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The Relationship Between Maximum Lower Limb Strength & Power, and GPS Acceleration Speed in Elite U20 Gaelic Football Athletes

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ABSTRACT

Previous research indicates positive relationships between high levels of lower limb strength and power, and acceleration sprint velocity in team sport athletes. This cross-sectional study aimed to investigate the relationship between lower limb absolute and relative strength, countermovement jump (CMJ) height, and Global Positioning System (GPS) recorded 20m acceleration sprint velocity in elite male U-20 Gaelic football athletes. Nineteen athletes (19.0 ± 0.5 years; 81.1 ± 5.5 kg; 182 ± 6.2 cm) from the same elite U-20 squad participated in this study during an in-season period. Subjects performed a ≥95% 1RM box squat, a 20m sprint test, and a CMJ test. Relative maximum lower limb strength (r = 0.54, 95% CI [0.11 to 0.8]; $p < 0.05$) and CMJ height (r = 0.66, 95% CI [0.29 to 0.86]; $p < 0.001$) showed strong correlations with 20m sprint velocity. A multiple linear regression analysis demonstrated that lower limb maximum relative strength and CMJ height significantly predicted 20m sprint velocity (Adjusted R^2 = 0.51, F (2, 16) = 6.29, $p < 0.05$). These findings provide evidence for the importance of elite under-age Gaelic football athletes acquiring high levels of lower limb strength and power characteristics to enhance acceleration sprint performance.

Keywords: strength, speed, acceleration, GPS, performance.

INTRODUCTION

Gaelic football is the national sport of Ireland and is indigenous to Irish sporting culture (34). From a physical and physiological perspective, Gaelic football comprises both aerobic and anaerobic energy system demands (39), with match-play requiring repeated and vigorous high intensity running efforts (27). Indeed, recent data suggests that senior inter-county (considered the elite level in Gaelic football) match-play requires male players to complete intermittent bouts of high-speed running (>17 $km \cdot h^{-1}$), interspersed with high intensity decelerations and accelerations (>3 m·s), alongside the execution of technical handling and kicking skills (26,40). Moreover, elite senior players typically perform an average of 166 accelerations during match-play, with acceleration speeds as high as 24.7 ± 0.5 $km \cdot h^{-1}$ (6.8 ± 0.1 m·s) and accumulating a mean acceleration distance of 267 ± 45m (40). It has been previously reported that the average distance covered per high-intensity acceleration effort in Gaelic football ranges between 10.6-13.5m (13). These high intensity running demands are generally interspersed with periods of light aerobic activity (32).

Given these significant intermittent and high intensity running demands (28), acceleration speed is well recognised as an important physical attribute for players (40). Sprinting and accelerating require sufficient maximum lower limb strength to overcome the inertia of body mass (12). Indeed, stronger and more powerful athletes generally perform better during sprint performances (5,8,11,12). In professional soccer, sprinting is the most frequent action preceding goal scoring situations during match-play (19). Given the similar sprint speed levels in both Gaelic football and soccer (30), it is likely that this also applies to Gaelic football match-play. With regard to the theoretical justification for the role of muscular strength in sprint performance, and considering Newton's second law (force = mass x acceleration), it can be inferred that enhanced 'speed-strength' qualities are generally represented by the amount of force an athlete is able to generate against their own body mass. Peak vertical ground reaction forces during the push-off phase in acceleration and in landing have been reported to be up to two times body mass (22) and four to six times body mass (15), respectively. Similarly, ground reaction forces during sprint starts and the acceleration phase are reported to be two to five times the athlete's body mass and two to three times the athlete's body mass (1,41), respectively. As the athlete's body mass must be accelerated, these speed-strength performances largely rely on maximum strength and subsequently on relative strength (22,43).

Strong correlations have been reported between 1 repetition maximum (1RM) back squat performance and acceleration sprint times in elite soccer players (45). Moreover, Comfort et al. (11) demonstrated that increases in back squat strength mirrored improvements in sprint performance in rugby league players, with similar findings previously reported in junior soccer players after 8 weeks of resistance training (8). The relationship between measurements of functional and isometric lower body strength, aerobic capacity, anaerobic power, sprint, and CMJ performance in professional soccer players was examined in a recent study by Boraczyski et al. (5). The authors found that players with greater lower body strength (knee extensor maximal voluntary isometric contraction and 1RM half squat) demonstrated higher sprint and CMJ performance, highlighting the importance of resistance training in developing lower body strength to ultimately maximise sprinting performance. This may be explained by the fact that peak ground reaction force and impulse are known to be significant predictors of sprint performance (22).

