THE ABSOLUTE AND RELATIVE PHYSICAL DEMANDS OF LEAGUE ONE FOOTBALL USING CATAPULT GPS

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Introduction

- Collection of individual match loads has become increasingly popular in football (soccer) for assessing the demands of match play.
- Research is limited in professional football examining competition loads using GPS technology (EFL agreed to competition use in August 2015).
- Most research examines non-competitive, friendly or youth matches and/or uses a semi-automated camera system (i.e. Prozone/Tracab) which have been shown to over-estimate high speed activities.[3,4,7]
- Matches are contested on an absolute basis, where the physical demands are traditionally expressed as distances covered in arbitrary velocity zones - assuming all players share the same performance capacity.[1,3]
- An individualised approach to load monitoring may enhance the practitioners understanding of the match and individual demands.[1]
- The purpose for this study was to examine the absolute vs. relative physical demands of League One Football League using Catapult GPS.

The need for relative velocity monitoring:

(1) Assume two athletes are running at the same velocity, the slower athlete will experience a higher workload, absolute velocity zones may miss these differences.

(2) Assume an athlete has a MSS** of 36km/h, can 25.2km/h (70% of MSS) really be defined as a sprint as it would in most research?

Approach

- Data was recorded via 10Hz GPS units (Catapult X4 system) during 48 League One fixtures in the 2016/17 season (including 2 play-off fixtures).
- 338 match observations for 18 players in five positions (FB, CB, CM, AM, STR). We excluded players who did not complete the full match.
- Total distance and distance in various velocity zones were analysed:
  - Absolute velocity zones (same for all athletes):
    - 14.4-19.8km/h (running distance)
    - 19.8-25.2km/h (high-speed running distance)
    - >25.2km/h (sprint distance)
  - Relative velocity zones (dependent on fitness testing data):
    - vVO_2*-80% MSS (high-speed running distance)
    - 80% MSS–95% MSS (very high-speed running distance)
    - >95% MSS (maximum sprint distance)

*vVO_2 = velocity at maximal oxygen consumption

**MSS = maximal sprint speed

Results

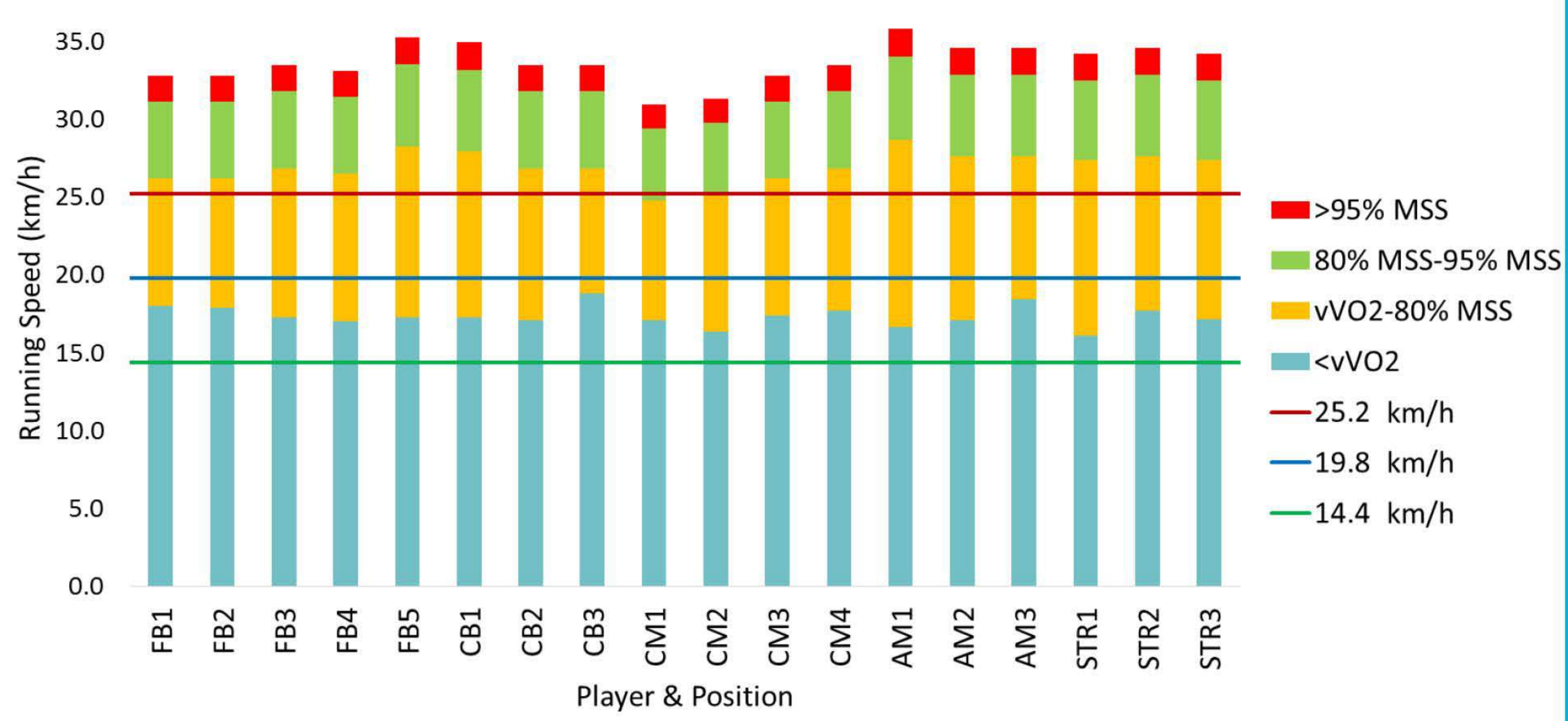

Figure 1: Velocity bands for each athlete determined from fitness testing for relative individualised thresholds (bar) and research for absolute arbitrary thresholds (line).

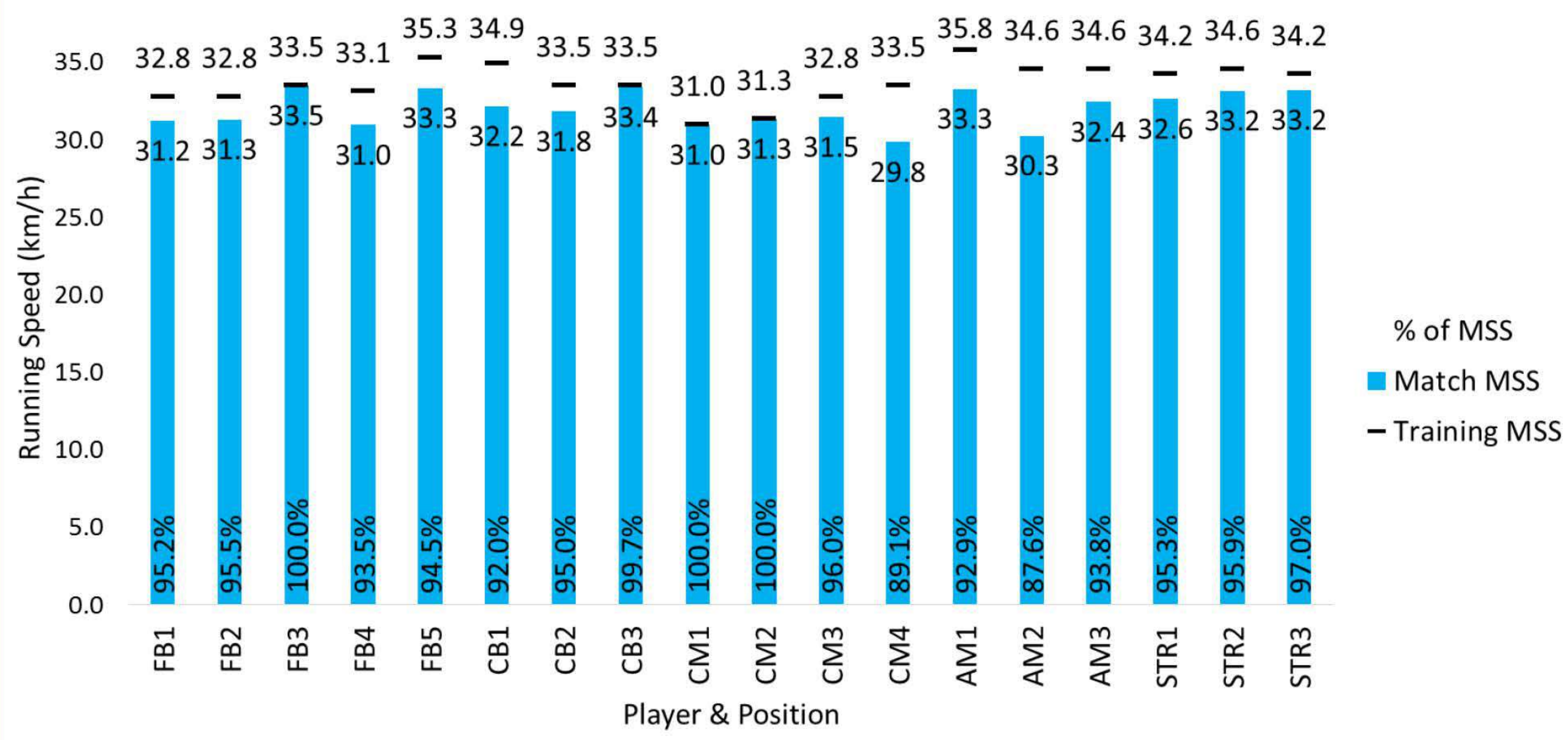

Figure 2: Match MSS (maximal sprint speed) achieved during the 2016/17 season compared with Training MSS descriptively and as a percentage for each athlete.

Table 1: Mean (±SD), maximum and minimum of the distances covered in various velocity zones (both absolute and relative) and positions.

Band	Total Dist. (m)	Absolute: Run Dist. (m)	Absolute: High Speed Run Dist. (m)	Absolute: Sprint Dist. (m)	Relative*: vVO_2-80% MSS Dist. (m)	Relative*: 80% MSS-95%MSS Dist. (m)	Relative*: >95% MSS Dist. (m)
Velocity		(14.4-19.8km/h)	(19.8-25.2km/h)	(>25.2km/h)	(17.4-26.9km/h)	(26.9-31.9km/h)	(>31.9km/h)
Mean (*n* = 338)	10743.3 (403.8)	1545.5 (146.7)	531.5 (81.1)	129.7 (35.2)	1041.8 (352.9)	55.5 (41.6)	0.7 (2.6)
Max	12742.1	2642.9	1293.1	439.4	2148.2	200.5	16.1
Min	8774.7	694.9	166.5	0.0	366.3	0.0	0.0
FB (*n* = 86)	10754 (597.1)	1623.8 (251.3)	599.7 (145.5)	142.3 (76.9)	1109.9 (261.6)	67 (45.6)	0.7 (2.4)
CB (*n* = 89)	10160.5 (543.8)	1218.7 (191.4)	351.5 (101.6)	73.2 (41.0)	614.3 (134.3)	30.7 (24.7)	0.6 (2.5)
CM (*n* = 79)	11165.3 (494.6)	1669.9 (298.1)	483.6 (149.3)	94.2 (62.5)	1177.7 (258.1)	61.8 (44.6)	1.1 (2.9)
AM (*n* = 50)	11091.1 (530.4)	1690.2 (244.8)	703.1 (133.7)	200.7 (80.2)	1236.3 (264.1)	54.1 (36.8)	0.0 (0.3)
STR (*n* = 34)	10655.4 (653.7)	1563.2 (284.6)	697.1 (178.1)	225.0 (85.9)	1394.7 (249.6)	82.1 (42.7)	1.5 (4.1)

* based on vVO_2 and MSS averaging 17.4 km/h and 33.7 km/h, respectively.

Conclusions

- Absolute & relative high speed activity consistently highest for attacking players (AM & STR) and lowest for centre backs (Table 1).
- Distances covered close to individual MSS occur but are rare in competitive football matches (Table 1 & Figure 2). Of the 338 observations, distance >95% MSS was achieved on 40 occasions (11.8%).
- Anecdotally, absolute sprint distance (>25.2km/h) appears to be more player specific than position specific (excluding centre backs).
- Defining 25.2km/h for a sprint appears to be too low for most athletes.
- Arbitrary velocity zones are not standardised in the research literature, which makes between study contrasts difficult.
- Further research could look to define a sprint and compare the difference between maximal efforts at different velocities and distances.

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Practical Applications

- Both relative and absolute monitoring can be useful:
  - Relative velocity zones can assist with individualised training prescription, longitudinal monitoring and it will help when reviewing effort levels (a coaches favourite).
  - Absolute velocity zones can compare athletes against each other, especially if they're competing for a position that requires specific physical outputs.
- Careful considerations are required for maximum velocity prescription in-season. The 2016/17 season was 39 weeks with a game every 4.9 days including 19 midweek fixtures.

Impact of accommodating resistance on potentiating horizontal jump performance in professional rugby league players.

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Introduction

It has been reported that short sprint accelerations of up to 20m are a key indicator of success in professional rugby league (6), with recent research highlighting the importance of horizontally oriented exercise such as the standing broad jump SBJ to sprint acceleration performance (2). Combining the use of a SBJ with post-activation potentiation (PAP) could augment its performance and enhance it's acute and chronic training adaptations (3). Furthermore, accommodating resistance in addition to a moderate intensity of traditional loading can allow the PAP effect to occur earlier than the previously reported 5-8 minutes (5,7). Previously, only box squats accommodated with bands have been studied as a conditioning activity within the PAP literature (1, 8) and it is hypothesised that deadlifts, which involve greater activation of the hip extensors, performed under similar conditions would prove an equally if not more effective potentiating stimulus (4).

Method and Design

12 professional rugby league players (age: 21.4 ± 2.5y; stature 181.3 ± 8.3cm; body mass 91.9 ± 8.8kg) were assessed for 1RM strength in the back squat 7 days prior to the experimental design. All subjects performed a baseline SBJ measurement before a contrast PAP protocol involving 2 repetitions of 85% 1RM paused box squat or deadlift, loaded with a combination of traditional barbell weight (70% 1RM) and elastic band resistance (~15% averaged over the entire range of motion), followed by two SBJs. 90sec separated the exercises and sets and four contrast pairs were performed in total. Subjects performed all three conditions in a non-randomized order of squat, deadlift, control (SBJ only) over consecutive weeks. Results were analysed using a repeated measures ANOVA with a bonferroni correction

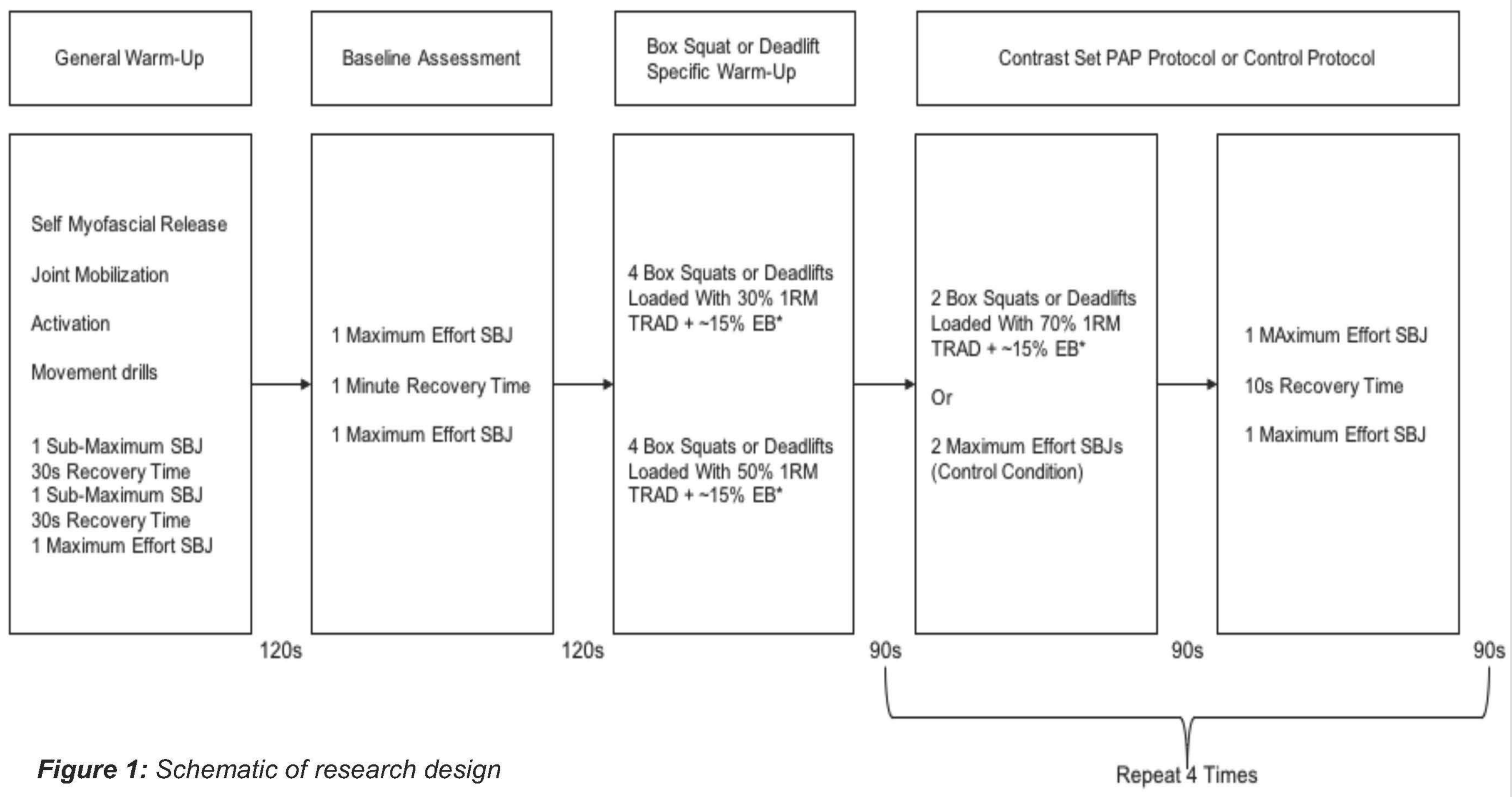

***Figure 1:** Schematic of research design*

Results

Table 1. Percent changes in standing broad jump performance across the four Sets of the contrast box squat, contrast deadlift, and control protocols.

	Set 1	Set 2	Set 3	Set 4
Contrast Box Squat Protocol				
% Change from baseline	6.01 ± 2.25	5.13 ± 2.04	5.14 ± 2.12	3.82 ± 2.08
P value*	< 0.001	<0.001	<0.001	0.001
Contrast Deadlift Protocol				
% Change from baseline	4.64 ± 2.24	5.35 ± 2.20	5.00 ± 3.10	5.31 ± 2.97
P value*	< 0.001	<0.001	0.002	0.001
Control Protocol				
% Change from baseline	0.80 ± 1.28	0.24 ± 2.73	0.30 ± 1.42	0.67 ± 2.24
P value	1.000	1.000	1.000	1.000

*SPSS Bonferroni adjusted P values

SBJ distance was significantly greater than baseline for all sets of the box squat (3.82 ± 2.08 to 6.01 ± 2.25%) and deadlift protocol (4.64 ± 2.24 to 5.35 ± 2.20%) while no PAP effect was observed in the control condition (Table 1). The magnitude of differences in PAP effect were considered medium (d = 0.61) for set 1 and trivial for set 3 (d = 0.05) in favor of box squats, and medium for set 4 (d = 0.58), and trivial for set 2 (d = 0.1) in favor of deadlifts (Figure 2). There were no significant differences between experimental conditions across all sets, nor for maximum PAP effect regardless of the set.

