number, and provide a description of the supplemental content. All descriptive text should be included in the call-out as it will not appear elsewhere in the article.

Example:

We performed many tests on the degrees of flexibility in the elbow (see Video, Supplemental Digital Content 1, which demonstrates elbow flexibility) and found our results inconclusive.

List of Supplemental Digital Content

A listing of Supplemental Digital Content must be submitted at the end of the manuscript file. Include the SDC number and file type of the Supplemental Digital Content. This text will be removed by our production staff and not be published.

Example:

Supplemental Digital Content 1. wmv

SDC File Requirements

All acceptable file types are permissible up to 10 MBs. For audio or video files greater than 10 MBs, authors should first query the journal office for approval. For a list of all available file types and detailed instructions, please visit http://links.lww.com/A142.

AUTHOR FEES

JSCR does not charge authors a manuscript submission fee or page charges. However, once a manuscript is accepted for publication and sent in for typesetting, it is expected to be in its final form.

OPEN ACCESS

LWW's hybrid open access option is offered to authors whose articles have been accepted for publication. With this choice, articles are made freely available online immediately upon publication. Authors may take advantage of the open access option at the point of acceptance to ensure that this choice has no influence on the peer review and acceptance process. These articles are subject to the journal's standard peer-review process and will be accepted or rejected based on their own merit.

Authors of accepted peer-reviewed articles have the choice to pay a fee to allow perpetual unrestricted online access to their published article to readers globally, immediately upon publication. The article processing charge for The *Journal of Strength & Conditioning Research* is $3,000. The article processing charge for authors funded by the Research Councils UK (RCUK) is $3,800. The publication fee is charged on acceptance of the article and should be paid within 30 days by credit card by the author, funding agency or institution. Payment must be received in full for the article to be published open access. Any additional standard publication charges, such as for color images, will also apply.

- ***Authors retain copyright***
- Authors retain their copyright for all articles they opt to publish open access. Authors grant LWW a license to publish the article and identify itself as the original publisher.

- ***Creative Commons license***
- Articles opting for open access will be freely available to read, download and share from the time of publication. Articles are published under the terms of the Creative Commons License Attribution-NonCommerical No Derivative 3.0 which allows readers to disseminate and reuse the article, as well as

share and reuse of the scientific material. It does not permit commercial exploitation or the creation of derivative works without specific permission. To view a copy of this license visit: http://creativecommons.org/licenses/by-nc-nd/3.0.

- ***Compliance with NIH, RCUK, Welcome Trust and other research funding agency accessibility requirements***
- A number of research funding agencies now require or request authors to submit the post-print (the article after peer review and acceptance but not the final published article) to a repository that is accessible online by all without charge. As a service to our authors, LWW identifies to the National Library of Medicine (NLM) articles that require deposit and transmits the post-print of an article based on research funded in whole or in part by the National Institutes of Health, Howard Hughes Medical Institute, or other funding agencies to PubMed Central. The revised Copyright Transfer Agreement provides the mechanism. LWW ensures that authors can fully comply with the public access requirements of major funding bodies worldwide. Additionally, all authors who choose the open access option will have their final published article deposited into PubMed Central.

- RCUK and Welcome funded authors can choose to publish their paper as open access with the payment of an article process charge (gold route), or opt for their accepted manuscript to be deposited (green route) into PMC with an embargo.

- With both the gold and green open access options, the author will continue to sign the Copyright Transfer Agreement (CTA) as it provides the mechanism for LWW to ensure that the author is fully compliant with the requirements. After signature of the CTA, the author will then sign a License to Publish where they will then own the copyright. Those authors who wish to publish their article via the gold route will be able to publish under the terms of the Attribution 3.0 (CCBY) License. To view of a copy of this license visit: http://creativecommons.org/licenses/by/2.0/. Those authors who wish to publish their article via the green route will be able to publish under the rights of the Attribution Non-commercial 3.0 (CCBY NC) license (http://creativecommons.org/licenses/by-nc/2.0/).

- It is the responsibility of the author to inform the Editorial Office and/or LWW that they have RCUK funding. LWW will not be held responsible for retroactive deposits to PMC if the author has not completed the proper forms.

FAQ for open access

http://links.lww.com/LWW-ES/A48

TERMINOLOGY AND UNITS OF MEASUREMENT

Per the JSCR Editorial Board and to promote consistency and clarity of communication among all scientific journals authors should use standard terms generally acceptable to the field of exercise science and sports science. Along with the American College of Sports Medicine's Medicine and Science in Sport and Exercise, the JSCR Editorial Board endorses the use of the following terms and units.

The units of measurement shall be Syste`me International d'Unite´ s (SI). Permitted exceptions to SI are heart rate—beats per min; blood pressure—mm Hg; gas pressure—mm Hg. Authors should refer to the British Medical Journal (1:1334 – 1336, 1978) and the Annals of Internal Medicine (106: 114 – 129, 1987) for the proper method to express other units or abbreviations. When expressing units, please locate the multiplication symbol midway between lines to avoid confusion with periods; e.g., mL_min-1_kg-1.

The basic and derived units most commonly used in reporting research in this Journal include the following: mass—gram (g) or kilogram (kg); force—newton (N); distance—meter (m), kilometer (km); temperature—degree Celsius (_C); energy, heat, work—joule (J) or kilojoule (kJ); power—watt (W); torque—newton-meter (N_m); frequency— hertz (Hz); pressure—pascal (Pa); time—second (s), minute (min), hour (h); volume—liter (L), milliliter (mL); and amount of a particular substance—mole (mol), millimole (mmol).

Selected conversion factors:

_ 1 N = 0.102 kg (force);

_ 1 J = 1 N_m = 0.000239 kcal = 0.102 kg_m;

_ 1 kJ = 1000 N_m = 0.239 kcal = 102 kg_m;

_ 1 W = 1 J_s-1 = 6.118 kg_m_min-1.

When using nomenclature for muscle fiber types please use the following terms. Muscle fiber types can be identified using histochemical or gel electrophoresis methods of classification. Histochemical staining of the ATPases is used to separate fibers into type I (slow twitch), type IIa (fast twitch) and type IIb (fast twitch) forms.Thework of Smerdu et. al (AJP 267:C1723, 1994) indicates that type IIb fibers contain type IIxmyosin heavy chain (gel electrophoresis fiber typing). For the sake of continuity and to decrease confusion on this point it is recommended that authors use IIx to designate what use to be called IIb fibers. Smerdu, V, Karsch-

Mizrachi, I, Campione, M, Leinwand, L, and Schiaffino, S. Type IIx myosin heavy chain transcripts are expressed in type IIb fibers of human skeletal muscle. Am J Physiol 267 (6 Pt 1): C1723–1728, 1994.