Global Positioning System (GPS) technology is most commonly used for quantifying the external locomotor and high intensity running demands in a variety of field-based team sports including rugby union, rugby league, soccer, and Australian rules football (14). Although sprinting is an essential aspect of performance in Gaelic football, no data currently exists that has specifically examined the acceleration sprint speed of elite U-20 Gaelic football players. Notwithstanding this limitation, to the best of the authors' knowledge, nor is there any research that has examined whether maximum lower limb strength and CMJ performance may be correlated to performance in this capacity.

The aim of this cross-sectional study, therefore, was to investigate the relationship between maximum lower limb absolute and relative strength, CMJ performance, and 20 metre acceleration sprint velocity in elite U-20 Gaelic football players sampled during training within an in-season period. It was hypothesised that players with higher levels of maximum lower limb relative strength and jump height would demonstrate higher GPS acceleration velocities in comparison to players with lower levels. Objective findings can be used to provide insights into the strength, power, and speed characteristics of U-20 elite Gaelic football players, thus informing practitioners working with this cohort to assist future programme design for the adequate physical preparation of players, positively benefiting the transition to the elite senior level.

METHODS

Experimental Approach To The Problem

This study was designed to assess the relationship between maximal lower limb absolute and relative strength, CMJ height, and GPS recorded maximum velocity for standing start sprint acceleration trials over 20m in elite male U-20 Gaelic football players. Thus, a $\geq$95% 1RM box squat absolute load and load relative to bodyweight (body mass in kg divided by top set load in kg), CMJ height, and GPS maximum velocity from sprint trials were measured. Pearson product correlation coefficients were calculated between selected variables (sampled from in-season strength & conditioning sessions).

Subjects

Nineteen Division 1 elite male U-20 (inter-county) Gaelic football athletes (n = 19; 19.05 ± 0.5 years; body mass = 81.1 ± 5.5 kg; body stature = 182 ± 6.4 cm) participated in this study as a part of their regular in-season strength and conditioning programme. All subjects were part of the same U-20 inter-county playing squad and were provided with a participant information leaflet before providing informed consent. Ethical approval was granted by the Institutional Ethics Review Board of Setanta College. Subjects were informed that they may withdraw from testing at any point without providing a reason, and that all collected and reported data would be anonymised. To meet the eligibility criteria, all subjects were required to complete all training and testing sessions, be over 18 years of age, and be considered ready to perform and injury free as indicated by the squad physiotherapist in conjunction with the squads' regular pre-training wellness monitoring system (Actimet, Athlete Monitoring Software, Galway, Ireland). All testing was led and carried out by the first author, who is an accredited strength and conditioning coach within the same U-20 inter-county playing squad to which the participants were sampled.

Procedures

Testing was completed over a two week in-season period during which time, all subjects were training four days a week, with sessions consisting of one competitive match, one strength and conditioning resistance training session (strength and power mesocycle phase), and two Gaelic football specific on-field sessions (Table 1). Subjects completed strength, CMJ, and acceleration sprint speed testing on separate training days, and at least 24 hours apart to mitigate against the effects of accumulated fatigue. Subjects were asked to ensure that they attended the sessions in their usual hydrated and fed state (following the squad nutrition framework to ensure adequate glycogen fuel stores pre-training based on O'Brien et al. (33) guidelines). Data collection was completed over the course of two weeks whereby strength and acceleration speed data were collected on week one and CMJ data were collected on week two. On arrival to the first testing session, all subjects' height and body mass were recorded using a portable stadiometer and a digital weighing scales while in bare feet and wearing shorts. Further details pertaining to the data collection protocols are depicted in Table 1.

Maximal Lower Limb Strength Testing

Maximum barbell box squat strength ($\geq$95% 1RM) was assessed following the subjects' usual standardised lower body strength and conditioning session warm-up which consisted of warm-up sets prior to commencing working sets with 1 set at 50% 1RM for 6 repetitions and 1 set at 70% 1RM for 4 repetitions (29). All testing was completed in the squad high performance facility at 18:00 to reduce the impact of variability in circadian rhythm on performance (17). A periodised linear loading scheme of 3 sets of 3, 2, and 1 repetition(s) at 85, 90, 95% 1RM was prescribed as it constituted the session load-volume and intensity for the unit of training within the micro-cycle of the in-season strength and power mesocycle. Rest periods of 3 minutes were allocated between working sets to ensure adequate recovery for maximum strength training (20). Absolute and relative strength values from subjects' top set ($\geq$95% 1RM) were used for data analysis. Squat depth was individualised to a half squat range of motion and standardised by placing a box behind the lifter set

Table 1. Overview of testing and data collection during an in-season strength and conditioning and training schedule.