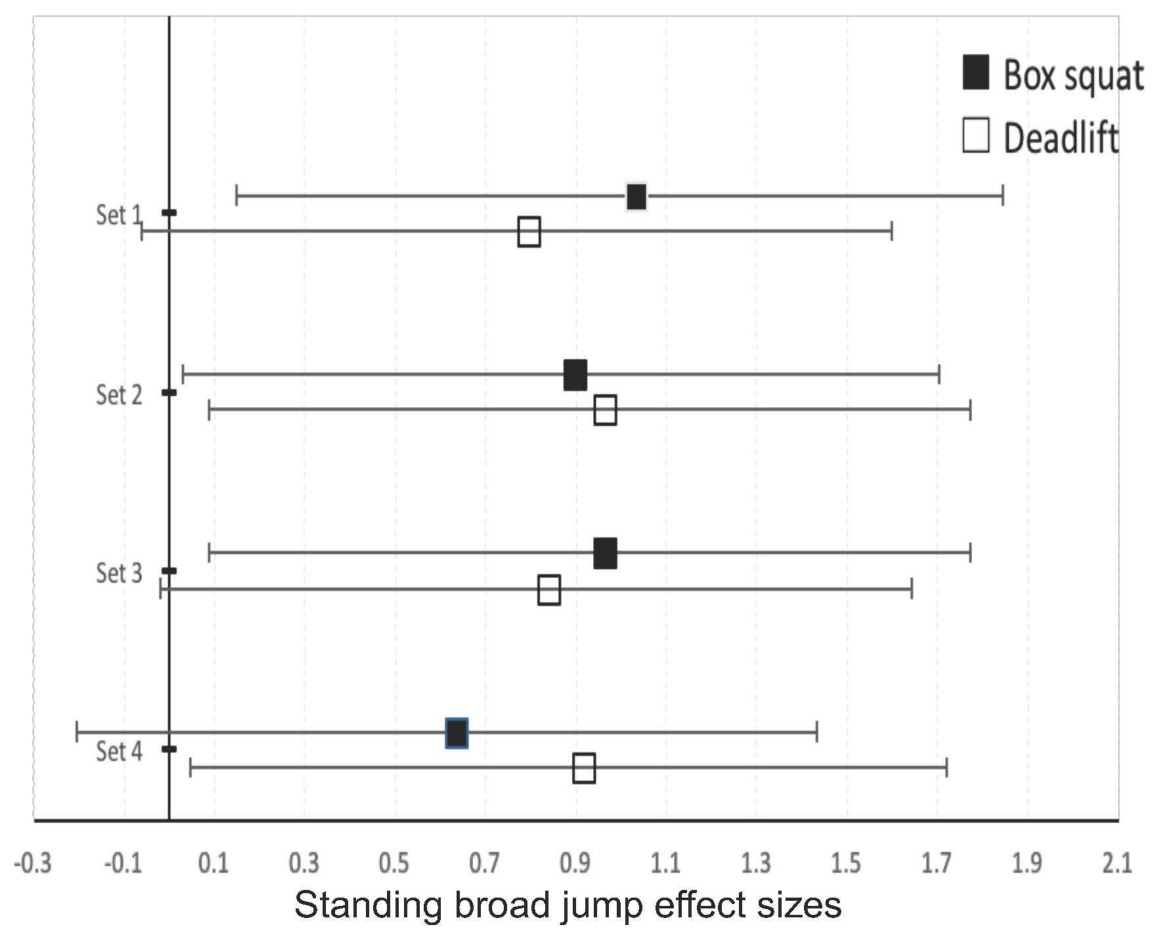

Figure 2. Standardized effect sizes of the box squat and deadlift conditions. Plots represent the magnitude of changes between baseline standing broad jump and the standing broad jump recorded in each of the four sets of the contrast protocol. Error bars indicate 95% confidence intervals of the mean difference between time points.

Conclusion

Accommodating resistance exercise, either box squats or deadlifts are an effective means of potentiating SBJ performance after only 90s of rest. In addition, the potentiating effect can be maintained across four sets of a PAP contrast set protocol. Previously, only box squats have been shown to potentiate horizontal jump performance after 90s and over multiple sets. The present findings are the first to report that similar levels of potentiation can be achieved with the deadlift as a conditioning stimulus.

Practical Applications

Based on the present results, strength and conditioning practitioners seeking to implement a contrast set PAP protocol should consider using either the box squat or deadlift loaded with a combination of 70% 1RM plus an additional ~15% 1RM from band resistance. This will allow a multiple set PAP protocol to be completed in approximately 12 minutes, during which SBJ performance can be potentiated by 3.82 ± 2.08 – 6.01 ± 2.25% across four sets.

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The effects of measurement error and testing frequency in applying the Fitness Fatigue Model to resistance training: A simulation study

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Introduction

- The four parameter, two component, Fitness Fatigue Model (FFM) posits that training causes two antagonistic after-effects, a long-lasting positive fitness effect and a shorter-lasting negative fatigue effect. [1]
- Whilst the model is frequently used as a conceptual framework, it can be applied using mathematical functions and fitted to individuals using recorded training and performance data. [2]
- Performance as a function of time, is denoted by the discretized form of the model (where w(s) is training load on day s and k_1, k_2, T_1, T_2 are the fitted individual parameters). [2]

$$p(t) = p(0) + k_1 \sum_{s=0}^{t} e^{-\frac{t-s}{\tau_1}} \cdot w(s) - k_2 \sum_{s=0}^{t} e^{-\frac{t-s}{\tau_2}} \cdot w(s)$$

- The use of mathematical models in training science may offer an approach to describe the effects of training, and improve coaching decisions.
- The emergence of affordably priced field devices for measuring variables commonly associated with athletic performance, opens up new possibilities for individualised, practitioner lead implementation of mathematical models of this type.
- However, not much is known about the precision of existing models such as the FFM, when operated using data collected from these devices.

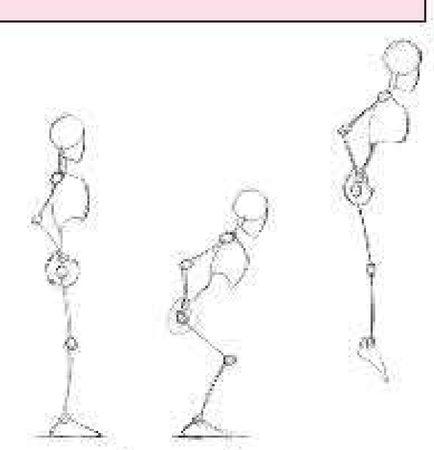
1. Quantify arbitrary training load (TRIMPS) for each individual athlete via suitable method (i.e. exponential weighting of intensity). Make reasoned guesses at initial model starting parameters.
2. Collect regular training derived criterion measure (i.e. vertical jump), or competitive performance (i.e. 50m swim sprint under simulated competitive conditions)
3. Fit model predicted values for performance to collected training derived measures using suitable method, i.e. minimising residual sum of squares (RSS)
4. Follow athlete through many training cycles. Model becomes more predictive, as better precision achieved in model fit (through manipulation of initial parameters and TL quantification).

Figure 1. A simplified method for applying the FFM in practice

Research Aim & Approach

To assess the effects of measurement error (typical error) and testing frequency on the ability of the FFM to accurately model resistance training data. A simulation approach assuming correct model specification was used to identify upper bounds for precision based on realistic measurement error and testing frequencies.

Method



- Representative training data and vertical jump power values were generated for an 80kg athlete over 24 weeks using the FFM and selected parameter values.
- Measurement error was added to the data to correspond with power values collected from a force platform (typical error: 100 W) or a linear position transducer (typical error: 175 W).[3]
- The FFM was fitted with least squares regression using data from the first 12 weeks and assuming performance measurement on a weekly or daily basis.
- Simulations of N = 10,000 were completed for each scenario comparing variability in predicted performance with values generated by the true parameters over the final 12 weeks.

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The simulation platform was custom built for this project using R

Results

Greater variability in predicted performance was obtained when reducing measurement frequency (weekly vs. daily measurement) compared with increasing measurement error (linear position transducer (LPT) vs. force platform). This is shown in table 1.

Measurement Tool	Measurement Frequency	2.5% CI	97.5% CI
Force Platform	Once Per Day (OPD)	- 44 Watts	+ 81 Watts
Linear Position Transducer	Once Per Day (OPD)	- 83 Watts	+ 138 Watts
Force Platform	Once Per Week (OPW)	- 222 Watts	+ 647 Watts
Linear Position Transducer	Once Per Week (OPW)	- 501 Watts	+ 1148 Watts

Table 1. Ninety five percent confidence intervals calculated for the difference between the true performance measure and simulated FFM predictions with fitted parameters at the end of the 24 weeks.

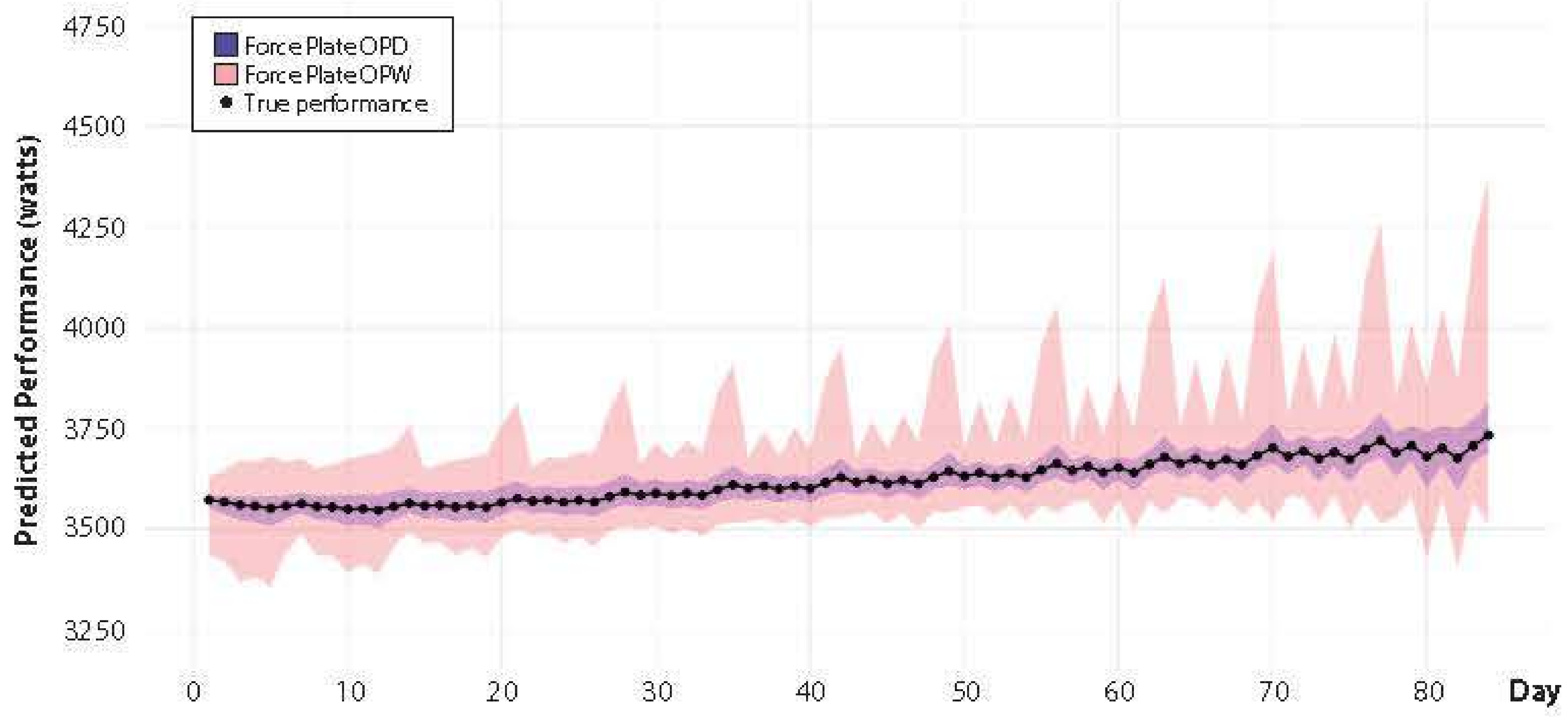

Figure 2. Variability in simulated predicted performance (VJ Peak Power Output), measured with a force plate once per week (pink) and once per day (purple), compared to values generated by true parameters (dots/line), over the final 12 weeks.

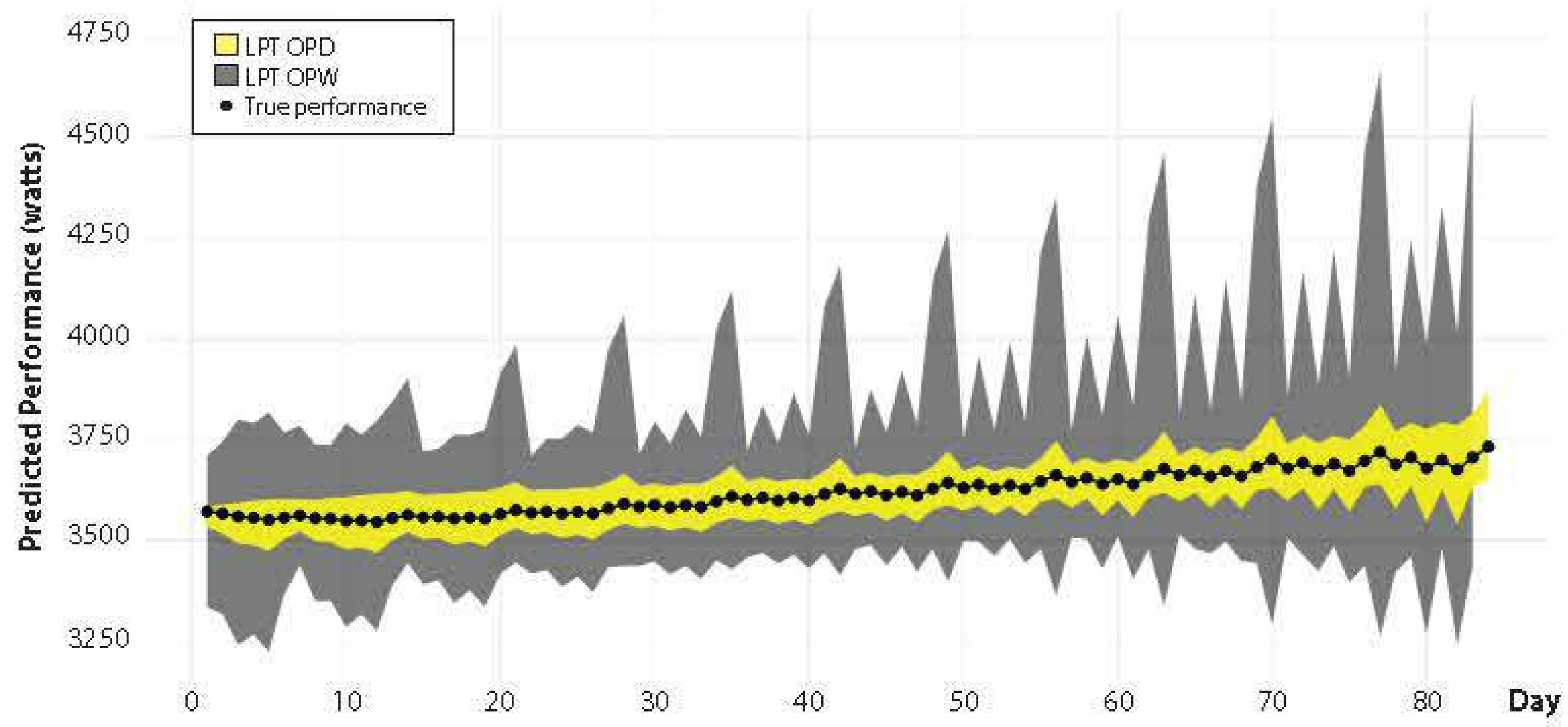

Figure 3. Variability in simulated predicted performance (VJ Peak Power Output), measured with a LPT once per week (grey) and once per day (yellow), compared to values generated by true parameters (dots/line), over the final 12 weeks.

Conclusions & Practical Relevance

- The Fitness Fatigue Model requires frequent measurements in order to consistently model the response to resistance training.
- Reliable measurement technology is preferred; however, frequent measurements may compensate to some degree for the use of less expensive and subsequently less reliable technology.
- Further simulations incorporating a greater range of training programs and response profiles are required to better understand the potential for applying the FFM in modelling and programming resistance training.

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The Practice of Resistance Training Among Irish Distance Runners and Knowledge and Perceptions of Coaches

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BACKGROUND

- The role of resistance training (RT) in endurance running performance remains a topic of debate among athletes, coaches and sports scientists.
- There is strong evidence to support the inclusion of RT in the training program of endurance runners[1,2,3], but few studies detailing knowledge and practices.

Objective: To explore the practice of RT among elite endurance athletes, and knowledge and perceptions of RT among high performance endurance running coaches.

METHODS

A mixed-methods approach was used:

A. Elite Irish distance runners (n=109, n=78 male and n=31 female; aged >18 y), competing from 800 m up to the Marathon from national competitive to international level of performance, completed an **online questionnaire** about their RT practices.

B. Semi-structured interviews took place with select **coaches (n=7) of Irish elite endurance runners**. All coaches were previously competitive athletes, three of whom competed at the Olympic Games. The coach interviews were audio-recorded and transcribed verbatim. A six-stage data analysis process was used to identify the common themes.

RESULTS (A) – COACH INTERVIEWS

Three primary themes emerged from the coach interviews:

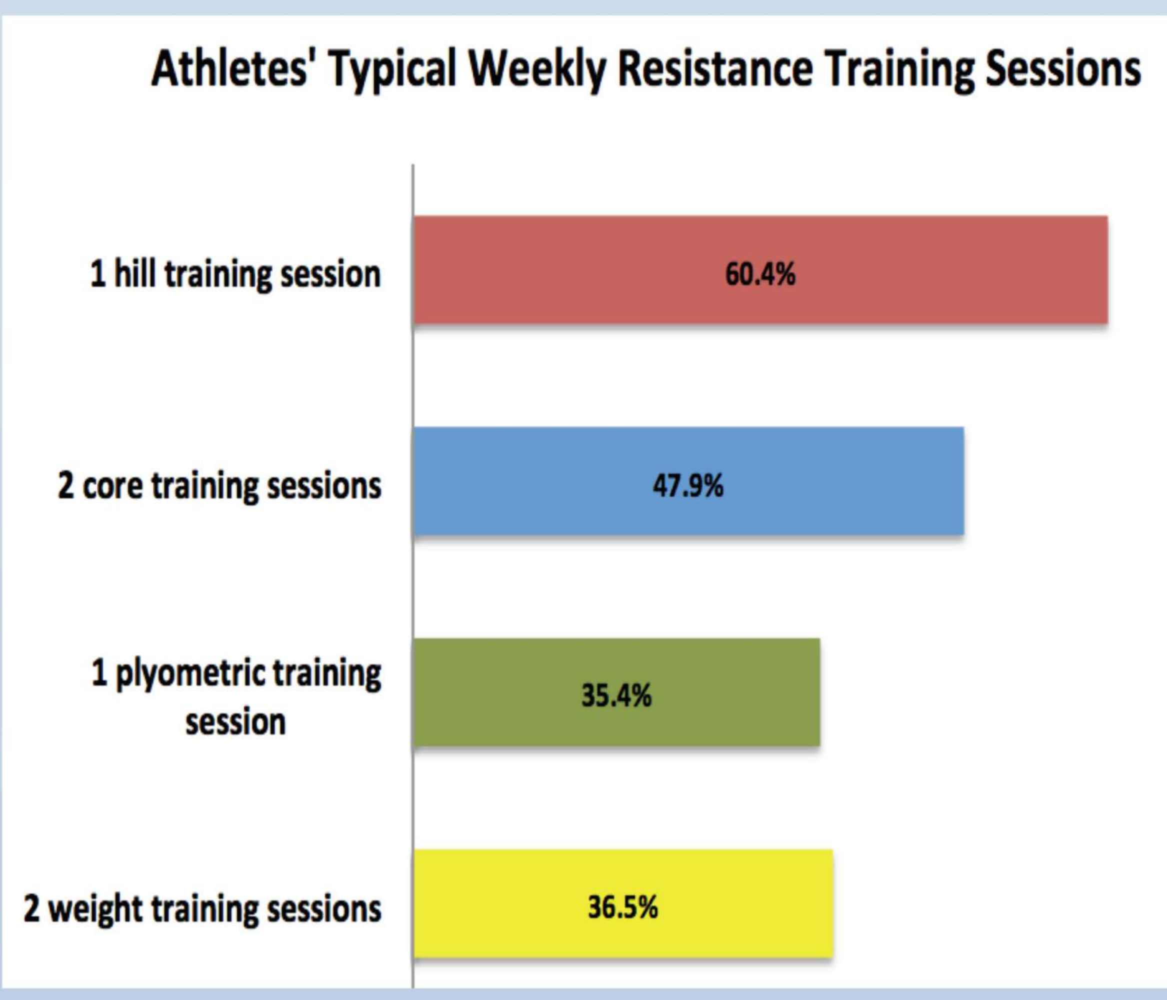
1. Perceptions of RT
Varying levels of knowledge and perceptions of RT, largely influenced by the coaches' own personal experiences as athletes.