Testing & Data Collection – In-Season Strength & Conditioning/Training Schedule

Week 1						
Mon (GD-1)	Tues (GD)	Wed (GD+1)	Thurs (GD+2)	Fri (GD+3)	Sat (GD-3)	Sun (GD-2)
			20m Sprint Data Collection		Strength Data Collection	
Recovery	Game	Recovery	Pitch	Recovery	Gym	Pitch
Week 2						
Mon (GD-1)	Tues (GD)	Wed (GD+1)	Thurs (GD+2)	Fri (GD+3)	Sat (GD-3)	Sun (GD-2)
					CMJ Data Collection	
Recovery	Game	Recovery	Pitch	Recovery	Gym	Pitch

Data collection and testing schedule over two weeks of regular in-season training and competition. Three timepoints for testing are outlined in the bordered boxes. A traffic light system was used to code session intensity (dark red = ++ intensity; amber = + intensity; green = - intensity/recovery). Game day (GD) timeline is denoted at the bottom of the figure (e.g. GD+2 = 2 days post-game).

at the height of the subject's inferior aspect of the patellar (approximately 90° knee flexion).

Countermovement Jump Testing

CMJ performance was tested using a portable jump mat (Jump Mat Pro, FSL Scoreboards, United Kingdom) as a part the subject's routine strength and conditioning session. The use of a contact mat for accurate CMJ testing has been previously demonstrated with ICC values of > 0.70 indicating an accepetable level of relative reliability (36). CMJ testing was completed post the standardised warm-up and prior to commencing strength lifts. Players were familiarised with the plyometric task as it has remained within the strength and conditioning programme since the start of the season (5 months of familiarity). The CMJ test was selected for use in the measurement of dynamic lower limb strength given the high stretch-shortening cycle involvement and rapid eccentric and concentric contribution to the movement which are also evident features in human sprint running (24). Subjects completed 3 hands-free vertical CMJ trials with one minute rest allocated between trials. A self-selected level of arm swing and countermovement speed and depth was allowed. It has been suggested that performing a CMJ with an arm-swing may be more sport specific and allow athletes to achieve greater jump height (16). Players were instructed to jump vertically "as fast and as high as possible", while achieving vertical leg stiffness during the flight phase and landing in a hip dominant position. The highest absolute value attained from the 3 trials was extracted for analysis.

Acceleration Speed Testing

Subjects underwent a standardised and progressive warm-up prior to 20m acceleration speed testing to control variables and prepare subjects for high-intensity sprint efforts (18). The warm-up was 10 minutes in duration and consisted of a "RAMP" style warm-up (23) with non-fatiguing activation and mobility exercises including bodyweight squat and lunge patterns, interspersed with linear speed mechanics drills, followed by extensive and reactive plyometric drills. Such a warm-up protocol was selected to emulate the subjects's usual standardised warm-up which they complete before training on a regular basis. Each subject wore a GPS unit (Apex, STATSports, Newry, Down, Northern Ireland) with a data sampling rate of 10 Hz (mass = 48g, size = 30x90 mm, 100 Hz gyroscope, 100 Hz tri-axial accelerometer, and 10 Hz magnetometer) mounted in a bespoke pocket fitted in an appropriately sized vest on the upper thoracic spine between the scapulae. GPS units were switched on at least 15 minutes prior to testing to ensure a high quality satellite signal (25). All subjects were familiarized with the devices as part of their regular training and playing practices. Testing was completed on a previously familiarised outdoor grass pitch. A 20m sprint channel was marked using a trundle wheel. The start and end point of the channel was clearly marked using coloured cones. Subjects were instructed to start in a "two-point" staggered stance position with their front foot in line with the start cone. Subjects were then instructed to accelerate and sprint as fast as possible to the end-cone. The best performance from the 3 trials was extracted for analysis.