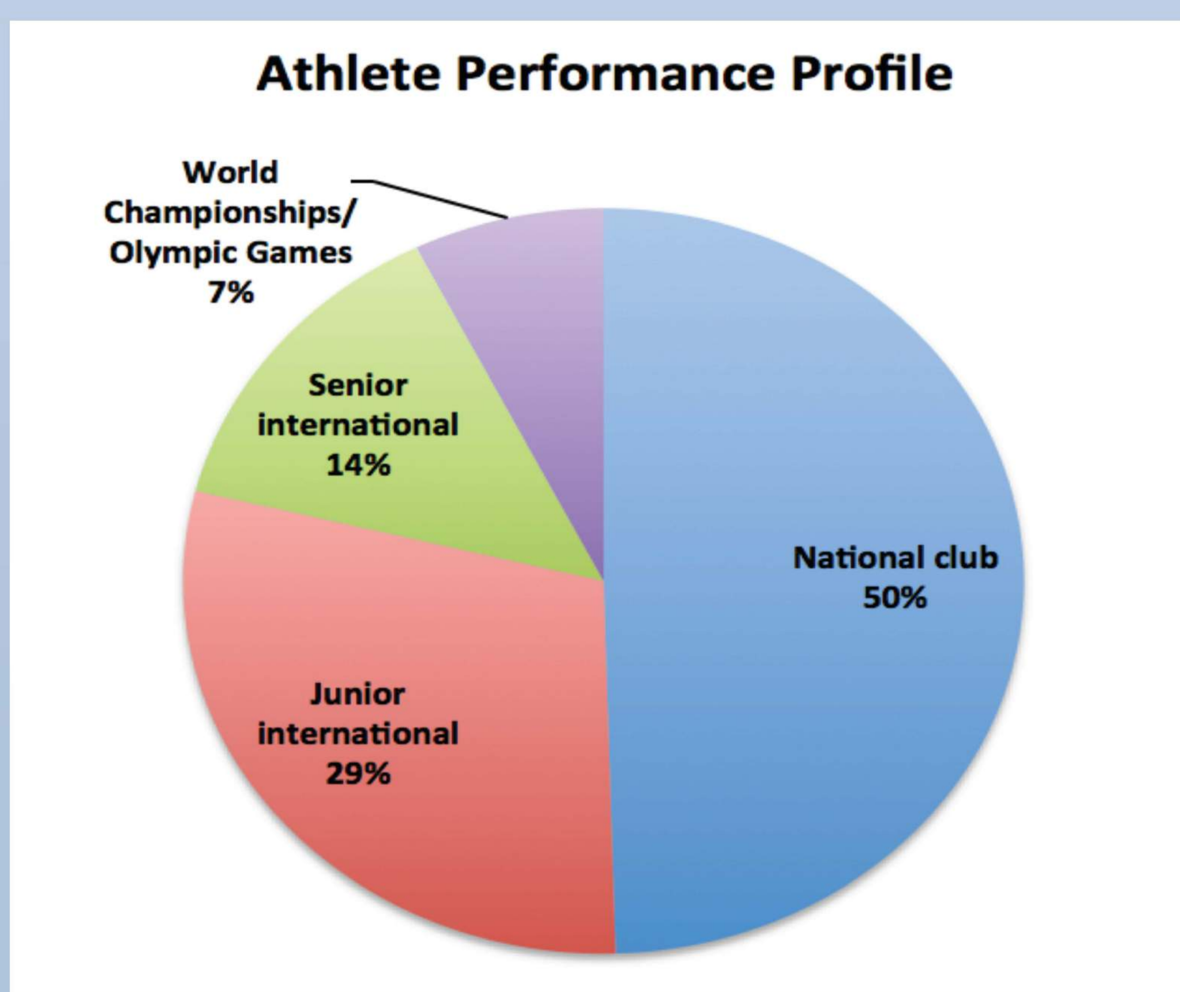
2. RT Methods
Hill training, weight training, plyometric training and core stability training are included in their programs to mixed degrees. Two coaches felt that hill training provides a sufficient RT stimulus. However, research does not support this perception[4].

3. Interaction with S&C coach
All of the coaches utilise the services of S&C coach, but with varying degrees of interaction.

RESULTS (B) – ATHLETE QUESTIONNAIRE

Eighty-eight per cent of athletes practice RT regularly:





Coach Profile

Coach	Gender (M/F)	Event Speciality	Years coaching	Currently coaching Irish elite international athletes (Y/N)	Coaching Award Level
A	M	800m-5000m	13	Y	AAI Level 2
B	M	800m-Marathon	20	Y	None
C	M	800m	8	Y	AAI Level 3 / IAAF Level 4
D	M	800m-Marathon	8	Y	UK Level 2
E	F	800m-Marathon	18	Y	AAI Level 3 / IAAF Level
F	M	Marathon	28	Y	AAI Level 2
G	M	800m-Marathon	22	Y	AAI Level 3

Resistance Training Methods Used By Coaches

Coach	Resistance Training methods used Hill training (Hill), Plyometric training (Plyo), Strength training (ST), core stability (Core)	Utilises S&C coach (S&C coach) or coach-led (coach)
A	Hill, Plyo, ST, Drills	S&C coach, coach
B	Hill	S&C coach, coach
C	ST, Plyo	S&C coach
D	Hill, ST, Plyo, Drills	S&C coach, coach
E	Hill, ST, core,	S&C coach
F	Hills, Core	Coach
G	Hills, Plyo, ST	Coach

CONCLUSION

- Irish distance runners and their coaches include resistance training methods that are typically employed to improve running economy and performance.
- Endurance running coaches lack sufficient knowledge of RT largely influenced by their own previous experiences as athletes.
- Improved interaction between the coach, athlete and S&C coach is needed, as well as greater collaboration in the decision-making regarding the athletes training program and performance management.

PRACTICAL APPLICATIONS

- This study highlighted the need for endurance running coaches develop healthier relationships with S&C coaches.
- Endurance running coaches would benefit from improving their theoretical knowledge and understanding of the principles of RT to optimise the training programs of their athletes.
- Future prospective studies should examine the periodization of RT in a distance runners training program over the course of a season.

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The Impact of Relative Age and Maturity Upon Fitness in Adolescent Males

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UNIVERSITY OF BATH TEAMBATH FUTURES

INTRODUCTION

- Fitness testing can inform the processes of talent identification and development in young athletes (1). Differences in relative age and maturation can, however, confound fitness testing among youth (2) with relatively older, more mature athletes demonstrating superior fitness (3).
- The degree to which age, relative age and maturation impact athletic fitness in the general population is unclear.

METHOD

Participants:

- British male school children 11-15 yrs (N=221)

Testing:

- **Demographics**
  - Age, Relative Age
  - Height, Weight
  - Percentage of predicted adult stature (maturation): Khamis - Roche method
- **Fitness Tests:**
  - Speed – Linear 10m, 20m and 30m Sprint
  - Sprint Momentum – 10m Initial Momentum
  - Agility – 505 Agility Test
  - Upper Body Strength – Hand Grip Dynanometer
  - Power – Countermovement Jump
  - Balance – Lower Extremity Y-Balance

Statistical Analysis:

- Multiple linear regression analyses were conducted to estimate main and interactive effects of age, relative age and maturity status upon athletic fitness

CONCLUSIONS

- Speed, power, momentum, agility and upper body strength performance indicate a trend towards improving with chronological age, reflecting the natural development of physical fitness during adolescence.
- There is a need to consider the impact of relative age and maturation upon performance in some, but not all, tests of physical fitness
- Late maturing and relatively younger individuals may perform worse in upper body strength tests
- Athletic fitness should be judged relative to both age and maturity specific standards

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PURPOSE OF THE STUDY

- To investigate the main and interactive effects of age, relative age and maturation upon athletic fitness in adolescent males aged 11 to 15 years
- Consistent with research conducted in athletic populations it was expected that age, relative age and maturation status would predict superior performance in tests of athletic fitness in British schoolchildren.

RESULTS

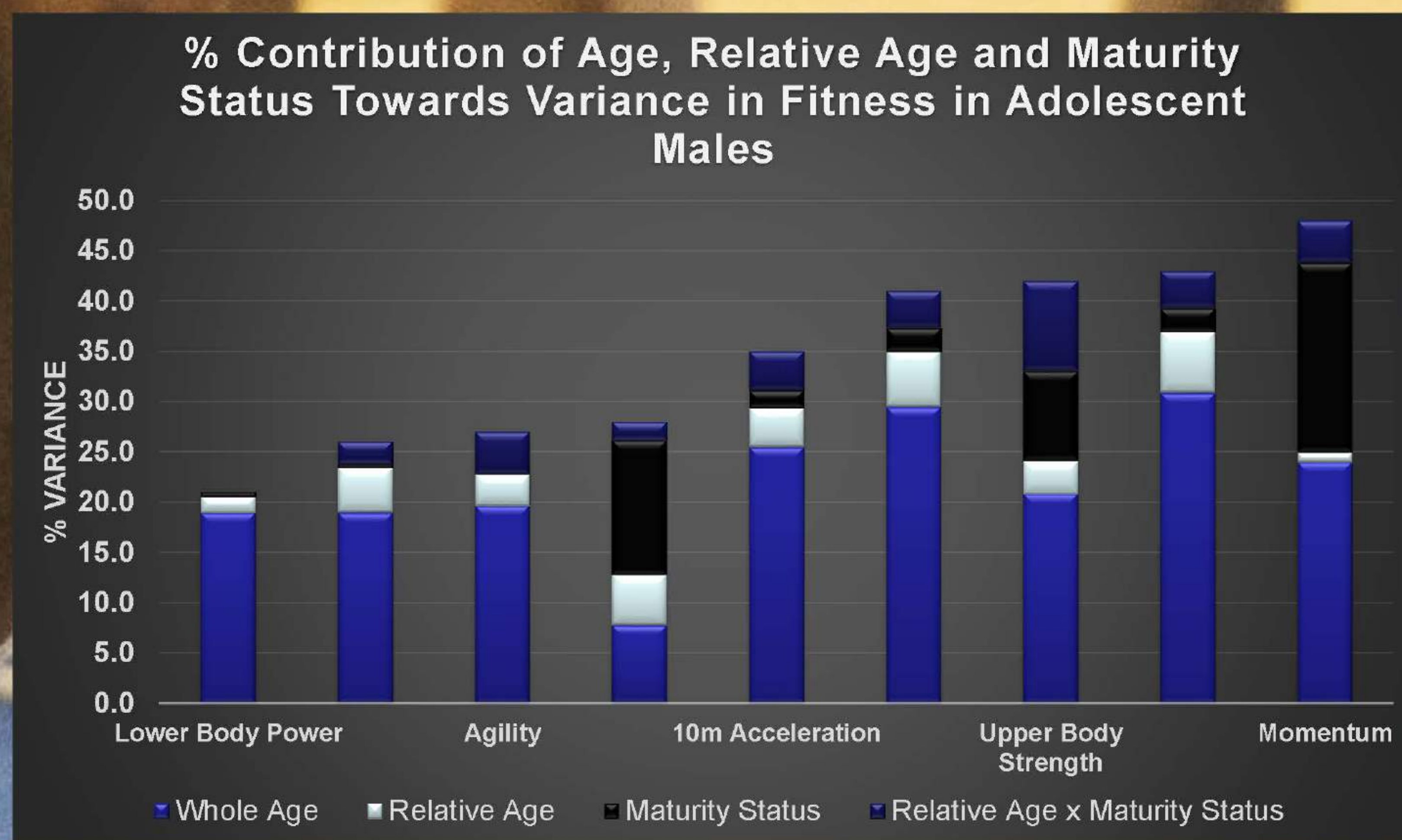
- The regression models predicted a significant proportion of variance in all fitness tests (table I)
- Whole year age positively predicted fitness on all tests ($p < 0.05$)
- Relative age positively predicted speed at 20m and 30m ($p < 0.05$); yet was inversely associated with balance ($p < 0.01$)
- Maturity status positively predicted momentum and strength ($p < 0.001$); yet was inversely associated with balance ($p < 0.001$)
- The interaction between relative age x maturity status predicted superior upper body strength ($p < 0.05$); specifically delayed maturation was associated with poorer performance in relatively young males, but not in older males

Table I: Summary of β Coefficients from Final Model Hierarchical Regression Analysis for Variables Predicting Fitness Variables in boys aged 11-15 years.

Variable	*Lower Body Power*	*Total Body Power*	*10m Acceleration*	*20m Speed*	*30m Speed*	*Agility*	*Momentum*	*Strength*	*Balance*
Age	.46***	.51***	-.59***	-.64***	-.66***	-.51***	.52***	.58***	-.25***
Relative Age	.04	.12	-.09	-.12*	-.13*	-.08	.02	.09	-.16**
Maturity	.01	-.01	-.04	-.05	-.05	.00	.41***	.25***	-.43***
Relative Age x Maturity	-.00	-.06	.09	.08	.08	.11	-.09	.25*	-.06
R^2	.21	.26	.35	.41	.43	.27	.48	.42	.28
F for change in R^2	.00	.90	2.32	2.27	2.50	3.15	3.37	5.44*	.95

Note: Relative Age and Maturity were centred at their means

**p* < .05. ***p* < .01. ***p.<.001



PRACTICAL APPLICATIONS

- Practitioners need to account for differences in relative age and maturation when evaluating fitness in males of the same chronological age; and, potentially, when grouping athletes for training and competition
- Age and maturity specific fitness standards derived from the general population could aid in the assessment and monitoring of fitness in athletic samples

Relationships Between Training Load, Neuromuscular Fatigue and Creatine Kinase Following Simulated Fast Bowling

UNIVERSITY OF HULL

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INTRODUCTION

Cricketers, specifically fast bowlers, are inherently exposed to irregular variations in competition training load (TL [overs bowled]) dictated by match format. As a result, there is an increased need to quantify the physical demands and "dose-response" relationships experienced by fast bowlers during training and competition. The aim of this study was to examine the TL response to differing lengths of fast bowling spell and the changes (Δ; from baseline) in neuromuscular fatigue (NMF) and plasma creatine kinase (CK) concentration.

METHOD

Participants

Eleven highly-skilled male fast bowlers (mean ± *SD;* age 27.3 ± 7.0 y; mass 83.7 ± 11.6 kg; stature 180.0 ± 6.3 cm) consented to participate.

Procedures

All bowlers completed an adapted version of the Cricket Australia-Australian Institute of Sport (CA-AIS) fast bowling skills test (Figure 1). Each bowling session was made up of four differing lengths of bowling spell typically experienced in limited overs cricket (4-, 6-, 10-overs plus a random number of deliveries [range 36 – 60]).

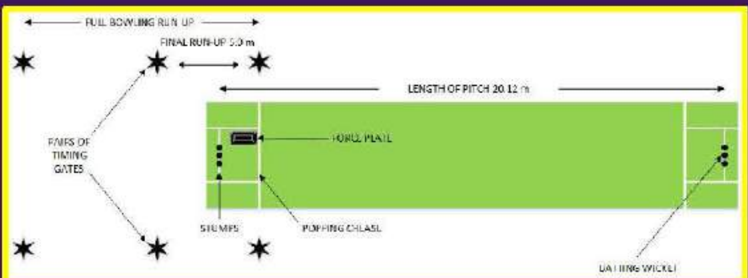

Figure 1. CA-AIS Simulation schematic (Duffield, Carney, and Karppinen, 2009).

A countermovement jump (CMJ) protocol was used to assess NMF before (-0.5 h) and after (+0.5 h & +24 h) each simulation. Blood samples were collected at the same time points. Internal (HR exertion [AU]) and external (GPS & PlayerLoad™ [AU]) TL were recorded using a micromechanical-electrical system (MEMS; Catapult Innovations, Australia). Sessional ratings of perceived exertion (sRPE; AU) were obtained within +0.5 h.

Statistical Analysis

Pearson product-moment correlations (*r*) combined with 90% confidence intervals (CI) were calculated to assess relationships between TL and Δ of CMJ flight-time (ms) and CK ($U \cdot L^{-1}$), respectively. Alpha of $P < 0.05$ was considered as statistically significant. All statistical analyses were performed using SPSS for Windows.

RESULTS

Significant reductions in CMJ flight-time -0.5 h to +0.5 h (Δ 21 ms; $P < 0.01$) and -0.5 h to +24 h (Δ 8 ms; $P = 0.001$) were found. Total distance (TD) and sRPE were significantly related to Δ CK (Figure 2). TD, PlayerLoad™ (PL), HR exertion and sRPE were significantly related to Δ CK24 (Figure 2).

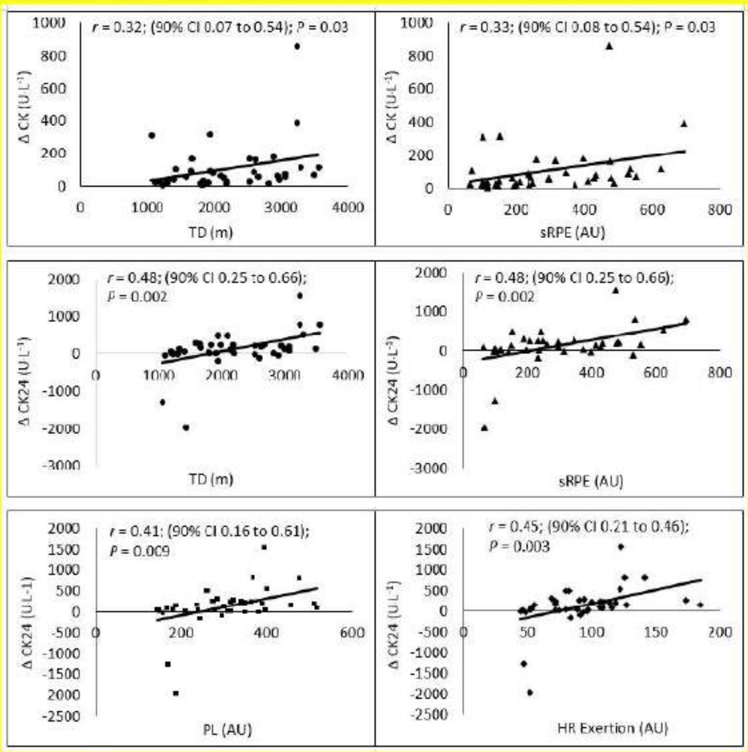

Figure 2. Relationships between TL and Δ CK and CK24

SUMMARY AND CONCLUSION

This study highlights that (1) CMJ flight-time can be used to monitor NMF following spells of fast bowling and (2) combing selected TL measures with CK offer an additional means of quantifying exercise induced muscle damage at +0.5 h and +24 h, respectively.

Practitioners may wish to consider these findings when planning training and recovery in the days following competition.

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The impact of maturity status on internal and external training load within elite youth soccer: A pilot study

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Introduction

It is common that physical adaptations and responses to training throughout maturation are highly individual in nature (Lloyd *et al.*, 2014). Often coaches prescribe training sessions for age groups aimed to elicit a desired training effect, however individual responses within that group may vary significantly with some suffering sub-optimal or negative effects. Frequent training prescription in this manner may contribute negatively to common growth related injuries and/or inadequately prepare the individual for the competitive demands of football. The purpose of this pilot study was to explore the responses of internal (sRPE) and external (GPS) loads experienced by players of different maturities within the same football training sessions.

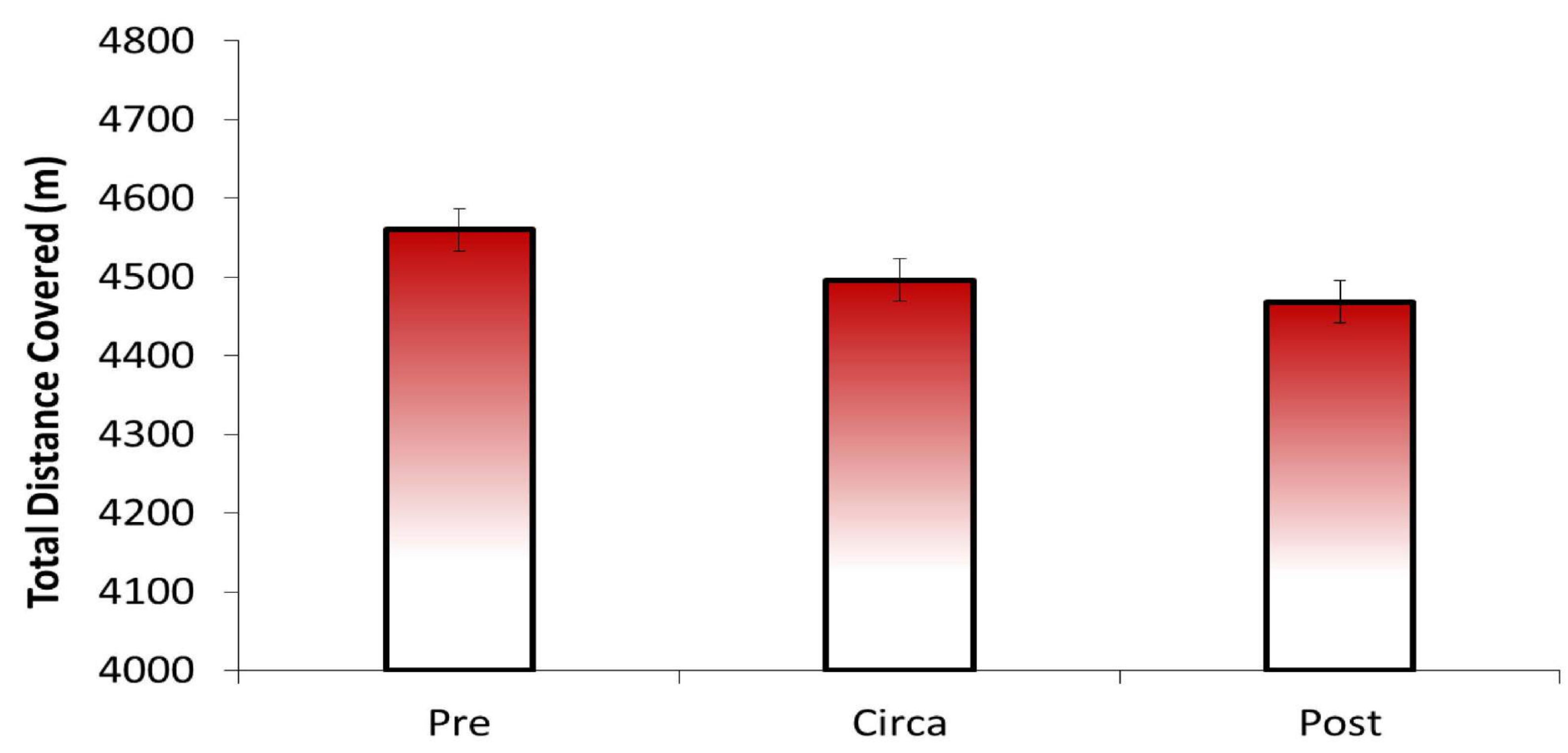
Method

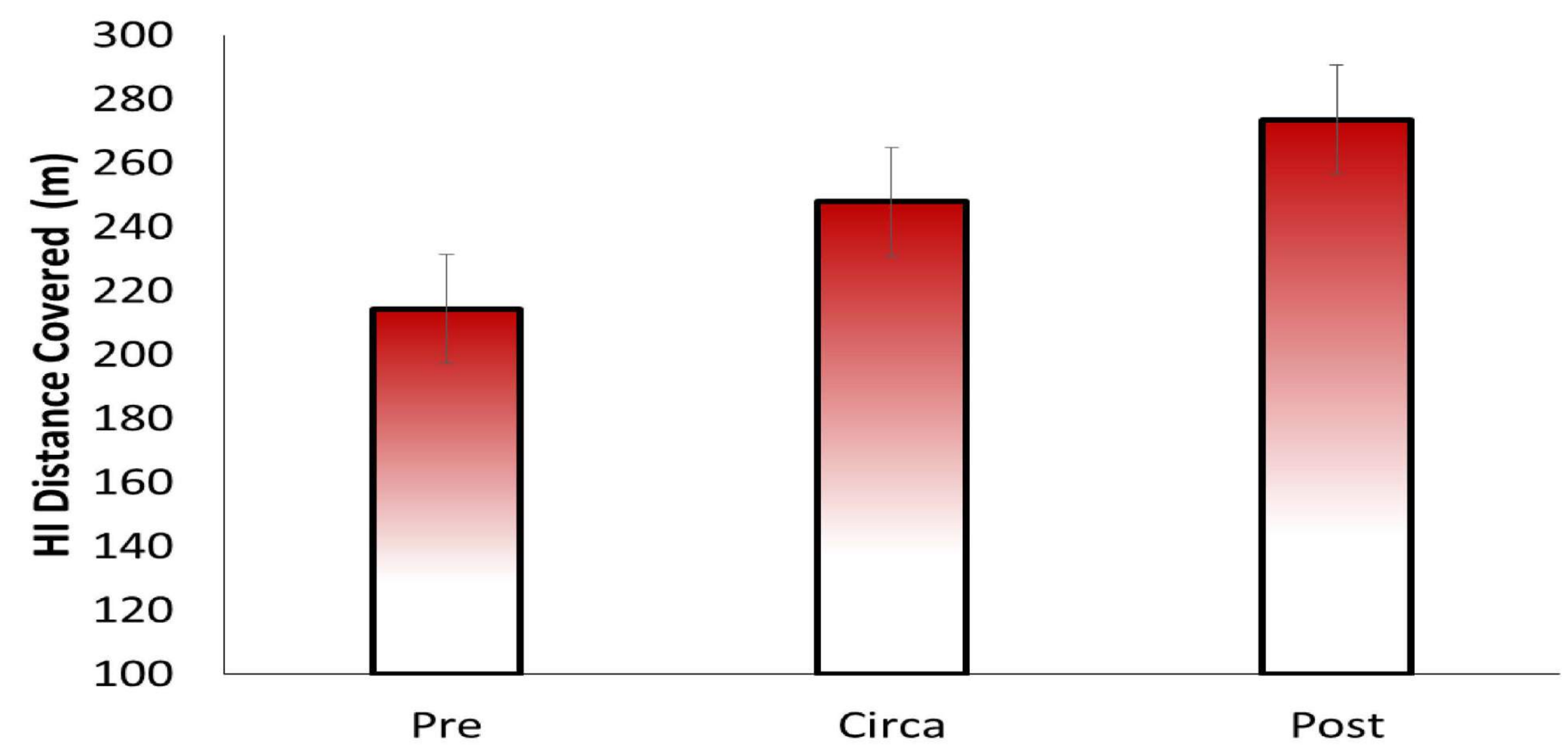
Fifty-six (U13 = 16, U14 = 21, U16 = 19) adolescent male football players from one category 1 academy took part in this study over a period of six-weeks. Initially the maturity status of each individual was calculated using a maturity–offset calculation (Mirwald, 2002) and was then classified into one of three groups; a) Pre Peak Height Velocity (PHV) (> 6 months pre PHV), b) Circa (± 6 months PHV) and c) Post (> 6 months post PHV). Individualised speed thresholds for GPS use were calculated for each individual based on the method outlined by Mendez-Villaneuva *et al.*, (2013) before players took part in two non-modified coaching sessions led by normal age group coaches. Session rating of perceived exertion (sRPE) using a CR-10 scale was familiarised in the lead up to the study and asked 10 minutes after each session. This was multiplied by session duration (mins) to provide an arbitrary figure of session internal load (Foster, 1996).

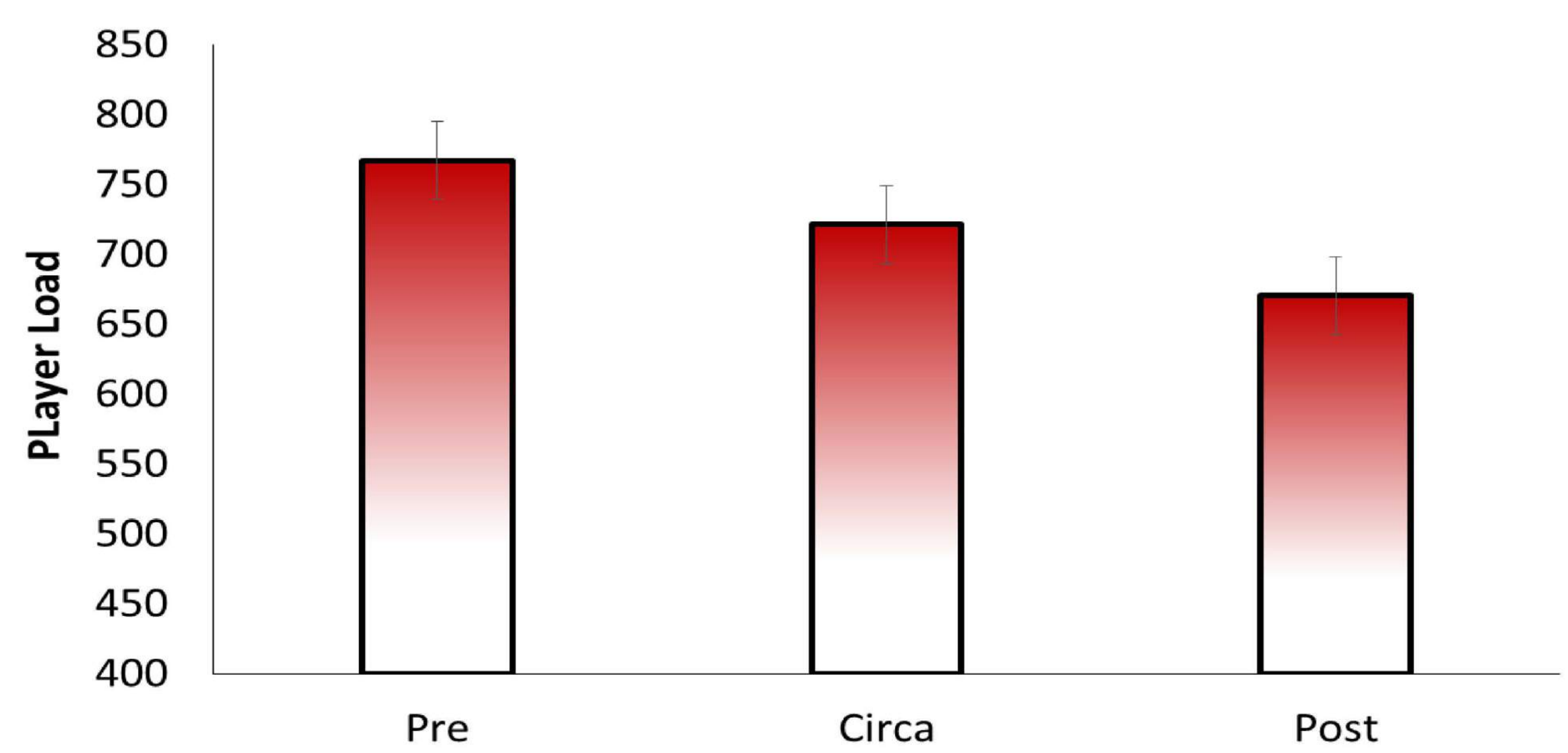
Results

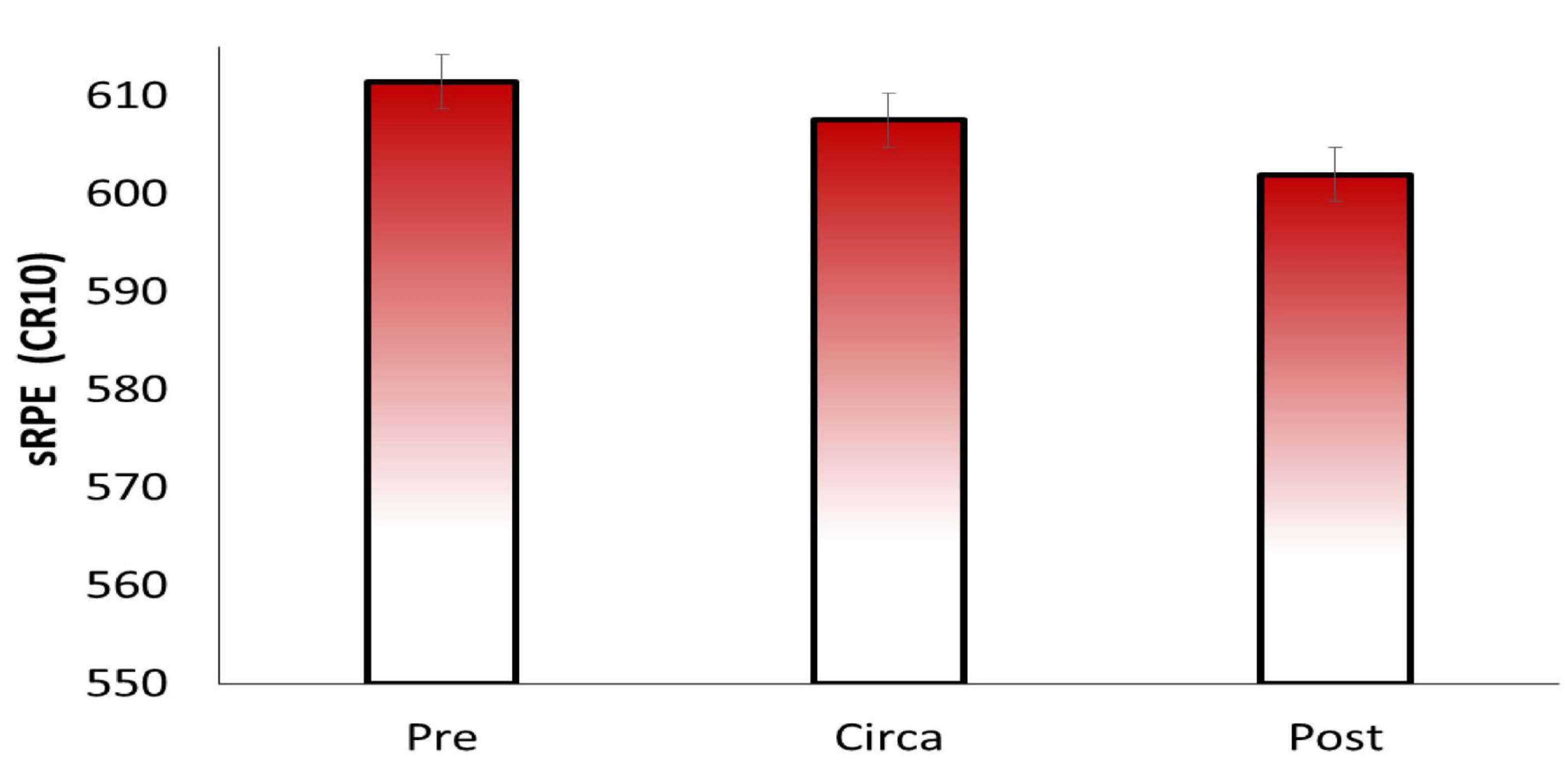
Results indicate that there was no significant difference (p = 0.881) between maturity groups in player load, distance covered (p = 0.152) or high-intensity distance (p = 0.67) across each age group. These findings suggest that maturity status does not impact on the external load of a given training session between individuals within the same age group. This is also apparent with the internal training load as there was also no significant difference (p = 0.575) in sRPE load between maturity groups. This illustrates that players of various maturities perceive the session to be similar physical difficulty.

Results









Conclusions

The findings from this study suggest that players of different maturity status experience similar physical load (internal and external) in standard football training sessions. These findings are unexpected as commonly players within each age group can vary in physical maturation by 12-18 months at any given time. For the practitioner these findings suggest that group based coaching around PHV may not be detrimental to performance and if managed can elicit the same physical stimulus to a diverse group. However, the findings from this pilot study need to be confirmed with more robust designs and larger sample sizes.

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A comparison of tempo vs supramaximal accentuated eccentric loading on the landing mechanics of youth netball players

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Introduction

Female team sports players have been linked to higher rates of lower limb injury (Gamble, 2011). Netball players are exposed to rapid acceleration kinematics that predisposes the knee and ankle to injury when landing from jumps (Otago, 2004; Swenson *et al*, 2005). Poor landing mechanics have been attributed to lower limb injuries and linked to poor strength levels. Previous studies have demonstrated the effectiveness of eccentric strength training in preventing injuries linked to landing mechanisms (Aerts et al., 2013; Bisseling et al., 2008). This study sought to investigate whether differing applications of accentuated eccentric loading (AEL) would improve landing mechanics in youth netball players.

Method and Design

Using a between subject, repeated measures design 18 youth netball players participated in this study. Participants were randomized into a 6 second eccentric Tempo (T) group (n = 9) or Supramaximal Loading (SM) group (n = 9) (Table 1). All participants engaged in a 6 week, two day per week, strength training and plyometric intervention of bilateral and unilateral movements primarily for the lower limbs. A rear-foot elevated split squat (RFE SS) was used as the AEL exercise, SM group were loaded with 105% 5RM RFE SS and T group were loaded with 80% 5RM RFE SS but instructed to lower the load over a strict 6s period to safety bars. The return was performed bilaterally in order avoid external aid. Participants' baseline data was collected on the tests in Table 2:

Table 1: Participant Characteristics

	Age (yr)	Height (m)	Mass (kg)	Age PHV (yr)
T group	14.7 ± 0.7	1.67 ± 8.1	57.2 ± 11	12.37 ± 0.8
SM group	14.9 ± 0.7	1.69 ± 8.4	65 ± 6.5	12.2 ± 0.8

Table 2: Performance measures

Landing Error Score System (LESS)
Knee Valgus angle
Y Balance Excursion Test (YBT)

Figure 1: RFE SS to lower with bilateral squat back to top

Results

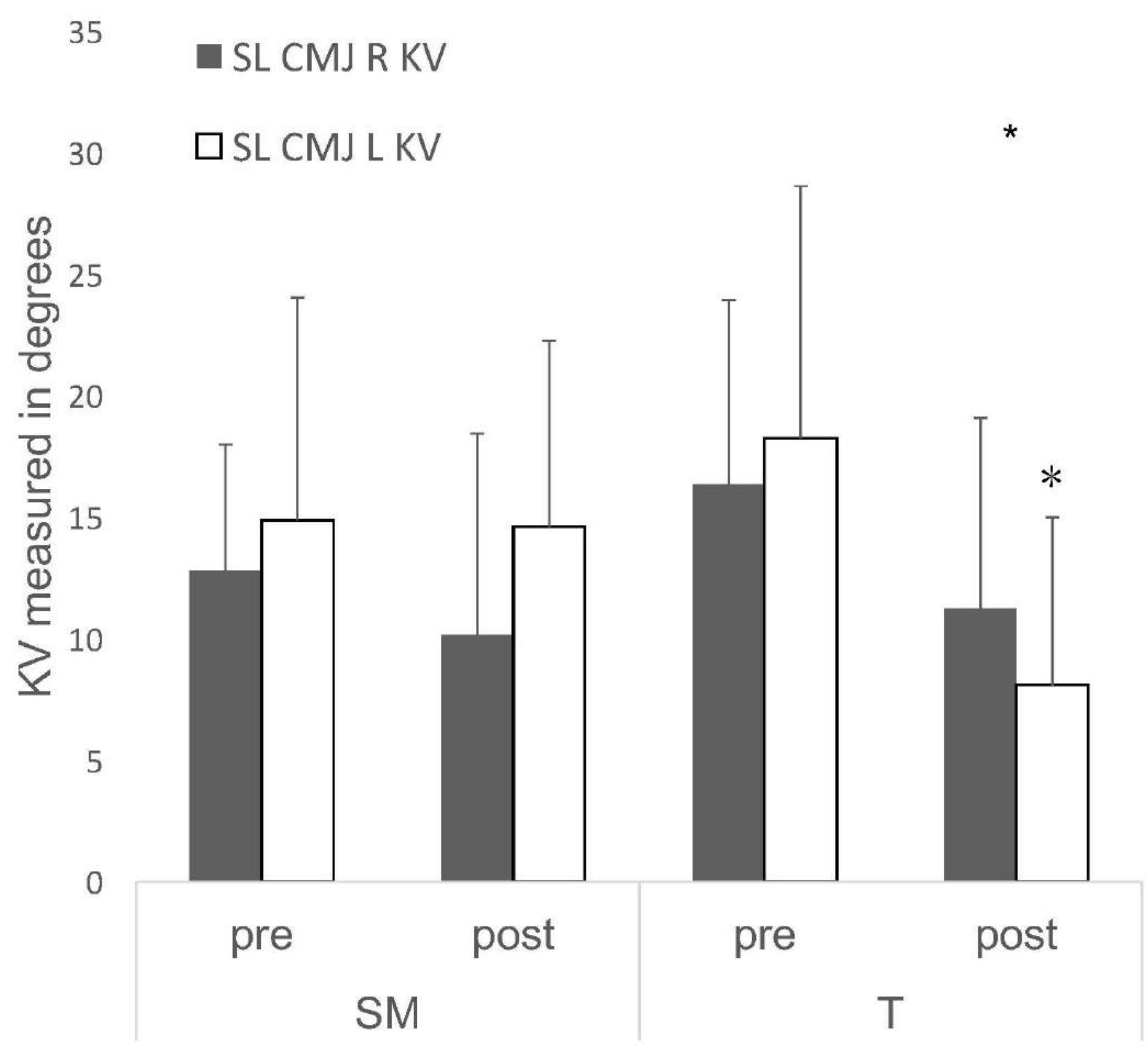

Figure 2: Changes in KV angle pre to post training (mean ± *SD*), *Significant diff to pre test(p = 0.05, d = 0.92)