Following testing, GPS data were downloaded to a laptop and analysed with STATSports Sonra software (STATSports, Newry, Down, Northern Ireland). The software was used to identify the highest recorded velocity in metres per second (m/s) from 3 acceleration sprint trials. The GPS data file for each participating player from the testing session was downloaded and exported to Microsoft Excel (Microsoft Corporation, USA) for further analysis. 10-Hz STATSports Apex GPS units demonstrated excellent reliability for all sprint acceleration trials (ICC = 0.95).

Statistical Analysis

Statistical analysis was performed using Real Statistics Excel Add-In Software (version Rel 8.7). A Shapiro-Wilk test for normality did not show evidence of non-normality across the dataset. Intraclass correlation coefficients were calculated to assess the reliability of trials between sprint and jump performances. Pearson-product correlations were performed to determine the significance of relationships between variables. The strength of correlations was considered low (0.1 to 0.3), moderate (0.3 to 0.5), high (0.5 to 0.7), very high (0.7 to 0.9) and nearly perfect (0.9 to 1.0) (37). The significance level was set at $p < 0.05$. Additionally, a multiple regression analysis was performed to investigate the relationship between the predictor variables of strength and countermovement jump height on the outcome variable of sprint velocity (CI = 95%).

RESULTS

Descriptive statistics for the variables of interest are presented in Table 2. Intraclass correlation coefficients outlined strong reliability between trials for CMJ (r = 0.95, p < 0.001) and 20m sprint performance (r = 0.95, p < 0.001). Pearson-product correlations indicated that there were positive correlations between lower limb relative strength (r = 0.54, 95% CI [0.11 to 0.8]; p < 0.05) (Figure 1), countermovement jump height (r = 0.66, 95% CI [0.29 to 0.86]; p < 0.05) (Figure 2) and 20m sprint performance. A multiple linear regression analysis was used to test if lower limb relative strength and countermovement jump height significantly predicted 20m sprint performance. The overall regression was statistically significant (Adjusted R^2 = 0.51, F (2, 16) = 6.29, p < 0.05). Lastly, absolute strength was poorly correlated with 20 metre sprint performance (r = 0.35, 95% CI [-0.12, 0.69]; p > 0.05) and relative strength was poorly correlated with countermovement jump height (r = 0.3, 95% CI [-0.18, 0.66]; p > 0.05).

Table 2. Descriptive statistics and reliability for jump and sprint performance.

	Absolute Strength (kg) ≥95% 1RM	Relative Strength (kg·kg) ≥95% 1RM	CMJ (cm)	20m Sprint Velocity (m·s)
Mean	138.7	1.7	55.0	8.7
SD	14.0	0.2	7.4	0.3
ICC			0.9	0.9
SEM			1.7	0.1

**CMJ = countermovement jump; SD = standard deviation; ICC = intraclass correlation coefficient; SEM = standard error of the mean*