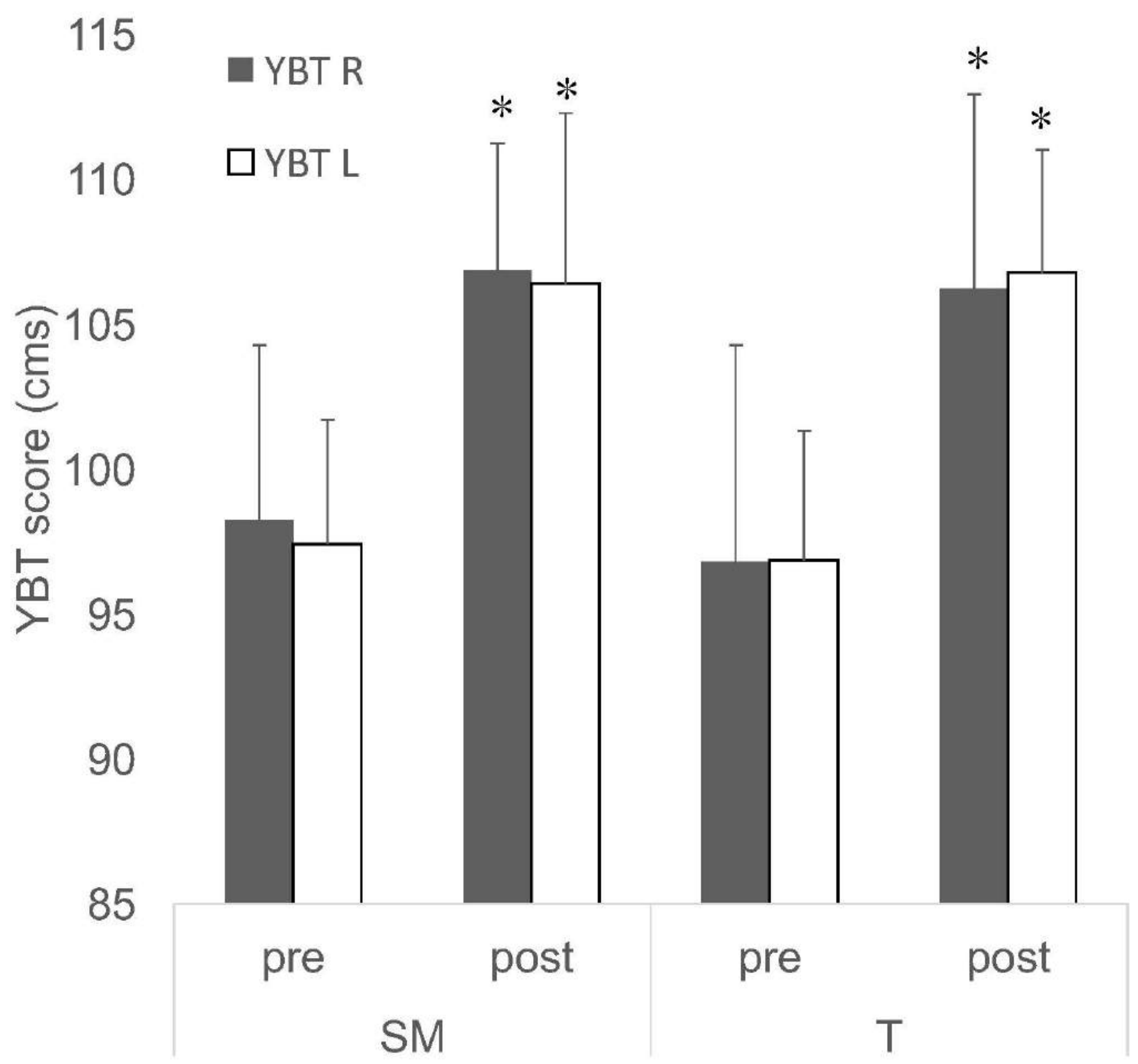

Figure 3: Changes in YBT score pre to post training (mean ± *SD*), *Significant diff to pre test (p = 0.05, d = 0.12)

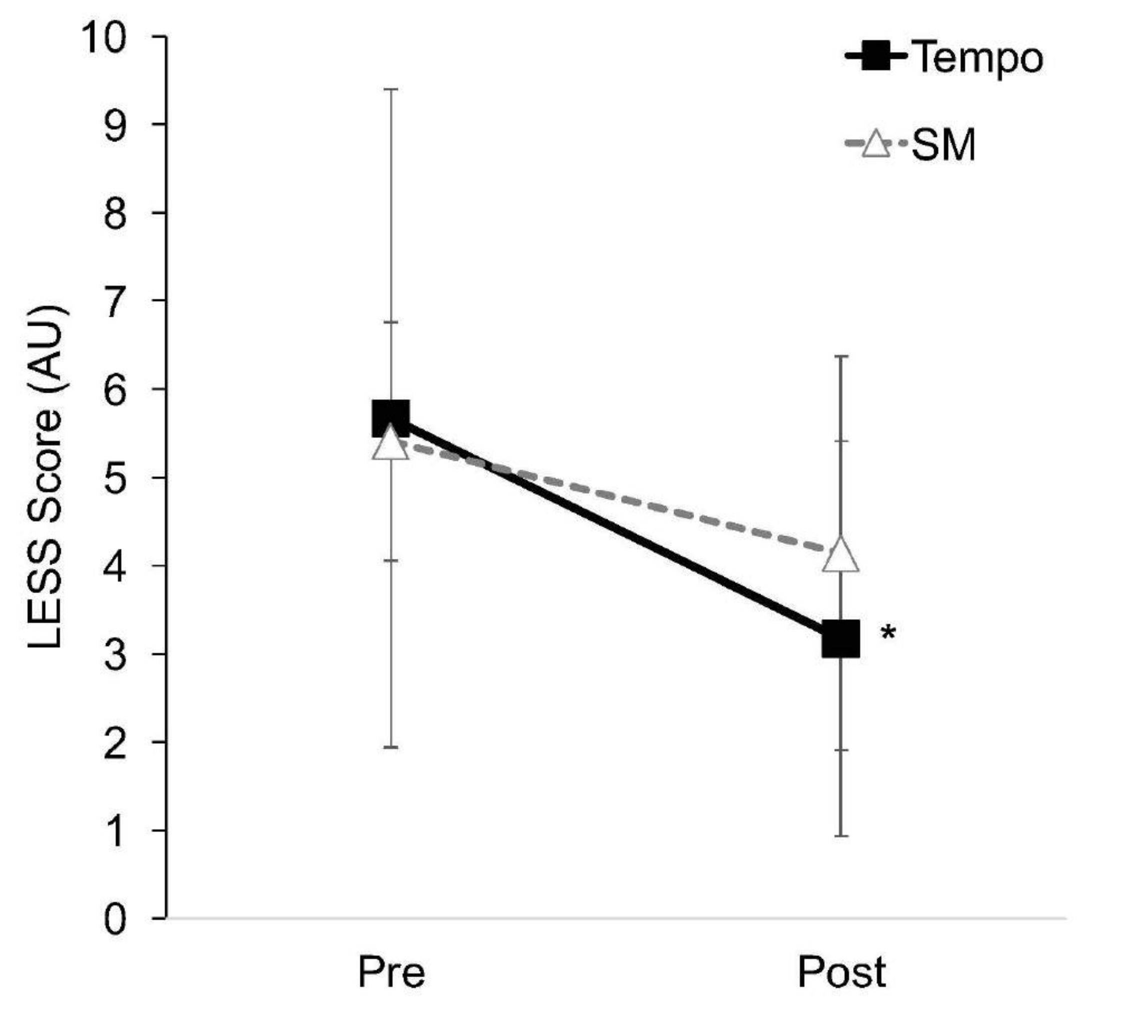

Figure 4: Changes in LESS score pre to post training (mean ± *SD*), *Significant diff to pre test (p = 0.05, d = 0.19).

Significant differences were evidenced between the two groups (2 way ANOVA RM) and in favour of the T group for YBT performance ($p < 0.05$, $d < 0.35$ "small" effect), KV ($p < 0.05$, d = 0.8-1.5 "moderate"), LESS ($p < 0.05$, $d < 0.35$ "small"), following the 6-week training protocol

Conclusion / Practical Application

Female youth athletes who participate in a 6-week eccentric tempo biased programme in addition to a standard S&C prescription designed for injury prevention, experienced significant improvements in landing mechanics. This would infer that AEL accelerates the physiological adaptation to improved landing mechanics and in particular tempo focussed AEL.

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3) Gamble (2011). *PJSC 22: 10-15*
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Poster abstract presented as part of the 13th United Kingdom Strength and Conditioning Association Conference, August 2017

High intensity match play running demands in elite Gaelic football: Does divisional status count?

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Introduction

It has been reported that soccer teams performing in higher divisions of competition cover less total distance & less high-speed running distance than teams performing in lower divisions (Di Salvo et al., 2013). Technical proficiency & economy of movement have been postulated as reasons for this. The purpose of this study was to analyse match-based high intensity running demands of elite Gaelic footballers from Division 1 & Division 3 & to examine the influence of playing position on such demands using selected GPS variables.

Methods

Data was collected across 25 competitive matches using 4-Hz GPS units (VX Sport, NZ). This resulted in 204 full data sets selected for analysis. High intensity running variables assessed included:

- high speed running (HSR) distance (≥17 km·h)
- number of high intensity sprint efforts (HSE) (≥17 km·h)
- relative high intensity distance (RHID) (≥17 km·h (m/min))
- proportion of time at high speed running (%HSR)

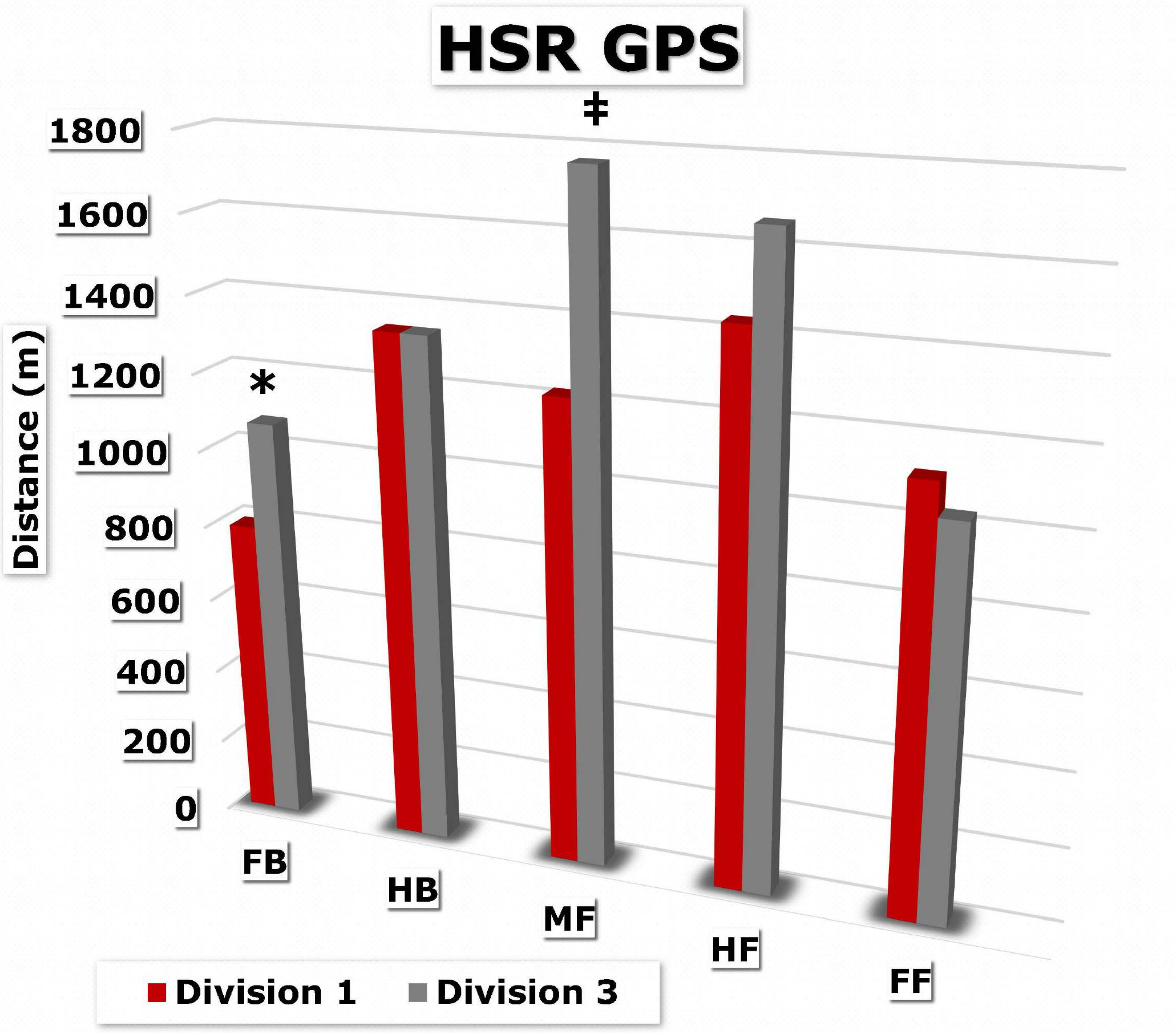
Results

The Division 3 team demonstrated significantly greater high intensity running than their Division 1 counterparts across all measured variables, HSR, HSE, RHID & %HSR ($p<0.05$) (Table 1). The magnitude of the differences in the means across all GPS variables was small to moderate (η^2 = .03 to .54). Position-specific analysis found that the FB and MF lines of the Division 3 team recorded significantly greater scores in HSR variables in comparison to their Division 1 counterparts ($p<0.05$) (Figure 1). This trend was also found for HSE, RHID and %HSR ($P<0.05$).

TABLE 1: Comparison of HSR variables from Division 1 and Division 3 players

	Division 1	Division 3	
Variable	Total (n=107)	Total (n=97)	Difference Total Mean
HSR (m)	1145±436	1358±462 ‡	-213.0 ^{s}
HSE (no.)	64±21	71±24*	-7.3 ^{s}
RHID (m/min)	14.9±5.7	17.6±6.1 ‡	-2.6 ^{s}
%HSR (%)	11.2±2.8	12.5±3.1 ‡	-1.3 ^{s}

Difference mean value; ^{s} Small effect: 0.01 < η^2 < 0.06.
‡ Significantly different ($p<0.01$) from Division 1 team
* Significantly different ($p<0.05$) from Division 1 team.



‡ Significantly different ($p<0.01$) from Division 1 team
* Significantly different ($p<0.05$) from Division 1 team

Figure 1: Positional specific HSR scores of Division 1 and Division 3 players

Conclusion

Results of the current study indicate that lower ranked teams perform greater levels of high intensity running compared to teams in higher ranking divisions. This may indicate that higher levels of technical execution and tactical awareness, rather than higher levels of physical fitness, are more important in determining success in Gaelic football.

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UK Strength and Conditioning Association Annual Conference, Leicestershire, 5 – 6th August 2017

Relationships between reactive strength index modified & 5, 10 & 20 m sprint times

13 ANNUAL CONFERENCE
5-6 AUGUST 2017
Jurys Inn Hinckley Island Hotel
Leicestershire
UKSCA

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Introduction:

Inverse relationships have been reported between drop jump-derived reactive strength index (RSI) and short sprint times, indicating that athletes with greater reactive strength characteristics demonstrate better sprint acceleration. An amended version of the RSI calculation, termed RSI modified (RSImod), was more recently created to enable reactive strength characteristics to be determined during the popular countermovement jump (CMJ). Numerous studies show relationships between CMJ height and short sprint times, but none have explored relationships between RSImod and short sprint times, which formed the purpose of this study.

Methods:

With institutional ethics approval and following a brief warm-up, Fifty-four male (n = 32; age = 19.8 ± 2.8 years; body mass = 73.9 ± 12.3 kg; height = 1.74 ± 0.06 m) and female (n = 22; age = 19.5 ± 1.6 years; body mass = 61.3 ± 11.6 kg; height = 1.66 ± 0.11 m) recreational athletes performed three maximal effort CMJs (arms akimbo) and 20 m sprints during one testing session. CMJs were performed on a force platform (1000 Hz) and analysed using a custom Microsoft Excel spreadsheet (Fig. 1).

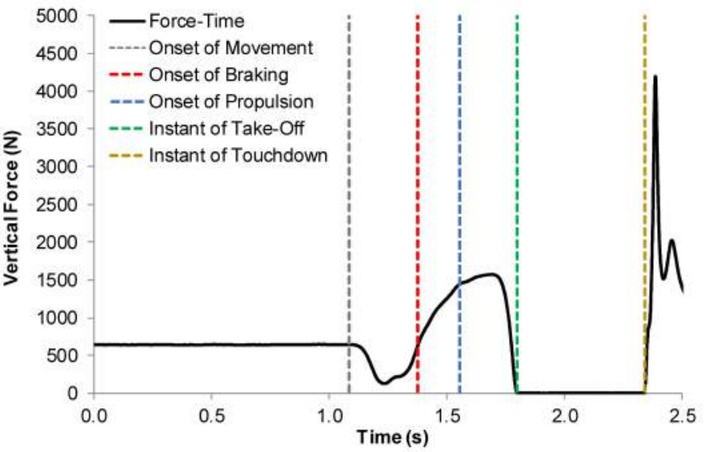

Fig. 1: Example CMJ force-curve analyses using Microsoft Excel.

20 m sprint times, with 5 and 10 m splits, were assessed via single photocell electronic timing gates set at hip height, with participants starting 30 cm behind the 0 m gates. RSImod was calculated as CMJ height divided by time to take-off (TTT). One-tailed Pearson correlation coefficients (Spearman equivalent for RSImod and 20 m sprint time) identified relationships between pooled and individual sex data ($P < 0.05$).

Results:

All data showed low between-trial variability (1.6-5.3%). For pooled data, RSImod was largely inversely correlated with 5 (Fig. 2a), 10 (Fig. 2b) and 20 m (Fig. 2c) sprint times. For men, RSImod was not significantly correlated with 5 m sprint time (r = -0.291, P = 0.053), but moderately inversely correlated with 10 (r = -0.380, P = 0.016) and 20 m (r = -0.466, P = 0.004) sprint times.

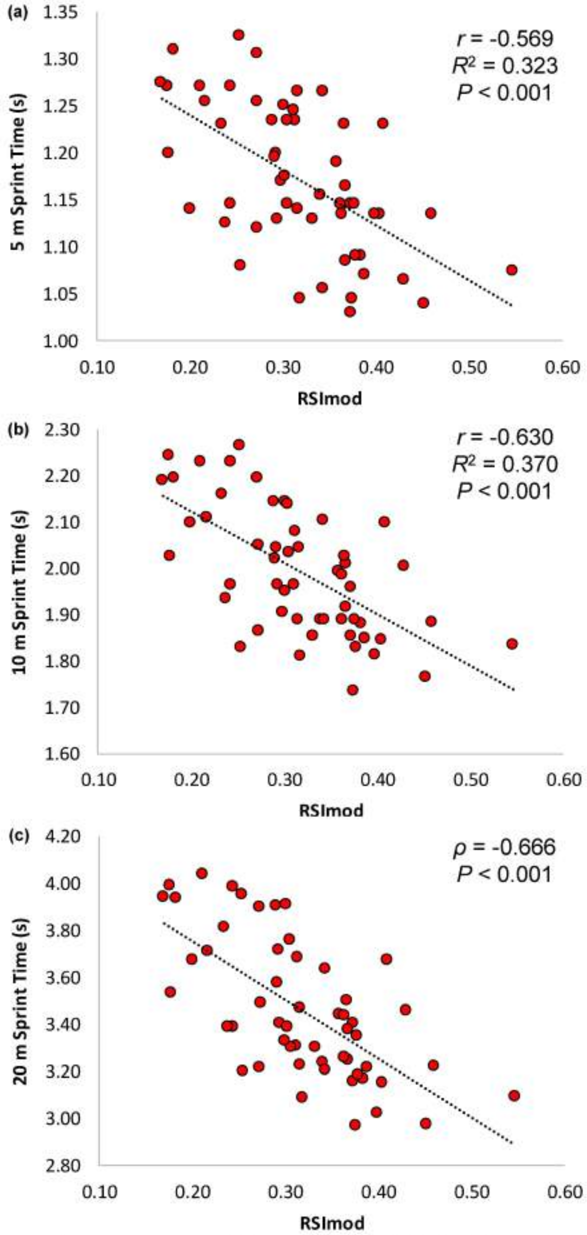

Fig. 2: Relationships between RSImod & 5 (a), 10 (b) & 20 (c) m sprint times.

For women, RSImod was moderately inversely correlated with 5 (r = -0.442, P = 0.020), 10 (r = -0.457, P = 0.016) and 20 m (r = -0.487, P = 0.011) sprint times.

Summary & Conclusion:

Higher RSImod correlates to better short sprint times, indicating that athletes who can jump faster (shorter TTT) and higher are likely to demonstrate better sprint acceleration. Although women demonstrated stronger relationships, RSImod was most highly related to 20 m sprint times, followed by 10 and then 5 m sprint times for both groups. RSImod may, therefore, be a useful parameter for monitoring athletes whose sport involves regular 10-20 m sprint performances.

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The Postactivation Potentiation Effect of Either Plyometrics or Speed, Agility and Quickness Exercises on Linear Sprint Performance

University of Cumbria

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INTRODUCTION

Postactivation potentiation (PAP) is a phenomenon whereby the contractile history of the muscle positively impacts the force generation capacity of an athlete for subsequent activities.[1] Traditionally, PAP protocols involve heavy resistance exercises that may not be applicable for all athletes due to logistical considerations. As such, warm-up routines incorporating plyometric exercises have previously been shown to result in a PAP response during athletic activities.[3] Other techniques such as speed, quickness and agility (SAQ) drills have not yet been identified as a viable warm-up tool that may potentiate performance.

AIM:
The purpose of this study was to explore the acute benefits of including either a plyometric or SAQ based warm-up, on linear sprint speed.

METHODS

Using a randomised repeated measures design, 16 (13 men, 3 women) recreationally trained athletes performed either a control (C), control and plyometric (P) or control and SAQ (SAQ) warm-up (table 1). The P and SAQ warm-ups were matched for total foot contacts. Following a four-minute recovery, subjects then performed three 10-metre linear sprints, recorded using the Smartspeed system (Fusion Sport, Coopers Plains, QLD, Australia). The fastest time (s) from each condition was used for statistical analysis. Testing sessions were separated by 48-hours. Ethical approval for this project was granted by the University of Cumbria ethics committee.