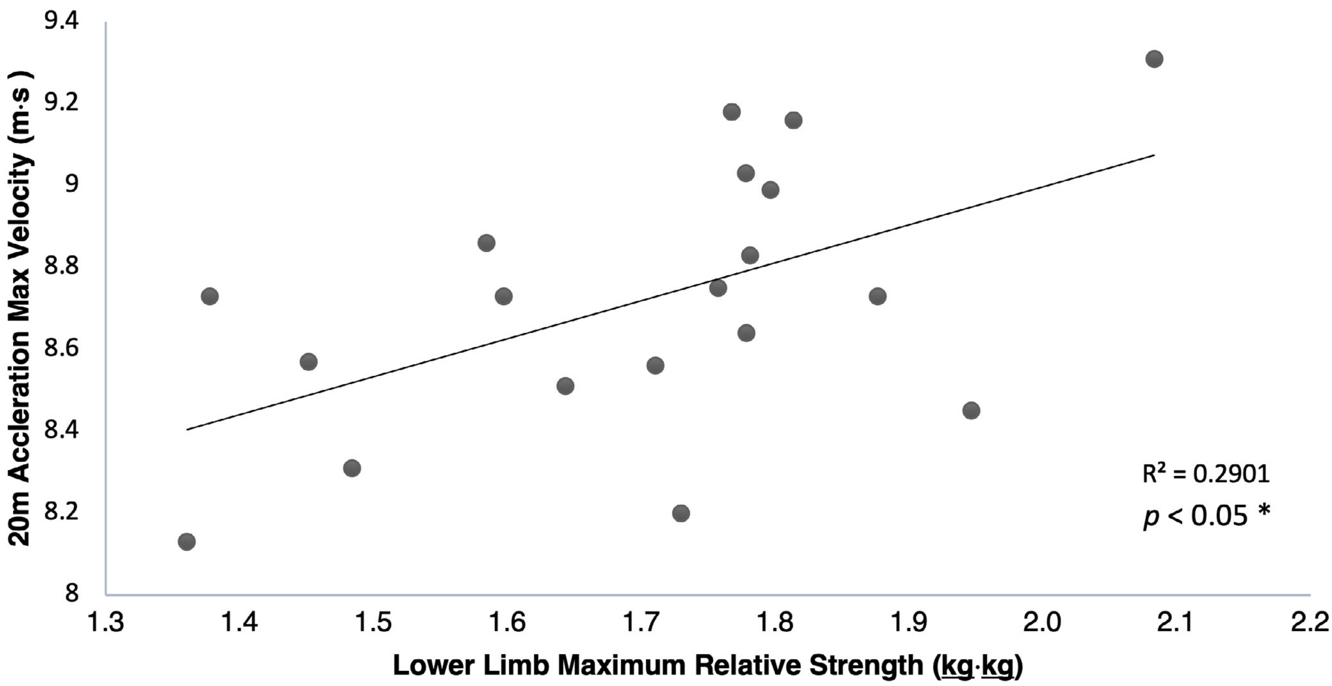

Figure 1. Relationship between lower limb relative strength and 20 metre acceleration sprint velocity.

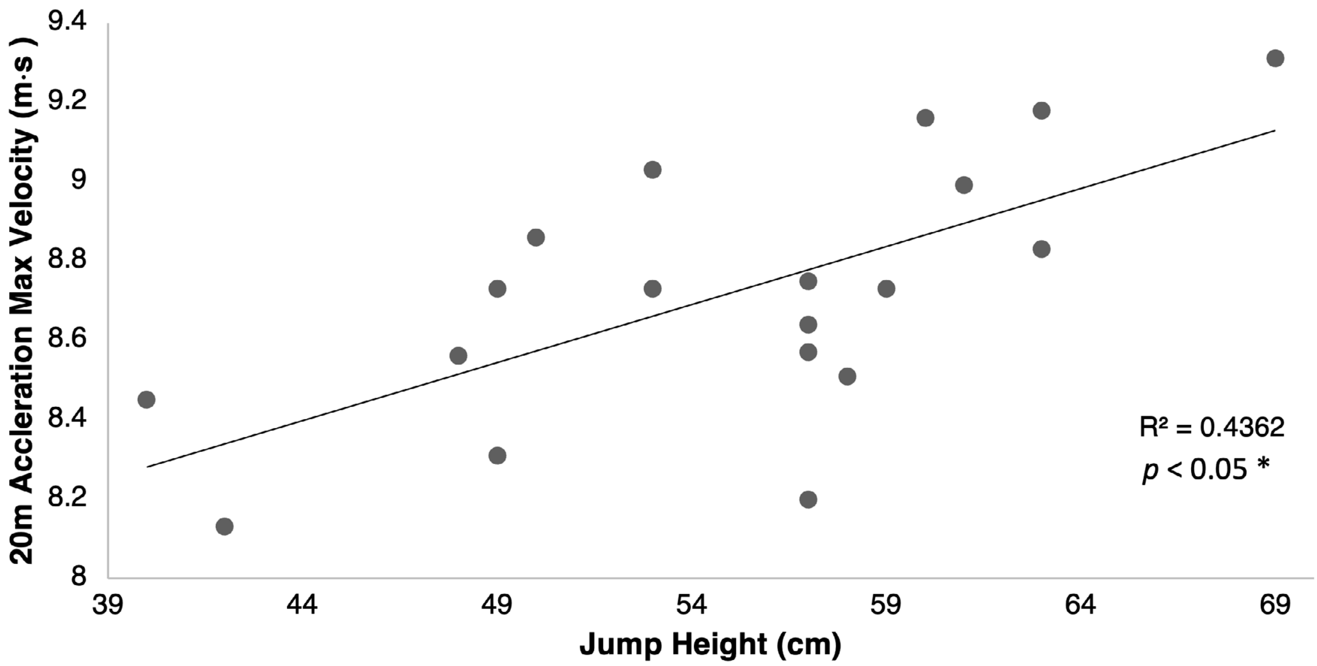

Figure 2. Relationship between countermovement jump height and 20 metre acceleration sprint velocity.