	EXERCISES	
Control	1. Linear jogging x20 metres 2. Side shuffling x20 metres 3. Backward running x20metres 4. Forward lunge x8 each side	5. Lateral lunges x8 each side 6. Leg swings x20 each side 7. 10-metre sprints at 50, 75 and 90% maximal effort
Plyometric	1. Hurdle hops x6 each leg 2. Lateral hurdle hops x10 each leg 3. Countermovement jumps x5	5. Drop jumps (20cm) x 10 6. Broad jumps x5
SAQ	1. Forward in and out x10 2. Slalom jumps x10 3. Lateral scissor jump x10	4. Single leg linear hops x6 each leg

Table 1. Exercises and repetitions for each condition. For both the plyometric and SAQ warm-ups, total foot contacts equalled 36 per foot.

RESULTS

There was a statistically significant difference between groups for the 0-10m following a Friedman's ANOVA ($\chi2(2) = 25.125$, p=0.00). Post Hoc analysis using the Wilcoxon signed-rank test with a Bonferroni correction identified no significant difference between the control and SAQ conditions (Z= -0.906, p= 0.365, ES=0.06). However, there was significant improvements between conditions in favour of P; P vs. C (Z= -3.518, p= <0.001, ES=0.50) and P vs. SAQ (Z= -3.522, p= <0.001, ES=0.44).

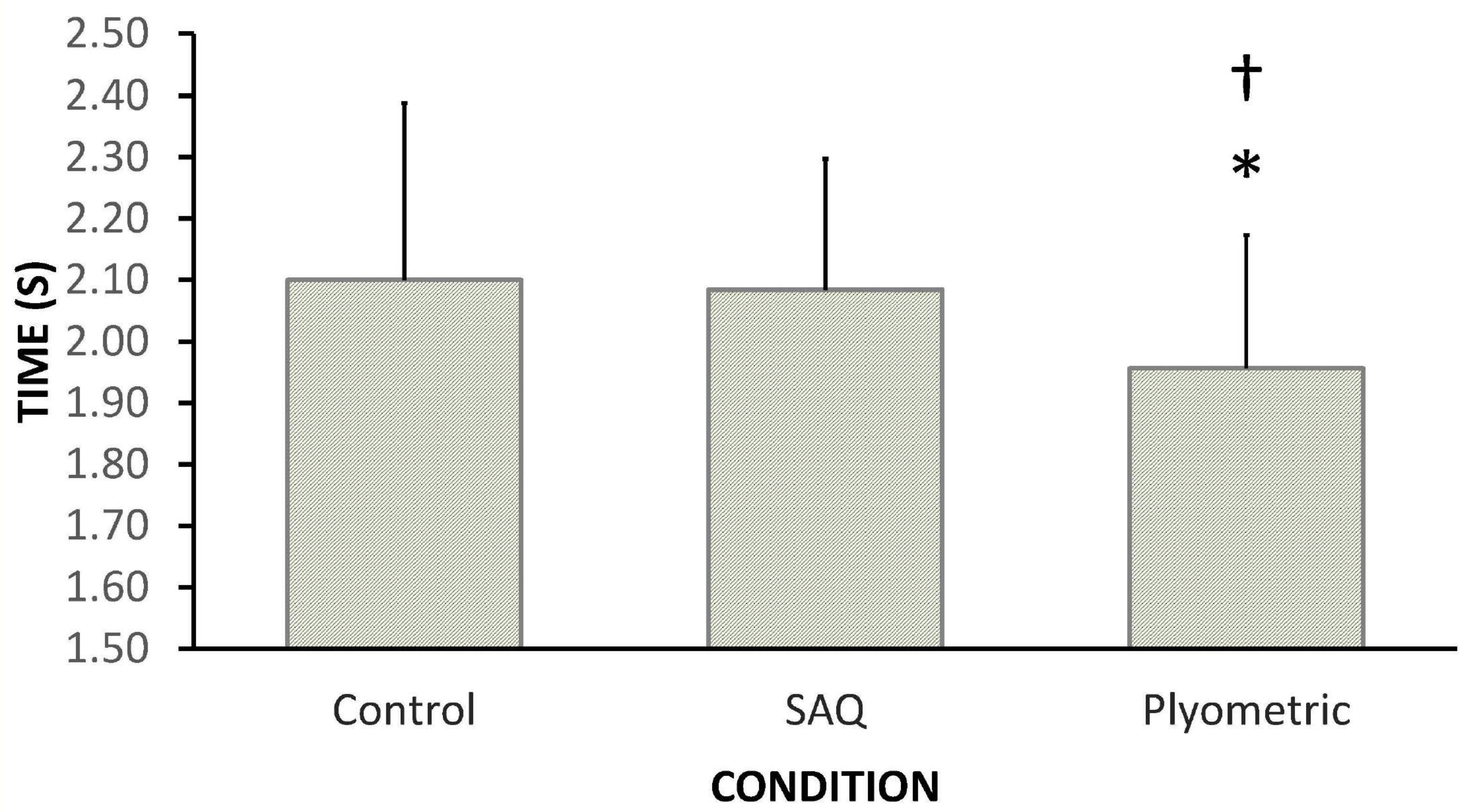

Figure 1. Times for 10-metre linear sprints following each warm-up condition. *Significantly different from control (p=0.001). † Significantly different from SAQ (p<0.001).

SUMMARY AND CONCLUSIONS

As sprint performance is strongly determined by the amount of force an athlete can effectively produce[2,4], a PAP response was not evident following the completion of the SAQ warm-up. Although not measured in this investigation, this is likely due to SAQ drills not requiring athletes to produce the high level of forces observed during plyometric exercises, therefore blunting the PAP response.

KEY POINTS:

- **Linear 10-metre sprint time is not acutely improved with the inclusion of Speed, Quickness and Agility drills as part of a dynamic warm-up.**
- **A warm-up consisting of plyometric exercises results in an acute decrease in 10-metre sprint times.**

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Analysis of Lower Limb Asymmetries in Previously Injured and Uninjured Professional Footballers

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INTRODUCTION AND PURPOSE

- Previous injury is the most important predictor of future injury (1). It is common practice to implement neuromuscular performance tests post-injury to monitor athlete progress during rehabilitation and inform return to play decisions (2).
- Significant neuromuscular asymmetries are reported in the takeoff phase of the bilateral countermovement jump (CMJ) (3).
- In preseason testing, significantly higher CMJ peak landing force asymmetries were observed in professional footballers who suffered any lower extremity injury in the previous season (4).
- Large force, impulse and power asymmetries could contribute to the risk of reinjury and reduce performance (5).
- Late stage rehabilitation and early phase of return-to-play could be optimised by identifying residual asymmetries associated with previous injury.

AIM: To characterise CMJ inter-limb asymmetries associated with prior severe injury in professional footballers.

METHOD

- Age 19 ± 2.5 years, body mass 76.59 ± 8.93kg, height 179.91 ± 6.44cm
- 34 professional football players were divided into 1) Injured (n=17): players who had suffered a severe injury (leading to loss of > 28 days) within the previous 12 months and 2) Uninjured (n=17)
- Players performed 3 bilateral CMJ's on a pair of vertical axis force platforms at a sampling frequency of 1000Hz
- Mean absolute symmetry was calculated according to the formula:

Left limb - right limb/(maximum left and right) x100

Results

Mean ± SD of Countermovement jump variables in the concentric and eccentric phases

Variable	Status	Mean Absolute Asymmetry %	95% CI	Effect Size
Concentric Impulse	Previously Injured	7.14 ± 3.33*	5.1 to 9.1	1.04
	Uninjured	4.01 ± 3.01	1.6 to 5.5	
Mean Concentric Force	Previously Injured	7.63 ± 3.38*	5.1 to 9.5	0.89
	Uninjured	4.08 ± 3.36	1.6 to 5.6	
Peak Concentric Force	Previously Injured	9.32 ± 5.88*	6.2 to 12.2	1.41
	Uninjured	3.18 ± 3.36	1.8 to 4.5	
Eccentric Impulse	Previously Injured	10.20 ± 8.62	7.6 to 16.5	0.24
	Uninjured	11.25 ± 7.38	6.1 to 14.3	
Mean Eccentric Force	Previously Injured	9.39 ± 7.33	5.2 to 13.2	0.24
	Uninjured	7.64 ± 5.61	4.3 to 10.6	
Peak Eccentric Force	Previously Injured	10.25 ± 7.82	8.1 to 16.2	0.01
	Uninjured	8.82 ± 6.51	5.5 to 12.1	
Eccentric :Concentric Ratio	Previously Injured	12.07 ± 8.51*	7.6 to 16.5	0.81
	Uninjured	6.31 ± 5.33	2.6 to 8.9	

*p < 0.05

CONCLUSION

- Professional footballers considered 'fit' but who had suffered a severe injury in the previous 12 months displayed significantly higher interlimb asymmetry in concentric phase force-time variables during the takeoff phase of the bilateral CMJ.
- Amongst the asymmetries assessed, the largest difference between injured v uninjured players was in concentric peak force (9.32% v 3.18%, *d*=1.41).
- Eccentric phase variables were not significantly different between Injured and Uninjured, and demonstrated trivial to moderate effects which appears to be related to higher eccentric asymmetries in the Uninjured as opposed to lower asymmetries in the Injured. However, Injured had a significantly higher ratio of eccentric to concentric force (12.07% v 6.31%, *d*=0.81).
- The CMJ provides a method of identifying asymmetries and a profile of residual neuromuscular deficit following severe injury.
- Monitoring of neuromuscular asymmetries can aid rehabilitation and post return to training regime to evaluate the effectiveness of the training intervention utilised.
- Prospective research is required to determine if these or other CMJ asymmetries may also be risk factor for primary injury occurrence and / or recurrence .

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Physical characteristics of a university cricket academy during the course of a pre-season

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Abstract

Purpose

Describe the anthropometric and physical characteristics of male English Academy University (MCCU) cricketers, and the impact of structured S&C support on physical and physiological development.

Methods

Four testing sessions during pre-season (30 weeks). The S&C programme lasted 30 weeks, with an average of 5 S&C sessions each week.

Results

Wide disparity across the playing positions within cricket although all experienced improvements in assessments following a pre-season training intervention.

Conclusions

The data presented demonstrates the positive impact that structured S&C training had on this cohort of individuals, with a low S&C training age.

Introduction

The purpose of this study was to describe the anthropometric and physical characteristics of male English Academy University (MCCU) cricket players during the course of a pre-season (September - March). From a literature search there is a paucity of data on cricketers in peer reviewed articles for all positions apart from fast bowlers. This research aims to provide some reference figures for future study and to assess any potential differences between four discrete positions, Batsman (BAT), Fast bowler (FAST), Spin bowler (SPIN) and Wicket Keeper (WK) alongside the impact of structured strength and conditioning provision during a pre-season. In cricket an individual will possess a specific set of attributes which defines their role within a team (3). It is evident that cricketers need to have high levels of physical capacity and durability in order to cope with high workloads alongside high skill levels, potentially under fatigue with athletes being exposed to >6 hours of play per day (1,2).

Methods

Four testing sessions during pre-season (30 weeks). Measurements taken: Height, Weight, Body Fat %, 10m Speed, 20m Speed, Counter movement jump (CMJ), Squat Jump (SJ), Yo-Yo IRL1. Total squad size n=24, Athletes grouped by position: Batsman (BAT) n=7, Fast bowler (FAST) n=6, Spin bowler (SPIN) n=7, Wicket Keeper (WK) n=4. Age (Yrs): BAT: 20.4±1.5, FAST: 19.8±1.6, SPIN: 20.2±1.3, WK: 21.1±1.1. The S&C programme lasted 30 weeks, with an average of 5 S&C sessions each week. Strength training was linear in approach, from high-low volume and low-high intensity/speed. The phases were; hypertrophy (10wks), strength-speed (10wks), speed-strength (10wks). Conditioning session were derived from their testing data. Volume and intensity was periodised throughout the preseason with an aerobic focus initially, working towards an anaerobic emphasis.

Results

Data is presented as means ± SD from test 4, with the mean change (+/ -) from test 1 in brackets shown in Table 1. FAST appear to have the greatest stature, are the heaviest and the fastest over 10m. With both FAST and WK being similar over 20m and SJ (Shown in figure 1.). WK appear to be more effective in the CMJ (figure 1.) and achieved a greater YO-YO IRL1 distance (figure 3.).

Table 1. Anthropometric and speed data

	Height (cm)	Weight (Kg)	Body Fat (%)	10m Speed (sec)	20m Speed (sec)
BAT	179 + 3.5	81.7± 10.6 (+3.6)	15.7 ± 4.6 (-0.6)	1.80 ± 0.08 (-0.12)	3.17 ± 0.15 (-0.18)
FAST	189.5 + 2.5	87.1 ± 3.9 (-2.4)	14.7 ± 2.8 (-0.9)	1.76 ± 0.05 (-0.10)	3.10 ± 0.06 (-0.12)
SPIN	179 + 7.0	76.2 ± 6.4 (-2.9)	15.2 ± 3.5 (-1.6)	1.82 ± 0.05 (-0.05)	3.21 ± 0.07 (-0.13)
WK	180 + 7.0	75 ± 7.5 (-5.5)	12.4 ± 3.6 (+0.7)	1.79 ± 0.02 (-0.09)	3.09 ± 0.08 (-0.22)

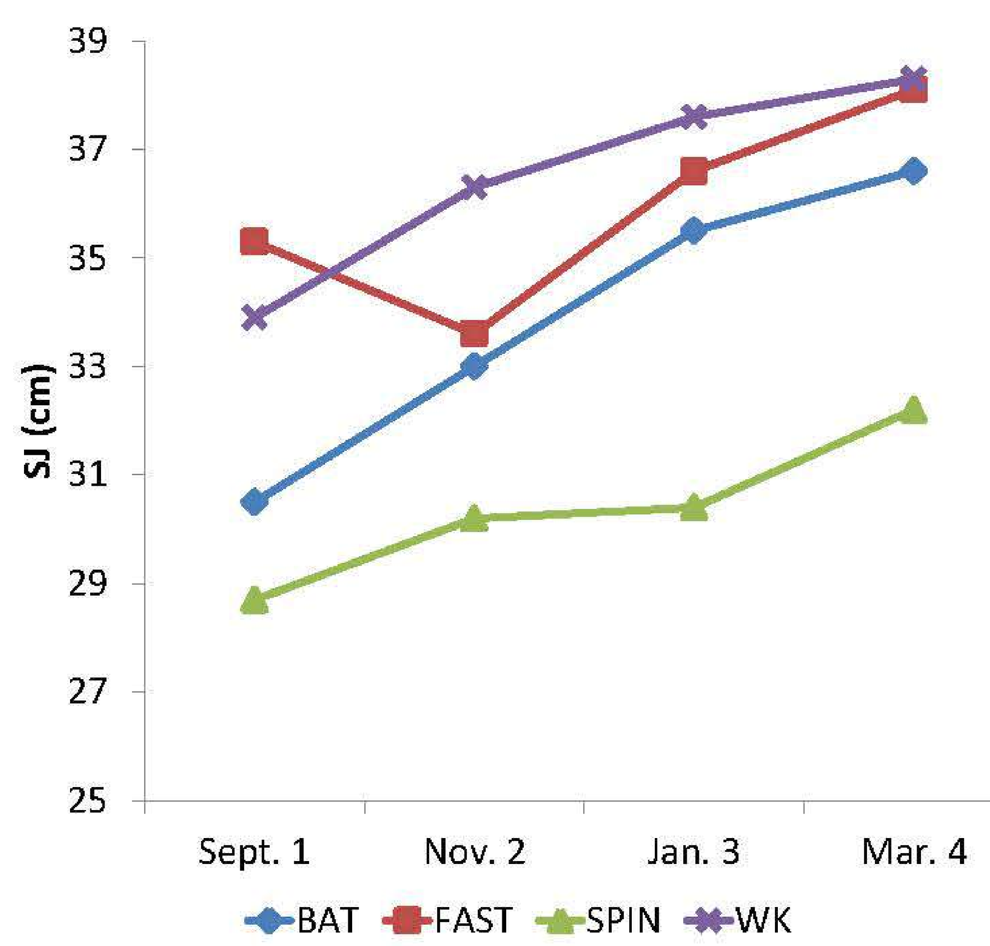

Figure 1. Changes in SJ during pre-season (group mean)

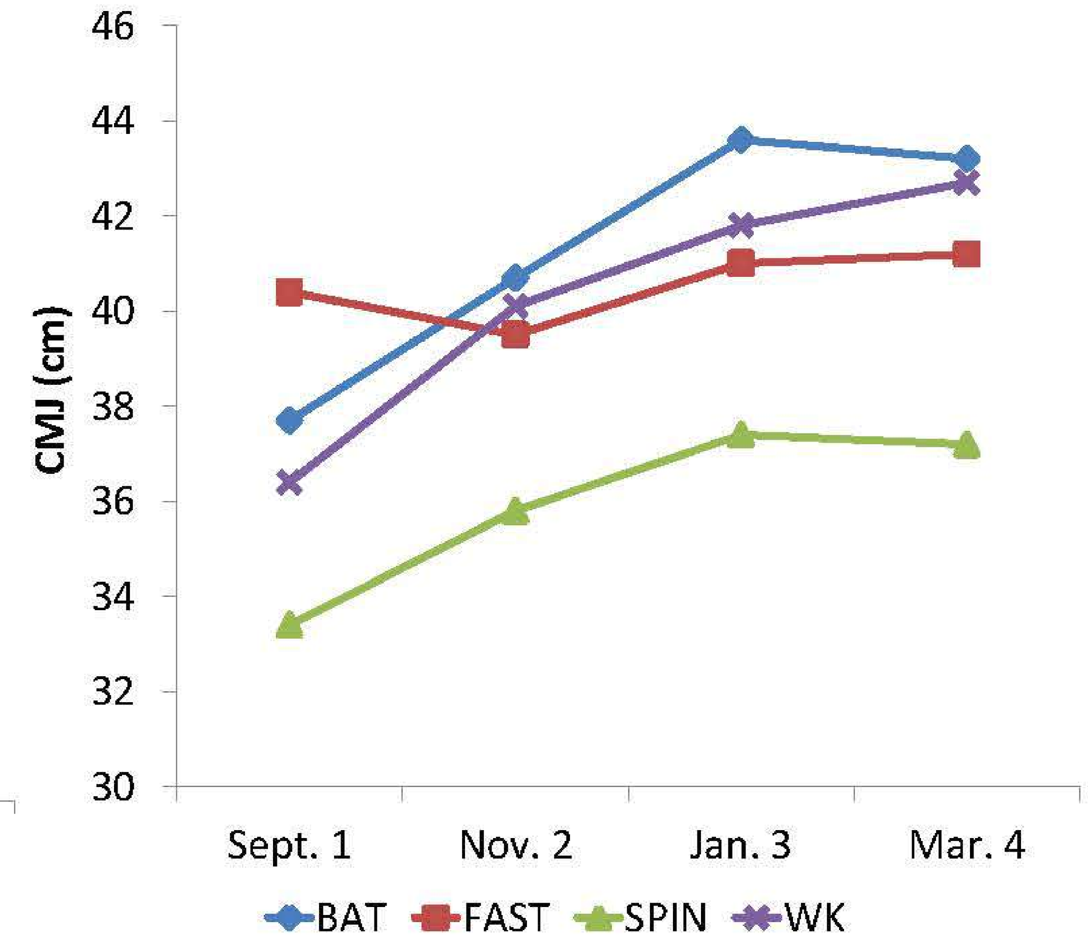

Figure 2. Changes in CMJ during pre-season (group mean)

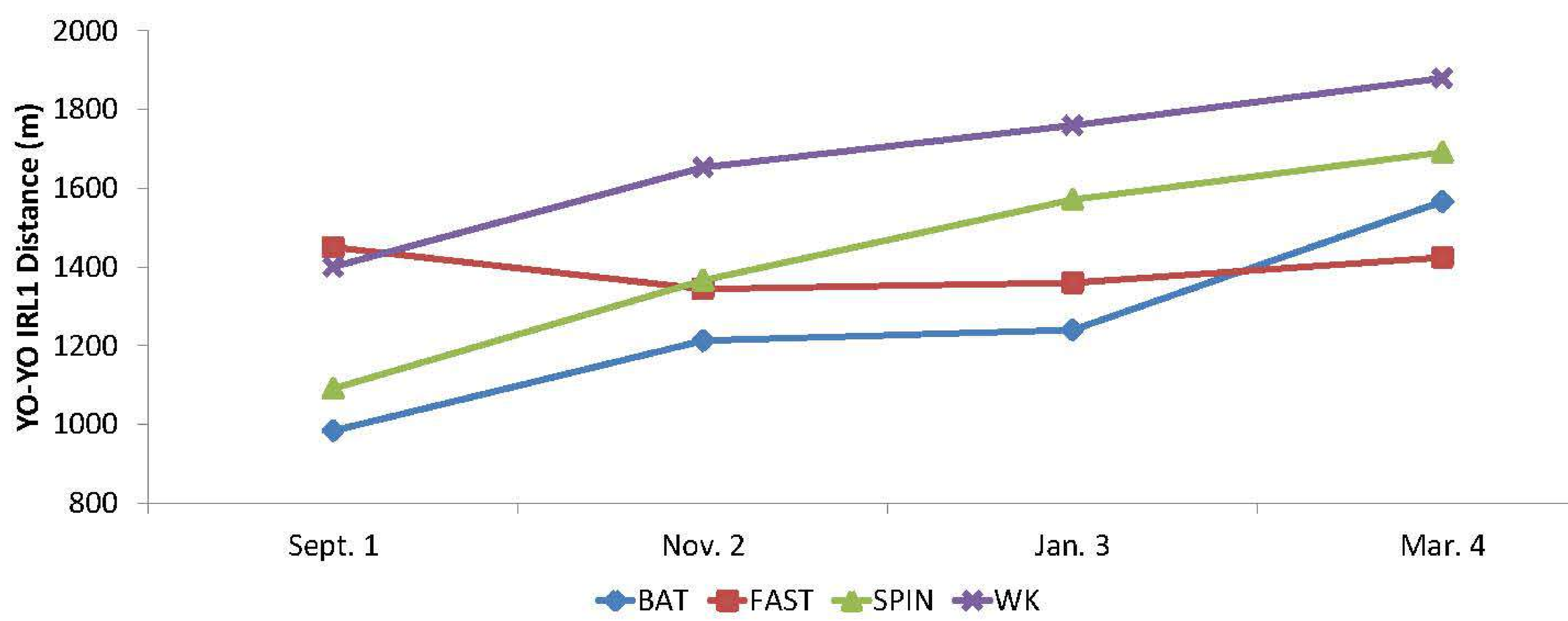

Figure 3. Changes in Yo-Yo distance during pre-season (group mean)

Conclusions

This study describes the anthropometric and physical fitness characteristics of male English Academy University (MCCU) cricketers and changes made during the pre-season period. The data presented demonstrates the positive impact that structured S&C training had on this cohort of individuals with a low S&C training age.