DISCUSSION

This investigation sought to investigate the relationship between lower limb absolute and relative strength, CMJ performance, and acceleration sprint velocity in elite U-20 Gaelic football players. The findings highlight positive relationships between maximum lower limb relative strength in the barbell box squat exercise, vertical CMJ height, and GPS recorded acceleration sprint velocity. Such findings are similar to those previously reported in elite under-age athletes in soccer (8,12). Moreover, lower limb relative strength showed a stronger relationship with 20m sprint performance when compared to absolute strength, similar to the findings of Wagner et al. (43). These findings may aid strength and conditioning practitioners with respect to the development and adaptation of strength and power qualities within physical conditioning training programmes.

When lower limb relative strength and jump height are considered as predictor variables for acceleration sprint velocity in a multiple regression analysis, the adjusted R^2 value indicates that 51% of 20m sprint velocity performance can be predicted by lower limb strength and power capacity. When squaring the reported correlational R value of 0.54 between strength and sprint velocity, 29% of 20m sprint performance can be influenced by lower limb relative strength. When squaring the R value of 0.66 reported between jump height and sprint velocity, 44% of 20m sprint performance can be explained by CMJ height. These results align with previous research findings (5,8,12) indicating that acceleration sprint velocity in team sport athletes is heavily reliant on lower limb relative strength and speed-strength capacity to overcome the inertia of body mass. However, it should be noted that the current sample represented a very select and relatively high-performing group of Gaelic Football athletes, and such relationships may not apply to all Gaelic Football cohorts.

Despite our demonstration of significant relationships between lower limb relative strength and power with acceleration sprint velocity, this study is not without limitations. Due to the fact that this study is a cross sectional, correlative study, and as correlation does not imply causation, we only consider one aspect of athletic development in isolation during an in-season period with athletes of a relatively low training age. As a barbell box squat and a CMJ are biomechanically dissimilar to an acceleration (albeit many of the same strength and power qualities are used in these movements), the law of diminishing returns must be considered. When predicting the transfer from physical capacity over time to improvement of specific technical on-field performance, lower limb strength and power does not provide a complete explanation, therefore, it should not be the only variable of interest for the long term development of athletes. Moreover, increasing lower limb strength, CMJ height or acceleration speed does not guarantee or predict enhanced on-field playing ability in match-play or training scenarios where lower body strength, power or acceleration speed comprise a component of technical skill execution. It is imperative to consider how the strength and conditioning domain fits into a broader picture of integration within teams and coaching staff and how it must be related to a technical model of multi-disciplinary coaching. A player's technical and tactical skills, injury history, psychological skills, interactions with teammates and coaching staff, as well as the players' broader development environment are other variables that influence on-field sport performance (42). Talent development in youth team sport is complex, dynamic, non-linear, and multi-dimensional, influenced by a range of biopsychosocial variables (9). Therefore, individual variables must not be considered in isolation within coaching models when the goal is to provide a holistic approach to development (7). In addition, this study utilised a sample size of 19 athletes, all from one U-20 inter-county squad. Future studies should aim to include larger cohorts across squads at this level.

FUTURE RECOMMENDATIONS

The findings from this study outline the importance of elite U-20 Gaelic football athletes developing high levels of lower limb multi-joint maximum and dynamic strength to improve acceleration sprinting speed. Assessments of lower limb strength and speed-strength capacity in elite youth players may form part of a multi-disciplinary comprehensive talent identification and development assessment battery for effectively transitioning players to higher intensity demands at the elite senior level. Conducting longitudinal correlational research can allow the strength and conditioning coach to effectively investigate relationships between physical training variables and to examine the efficacy of training programmes, although the limitations of these methods need to be considered (e.g., the law of diminishing returns, other biopsychosocial factors related to athletic development and performance).

A comprehensive gym-based strength and conditioning programme with this cohort should target lower limb maximum strength and speed-strength development as a primary focus to assist in the development of linear acceleration performance. It is recommended that during the pre-season, coaches seek to progressively overload these strength, speed, and power athletic motor qualities to allow for appropriate and effective in-season maintenance during an in-season playing period (35). Importantly, strength and conditioning coaches should not lose sight of biomechanical training specificity (21) and should prescribe regular periodised exposure to high-intensity acceleration and maximum velocity sprinting as key components of on-field linear speed development. Future research should now focus on collaboration amongst strength and conditioning practitioners working within elite inter-county age-grade environments on a national scale to expand investigative networks and gain further insights into the relationships between lower limb maximum strength, power, and sprint variables in this cohort.

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