Due to the nature and task demands of each position, there were large differences in groups physical and anthropometry characteristics and a wide disparity in changes made during pre-season. These figures can act as a reference point for future research and demonstrate the need for individualised programming in reference to playing position and task demands.

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VARIABILITY OF PLYOMETRIC AND BALLISTIC EXERCISE TECHNIQUE MAINTAINS JUMP PERFORMANCE

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1. INTRODUCTION

Jump height or distance is considered the main performance output of a ballistic or plyometric exercise. Therefore, jump performance is measured by practitioners to identify the intensity of each ballistic and/or plyometric repetition in a training session. However, jump performance does not identify how said jump height or distance is achieved. Measurement of kinetic parameters, such as peak ground reaction force or impulse, may better identify repetition intensity, but would be influenced by range of motion and jump timings during different phases (i.e. touch down, peak joint flexion and take-off) of a ballistic or plyometric jump. Monitoring the latter will provide insight into if, and how the range of motion and timing of said range of motion varies across repetitions of a training session to achieve jump performance.

No research has been published investigating athlete jump technique and its effects on jump performance. Therefore, the aim of this study was to investigate kinematic changes of plyometric and ballistic exercise technique over the course of a training session

2. METHOD

- This study was a cross sectional study design.
- Twelve plyometric and ballistic exercise trained male athletes (age = 23.4 ± 4.6 years, body mass = 78.7 ± 18.8 kg, height = 177.1 ± 9.0 cm) participated in the study.
- All participants performed three sets of 10 repetitions of drop (DJ), rebound (RJ) and squat jumps (SJ).
- Jump height, flexion and extension time and range of motion and instantaneous angles of the ankle, knee and hip joints at touch down, peak joint flexion and take-off were measured.
- Touch down was not analysed for SJ.
- One-way repeated ANOVA compared vertical jump technique across exercise repetitions. Where significant differences were detected a paired samples t-test was used to determine the differences.

3. RESULTS

- Jump height did not differ between repetition.
- RJ showed an increase in knee angle at take-off across all sets, which increased at the start of the subsequent set compared to the end of the previous set (Figure 1). Set 3 repetition 2 resulted in the lowest angle at take-off, which was significantly different to set 1 repetition 3 and 9 and set 3 repetition 5, 6, 7, 8 and 9 (P = < 0.5, ES = 0.58 – 0.69).
- SJ highlighted a decrease in extension range of the knee joint across sets. Extension range was highest for the first repetition of each set and subsequently decreased throughout the set. (Figure 2). Set 1 repetition 1 showed the greatest extension range, been significantly different to set 1 repetition 7, 8 and 9, set 2 repetition 2, 3, 4, 6, 7, 8, 9, 10 and set 3 repetition 2, 4, 8 and 9 (P = < 0.05, ES = 0.58 – 0.78).
- RJ displayed an increase in ankle joint angle at take-off across sets, with the first repetition been the lowest and subsequent repetitions increasing (Figure 3). Set 1 repetition 2 showed the lowest angle at take-off, been significant different to set 1 repetition 5, 7 and 10, set 2 repetition 9 and set 3 repetition 5, 6, 7, 8 and 10 (P = < 0.05, ES = 0.58 – 0.81).
- SJ showed an decrease in hip angle at touch down throughout each set (Figure 4). The greatest repetition was set 1 repetition 1, which was significantly different to all receptions except set 2 repetition 1 (P = < 0.05, ES = 0.58 - 0.81)

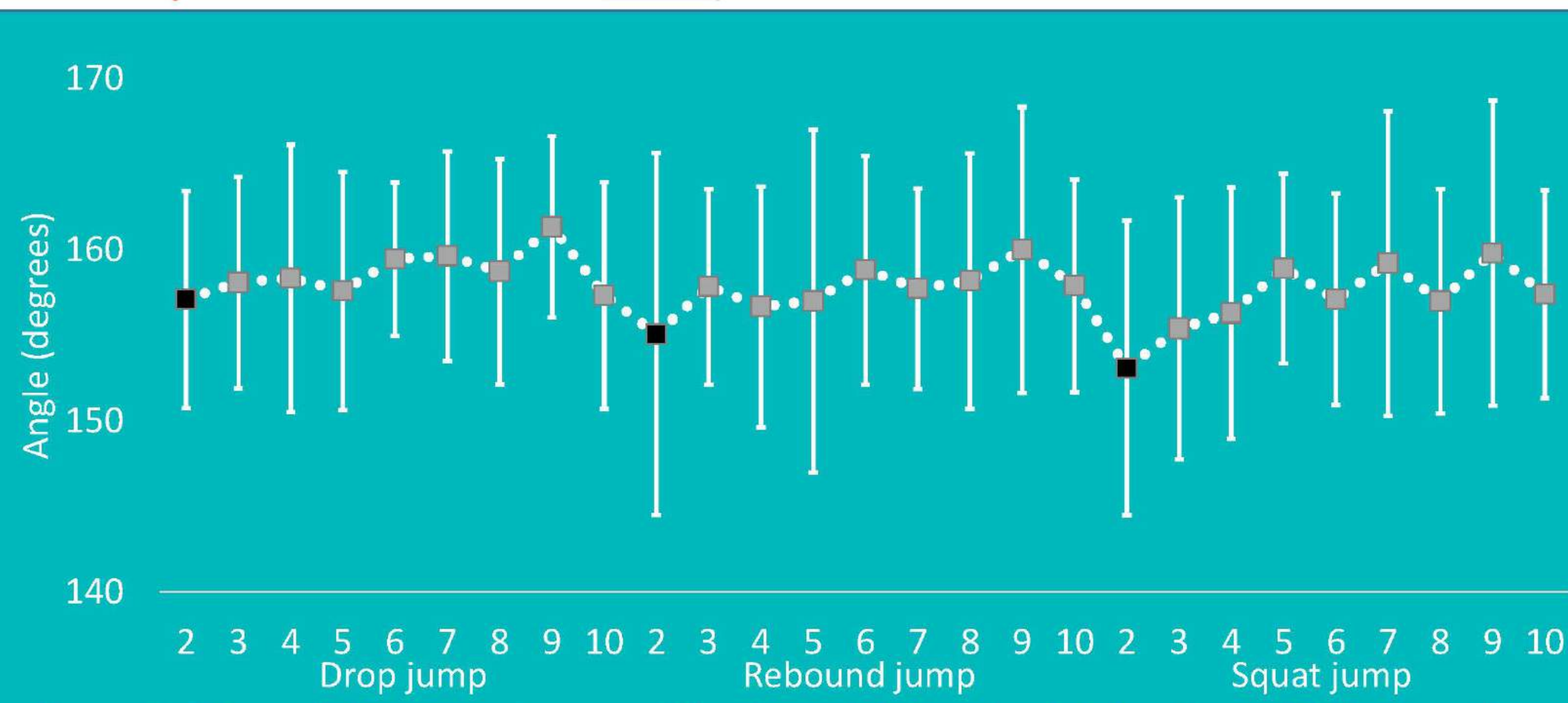

Figure 1. Rebound jump exercise repetition knee joint angle at take-off result Black marker denotes first repetition of each set. Significance set at *P* < 0.05. Error bars show SD.

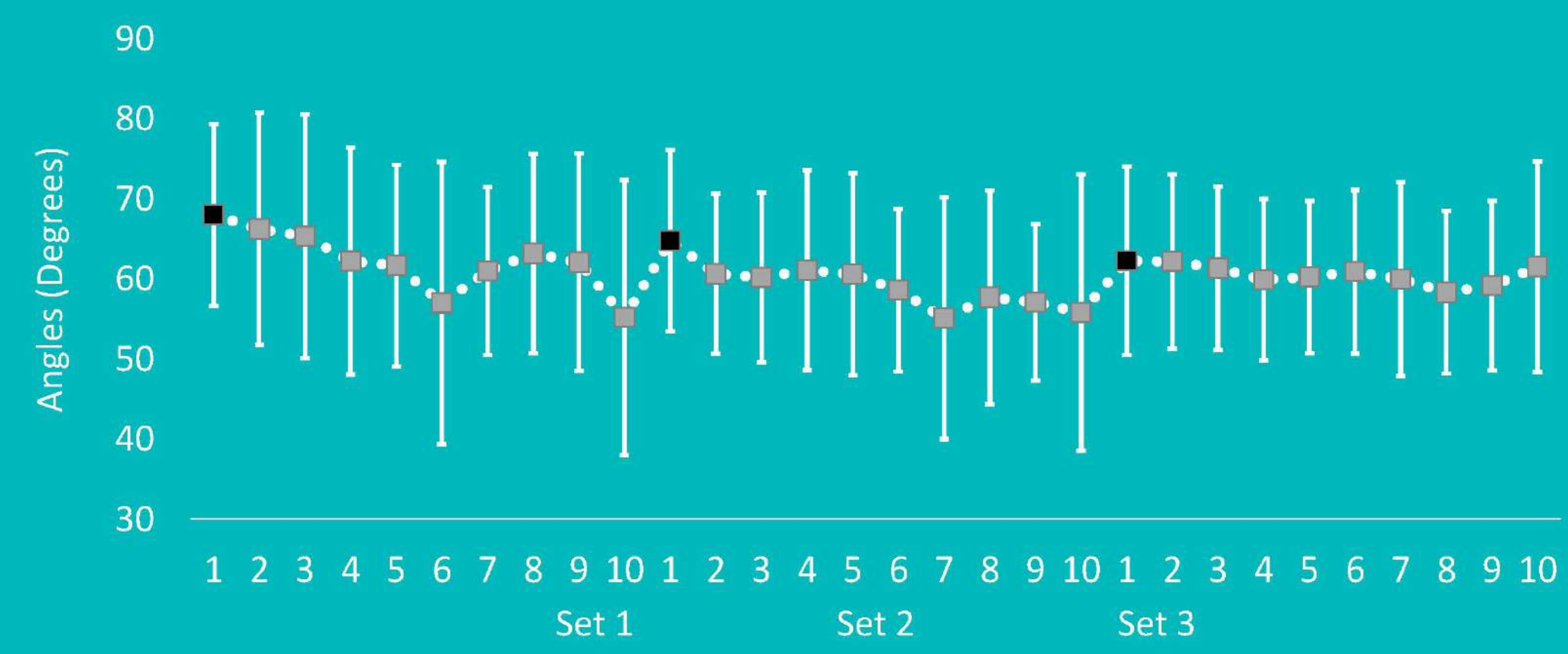

Figure 2. Squat jump exercise repetition knee joint extension range result. Black marker denotes first repetition of each set. Significance set at *P* < 0.05. Error bars show SD.

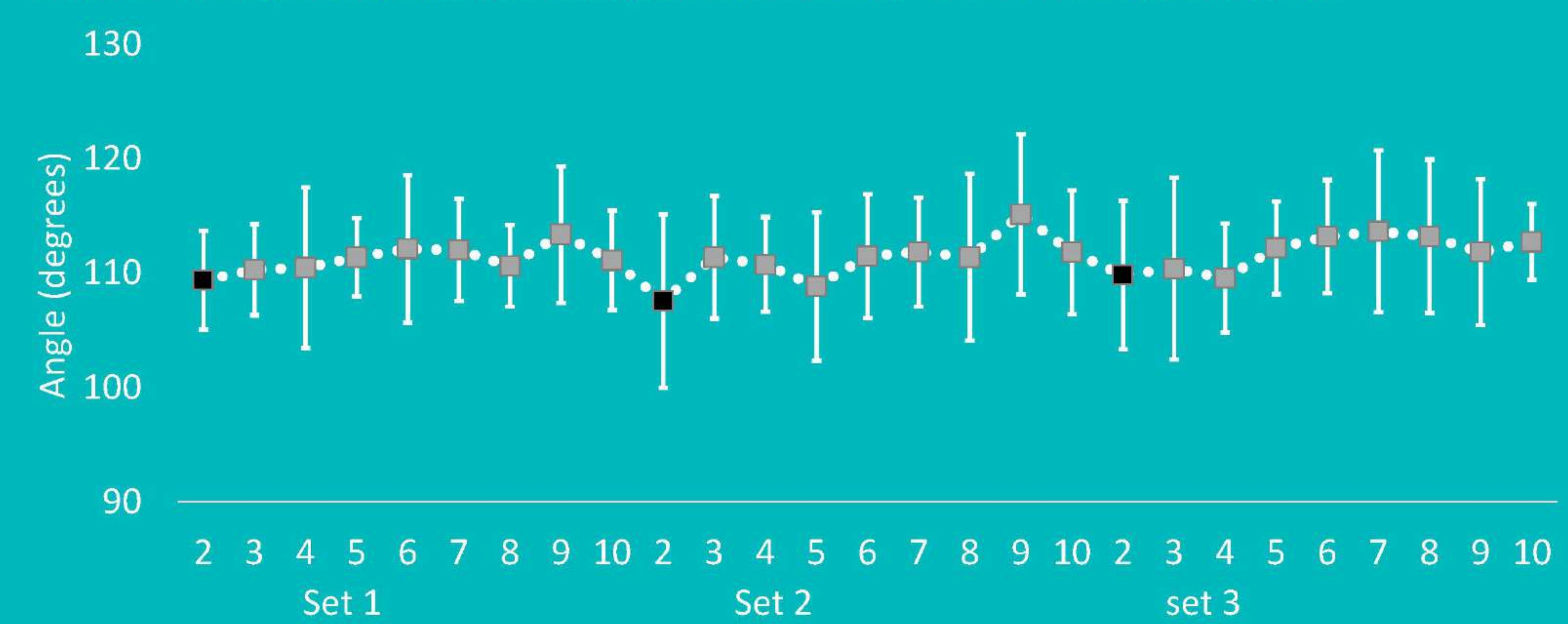

Figure 3. Rebound jump exercise repetition ankle joint angle at take-off result. Black marker denotes first repetition of each set. Significance set at *P* < 0.05. Error bars show SD.

Figure 4. Squat jump exercise repetition hip joint angle at toe land result. Black marker denotes first repetition of each set. Significance set at *P* < 0.05. Error bars show SD.

4. SUMMARY

Large variability in kinematic measurements were found between repetitions, highlighting the use of variable technique. The variation in technique was used to overcome constraints, such as exercise variety and repetition range, imposed on the athlete to maintain jump performance.

5. CONCLUSION

It may be beneficial for the strength and conditioning coach to expose a range of constrains, such as exercise variety and varied repetition ranges, on vertical jump exercises allowing athletes to gain a wider experience of constraints that may affect them in competition.

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A ten-week neuromuscular training intervention improves movement competency in adolescent middle-distance runners

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ABSTRACT

Aim: The purpose of this study was to investigate the effect of a ten-week strength and conditioning (S&C) programme, on movement competency, as measured by the Functional Movement Screen (FMS), in young middle-distance runners.
Methods: Nine males and nine females (mean ±SD age: 17.2 ±1.2 years) were assessed on the FMS before being randomly assigned to an intervention group (IG), or a control group (CG) who continued to train as usual. The IG added two weekly S&C sessions to their normal routine of running, which included movements skills, plyometrics and resistance training. All sessions were delivered by UKSCA accredited coaches.
Results: Composite FMS score showed significant improvement (p<0.001) in the IG (effect size: 1.43, large), whereas the CG displayed no change. Individual tasks all showed moderate improvements (effect size: 0.64-0.97) with the exception of the deep squat and active straight leg raise.
Conclusion: A ten-week programme of S&C activities, coached by qualified practitioners, provided a large improvement in FMS score in young runners, which may help offset injury risk and facilitate the development of more complex skills.

INTRODUCTION

A primary goal of the S&C professional is to enhance the movement competency of athletes. This is particularly important for adolescent athletes, as becoming proficient in a range of fundamental motor skills at a young age can provide significant benefits in later years (Mostafavifar et al., 2013). Fundamental movements also underpin more complex motor patterns and competency is a prerequisite for increases in exercise intensity.
The FMS is a comprehensive tool comprising seven movement tasks designed to assess an individual's motor control and mobility (Cook, 2006). FMS score has shown improvement (Bodden et al., 2015) and no change (Frost et al., 2012) in adult athletes who include a period of supplementary neuromuscular training, which includes co-ordination, balance and strength training exercises.
A low score (≤ 14) on the FMS has been associated with an increased risk of injury in some populations (Kiesel et al., 2007; Chorba et al., 2010), however the efficacy of a training intervention designed to enhance FMS performance in young athletes has not yet been investigated.

AIM

This study aimed to evaluate the effects of a ten week S&C intervention on FMS score in a group of young middle-distance runners.

METHODS

Participants
Eighteen young competitive middle-distance runners (male n=9, female n=9, age 17.2 ±1.2 years; body mass 58.5 ±7.1 kg) took part in this study.
Procedure
Participants were assessed on the FMS in accordance with the standardised protocol (Cook, 2006). The seven movement tasks are the deep squat, hurdle step, inline lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability. Participants were subsequently randomised to an intervention group (IG, n=9) or a control group (CG, n=9) matched by sex and running economy. For ten weeks, the IG performed two weekly S&C sessions in addition to their running training, which included exercises designed to enhance movement control, mobility and balance in addition to resistance training and plyometric exercises (see Table). The CG continued their normal running training. All S&C sessions were coached by Accredited members of the UKSCA.
Measures
Each task was scored on a four point scale from zero to three, as per FMS scoring criteria (Cook, 2006). A composite score for the FMS out of 21 was noted for each participant at baseline and again after ten weeks.
Statistical analysis
A two-way repeated measures ANOVA (time x group) was conducted to ascertain the effect of the intervention on FMS composite score and each item in the IG compared to the CG. Effect sizes were also calculated and were interpreted as <0.2 trivial, 0.2-0.6 small, 0.6-1.2 moderate, >1.2 large.

Session component	Weeks 1-3	Weeks 4-6	Weeks 7-10
Movement skills (2x8 each)	4pt shoulder touch, crab walk, split squat, hamstring stretch w/tap, knee hug, toe touch to squat, inchworm, arabesque	4pt thoracic reach, band walk, hamstring stretch w/tap, reverse lunge, single leg glute bridge, prisoner squat, arabesque	Rotary stability, inchworm, jump and stick, walking lunge, active straight leg raise, reverse hurdle wall touch, overhead squat
Plyometrics	Box jump 3x6 A-skip 3x15 m Jump & stick 3x6	Single leg box jump 3x6 High-knees 3x15 m Mini hurdle jumps 4x6	Drop jumps 3x6 Sprints 3x30 m Mini hurdle jumps 4x8
Resistance training	Back squat 3x8 Romanian deadlift 3x8 Sing leg press 2x8 Calf raise 2x12	Back squat 3x8 Rack pull 3x8 Single leg press 3x8 Calf raise 3x12	Back squat 3x6 Deadlift 3x6 Step-ups 3x8 Calf raise 3x12

Table. Ten week S&C programme followed by the IG ($2\ d\cdot wk^{-1}$). All exercises were prescribed as sets x repetitions (unless stated)

RESULTS

Pre-training, FMS scores did not differ between groups (IG: 12.7 ±1.5, CG: 13.6 ±2.6). Following the intervention period, a significant increase in the IG score (15.7 ±2.1, p<0.001) compared to the CG score (13.9 ±1.8) was observed. In practical terms, this represented a large change (effect size: 1.43). Seven of the nine participants in the IG group also had composite scores of ≥ 14 post-training, which may be an important threshold for injury risk. Inspection of individual items within the screen revealed that only the inline lunge improved (p<0.05) as a result of the S&C training (see Figure). However effect sizes showed moderate improvements in the IG for the hurdle step (0.92), inline lunge (0.96), shoulder mobility (0.64), stability push-up (0.94), and rotary stability (0.97).

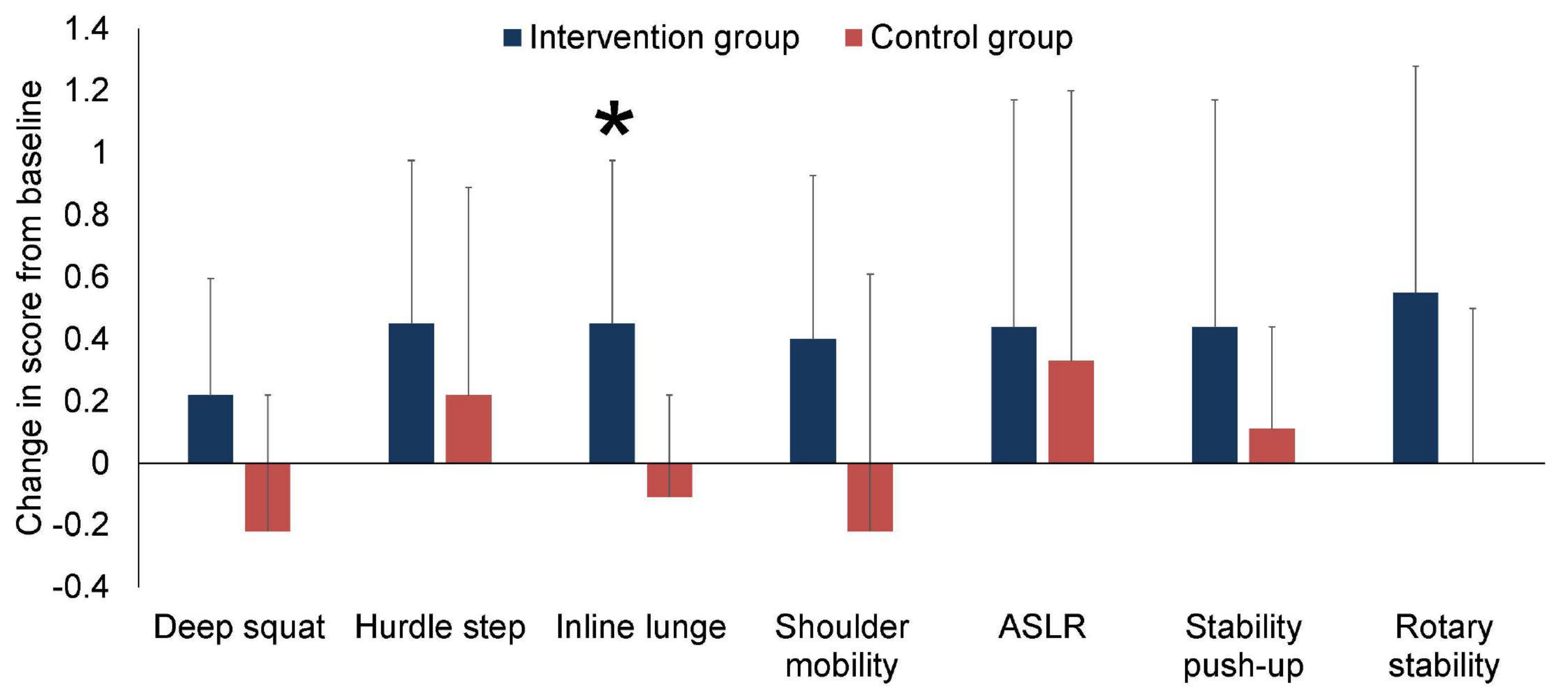

Figure. Changes in movement task score for the intervention group. * statistically significant from baseline value and control group change (p<0.05). ASLR = active straight leg raise

CONCLUSIONS

Including bi-weekly S&C sessions aimed at developing a range of movement skills, strength-qualities and mobility is likely to provide large improvements in movement competency in young athletes. The FMS assesses compensatory movements, imbalances and mobility, therefore is a helpful tool in determining potential risk of injury in runners who perform a high volume of repetitive actions (O'Connor et al., 2011). Improving FMS score may therefore offset the risk of injury, so it is advisable to schedule coached S&C sessions into the weekly routine of young distance runners.

ACKNOWLEDGMENTS

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Physical Profiling of Elite Equestrian Athletes

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Background

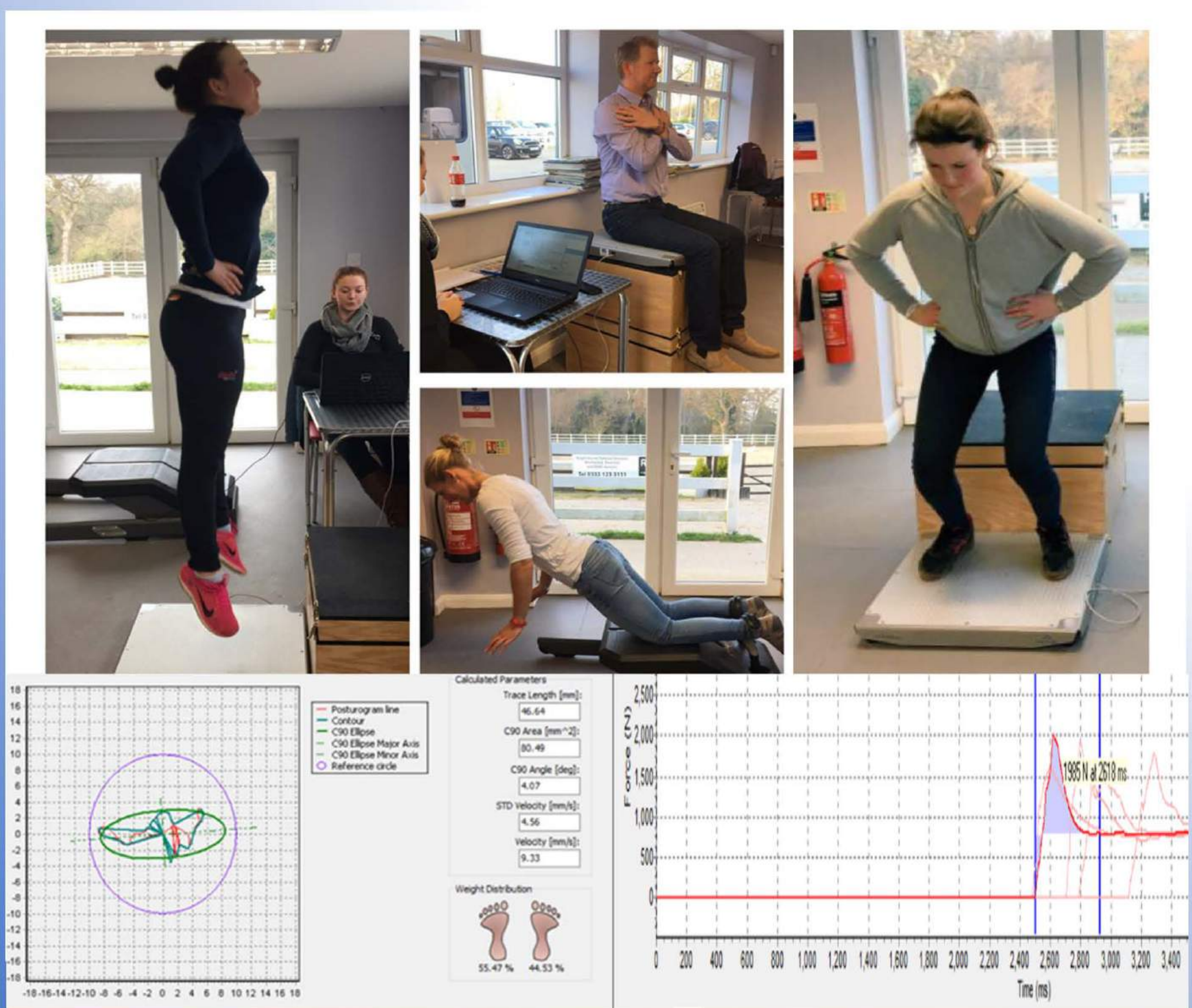
Horse riding is a highly popular and well-funded sport, with 2.7 million participants reported in 2015 [1] and £15,361,769 of funding for the 2017-2020 Olympic cycle [2]. Despite these figures, limited information exists surrounding the physical requirements of the rider to perform [3]. This is possibly attributable to the unique nature of equestrian sport, in which performance relies largely upon the human and horses' functionally different complex adaptive systems to synchronise.

As the horse has its own free mind, the rider must be able to react and coordinate with unpredictable motion patterns, whilst simultaneously perceiving environmental stimuli and producing effective signals for action to the horse. Moreover, both genders compete on equal terms, age is not a limiting factor to career longevity and there is a variety of disciplines with differing demands to consider. Due to scarce and inconsistent research [4,5,6], the physical requirements of equestrian sport remain unknown. Thus, establishing the riders physical profile could aid talent development and rider progression within the sport.

- **Aim** Produce a tool that can define the physical profiles of equestrian athletes from the three Olympic disciplines (Dressage, Show Jumping and Eventing).
- **Objectives** Determine whether physical qualities differentiate between the Olympic disciplines/between the competition levels. Improve the understanding of the physical requirements of equestrian sport.

Experimental Design

- 8 Eventers (Ev) and 8 Dressage riders (Dr) (aged 18-24) on the British Equine Federation (BEF) Excel Talent Programme took part in the study.
- Testing was split into two phases; force capabilities and balance capabilities.
- Force: countermovement jump, squat jump, drop landing, drop jump, and nordic curls. Each participant repeated each test three times using the Hur Labs 4 force platform and Nordboard.
- Balance: 1 minute standing and seated (eyes open (EO), eyes closed (EC)), 5 seconds 30 degree squat, 60 degree squat and 90 degree squat, one minute prone hold. Each test measured postural sway in the X and Y axis using the Hur Labs 4 force platform.



Results

Table 1: Mean ± SD and differences in force capabilities between disciplines

	SJ	CMJ	EUR	RSI	TTS	PF	Nordic L	Nordic R	Imbalance
Dr	22.78±3.09 (CI 20.55-24.85)	23.4±3.91 (CI 20.69-26.11)	1.04±0.12 (CI 0.96-1.12)	1.16±0.63 (CI 0.72 -1.60)	0.85±0.0915 (CI 0.79 -0.92)	30.95±9.84 (CI 24.13 -37.77)	235±43.5 (CI 202.77 -267.23)	227±79.1 (CI 168.40 -285.60)	11.2±8.48 (CI 4.92 - 17.48)
Ev	22.5±6.05 (CI 18.3 - 26.68)	22.03±5.5 (CI 18.22-25.84)	0.99±0.11 (CI 0.91 - 1.07)	1.13±0.44 (CI 0.83-1.43)	0.8±0.07 (CI 0.75 - 0.85)	27.21±3.80 (CI 24.58 -29.84)	246.57±97.66 (CI 178.90 - 314.24)	268.60±114.83 (CI 189.03 - 348.17)	12.90±4.45 (CI 9.82- 15.98)
P value	0.213	0.486	0.652	0.746	0.202	0.171	0.137	0.518	0.095

Table 2: Mean ± SD and differences in balance capabilities between disciplines

	Standing Eyes Open		Standing Eyes Closed		Seated Eyes open		Seated Eyes Closed	
COP axis	SD X	SD Y	SD X	SD Y	SD X	SD Y	SD X	SD Y
Dr	2.34±1.49 (CI 1.31-3.37)	3.85±1.63 (CI 2.72-4.98)	2.93±1.84 (CI 1.65-4.21)	5.09±2.22 (CI 3.55-6.63)	1.88±1.73 (CI 0.68-3.08)	0.94±0.44 (CI 0.64-1.24)	2.31±2.16 (CI 0.81-3.81)	1.17±0.79 (CI 0.62-1.72)
Ev	4.70±2.78 (CI 2.77-6.63)	2.29±1.57 (CI 1.2-3.38)	5.06±2.51 (CI 3.32-6.8)	3.16±2.15 (CI 1.67-4.65)	1.41±0.66 (CI 0.95-1.87)	0.75±0.22 (CI 0.6-0.9)	1.71±1.22 (CI 0.86-2.56)	0.66±0.18 (CI 0.54-0.78)
P value	0.553	0.744	0.586	0.715	0.027	0.021	0.073	0.043
	Squat 30˚		Squat 60˚		Squat 90˚		Prone hold X	
COP axis	SD X	SD Y	SD X	SD Y	SD X	SD Y	SD X	SD Y
Dr	2.7±1.39 (CI 2.15-3.25)	2.39±1.19 (CI 2.34-2.44)	3.23±2.04 (CI 1.82-4.64)	2.86±0.79 (CI 2.31-3.41)	4.09±2.05 (CI 2.67-5.51)	2.87±1.18 (CI 2.57-3.17)	2.86±0.66 (CI 2.4-3.32)	5.43±2.99 (CI 3.36-7.5)
Ev	2.96± 0.8 (CI 2.41-3.51)	2.29±0.73 (CI 1.47-3.11)	3.91± 1.46 (CI 2.9-4.92)	2.79±0.66 (CI 2.33-3.25)	3.66±1.21 (CI 2.82-4.5)	3.25±1.1 (CI 2.9-4.42)	2.74±1.56 (CI 3.82-1.66)	6.43±2.14 (CI 6.35-6.51)
P value	0.049	0.188	0.653	0.585	0.05	0.668	0.044	0.47

There was a significant correlation between TTS and SJ (-0.704, 0.001), RSI and CMJ (0.657. 0.006), SJ and CMJ (0.857, 0.000), SJ and nordic curls (left leg) (0.704, 0.003), and SJ and nordic curls (right leg) (0.523, 0.045). There was also a significant difference between groups in postural sway: seated EO (SDX p=0.027, StdY p=0.021), seated EC (SDY=0.043), squat 30˚ (SDX p=0.049), squat 90º SDX (p=0.05), and prone hold (SDX p=0.044). Moreover, a significant correlation between the seated EO (SDX) condition and 30˚ squat (0.653, 0.006) and seated eyes closed (SDX) and standing EC (SDX) (0.623, 0.01) was found.

Summary

- These results show that Dressage and Event riders do not differ significantly in force production capabilities but there are significant differences in specific balance capabilities. This could indicate that balance and postural control indices have a more prominent role in distinguishing performance for the different disciplines.
- Findings could aid scientifically informed training programmes for Dressage and Event riders, and thus development within the sport.

Future directions

- Riders of different levels should be tested to determine whether physical profiles differ from novice to advanced.
- More riders should be tested to improve the reliability and applicability of results, including Show Jumpers so that profiles of each Olympic discipline can be analysed.
- Interventions that develop physical capabilities should be examined in context of actual riding performance.

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Canadian Assessment of Physical Literacy:

Evaluating Physical Literacy Levels of KS1 Children in Jersey, Channel Islands

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ABSTRACT

Purpose: The purpose of the study was to determine the physical literacy (PL) levels of KS1 children in Jersey with the use of the *Canadian Assessment of Physical Literacy* (CAPL).

Methods: 954 students (female; n=518, male; n=436), aged 8-9 years old (*M*=8.7, *SD*= ± 0.41) in KS1 across Jersey were assessed. The CAPL is a reliable and validated measurement tool that evaluates the physical literacy of children in four domains. The domains are; 1) physical competence, 2) daily behavior, 3) knowledge and understanding, and 4) motivation and confidence. The combination of all four domains yielded a composite physical literacy score.

Results: Scores were ranked into one of four interpretation categories: beginning, progressing, achieving or excelling. The CAPL deems achieving and above as the physical literacy benchmark. 60% of children fell below the achieving level of the overall domain composite score. Within the subdomains 75% of children fell below the achieving level for physical competency measure; 67% of children fell below the achieving category for; motivation and confidence; 65% of children fell below the achieving category for the knowledge and understanding domain; and 44% of children fell below the achieving level for daily behavior.

Conclusion: The majority of children fell below the achieving level for physical literacy. Particular focus should be paid to the physical competence and knowledge and understanding results in order to strengthen both physical literacy and athletic pathway development.

Keywords: Physical Literacy, Benchmarking, Children, Physical Competence, Daily Behaviour, Knowledge & Understanding, Motivation & Confidence.

PHYSICAL LITERACY

A universally accepted definition of physical literacy (PL) has recently been adopted. Originally introduced by Margaret Whitehead in 1987, PL has been redefined and conceptualised to meet current societal perceptions. In May 2015, stakeholders at the International Physical Literacy Conference in Vancouver agreed to the following statement describing PL:

Physical literacy is the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life. Whitehead, M (2014).

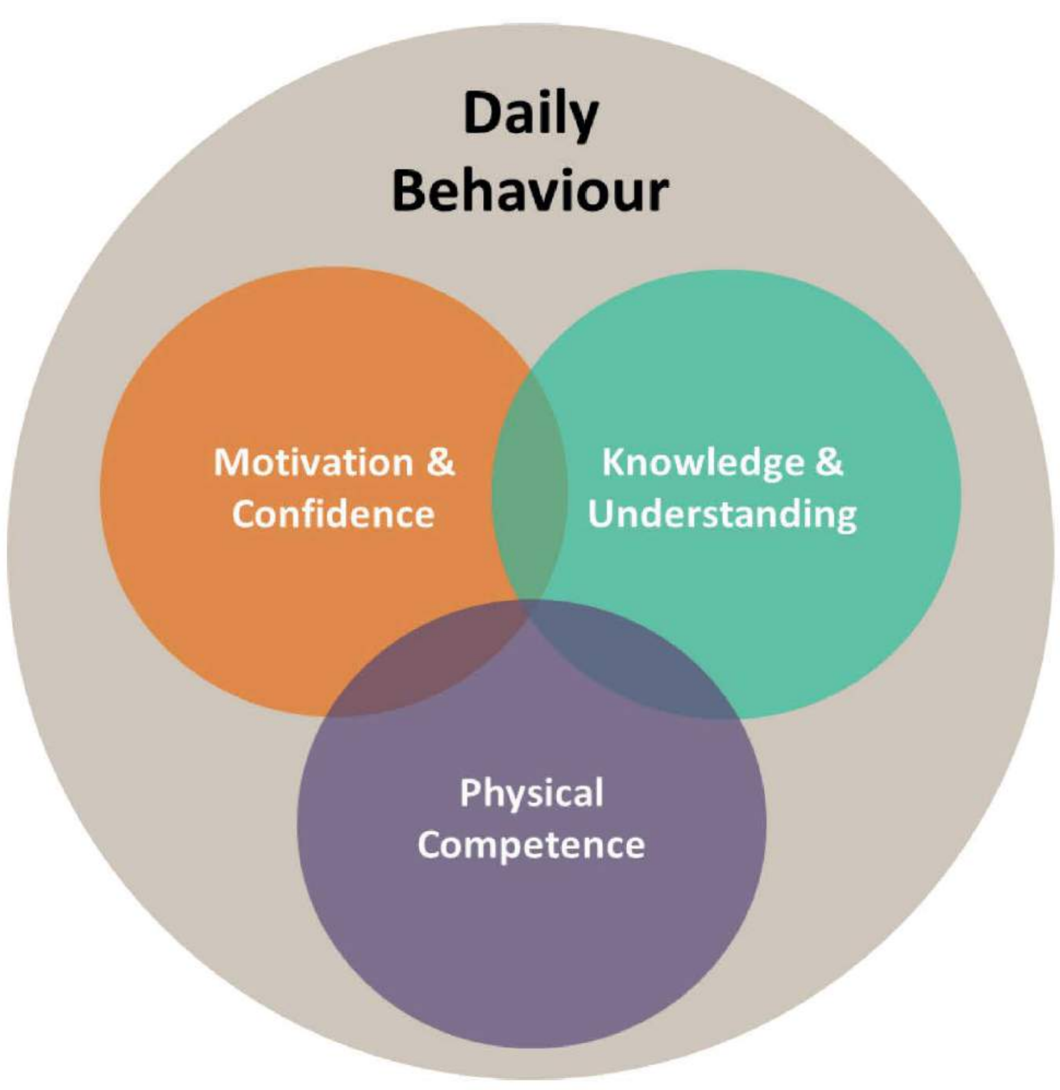


Figure 1: Physical Literacy Conceptualization. CAPL Assessment Manual.

PHYSICAL LITERACY ASSESSMENT

Most assessments of PL only look at a measure of physical competence and in particular fundamental movement skills assessment (FMS). They fail to account for the cognitive and affective domains when evaluating what it means to be physically literate. The CAPL evaluates all three plus consideration for daily physical activity (PA). Providing a broader view of PL enables educators and coaches to design a programme of development that is aligned with the child's knowledge and understanding of what it means to be physically literate. This may lead to increased confidence and motivation as PA experiences begin to meet the specific needs of the child and in turn improve outcomes for both PA and athletic development programmes.

METHODS AND DATA COLLECTION

Data was collected from 18 primary schools in Jersey during designated physical education (PE) sessions. Physical competence was measured by using a variety of activity stations set up in sports halls. Stations included a comprehensive CAPL motor skills obstacle course, VO2Max via Fitnessgram™ 20m shuttle run, trunk stability via a plank; posterior chain flexibility via a portable flexometer and grip strength via a dynamometer.

Cognitive understanding of developmentally appropriate PE terminology and levels of motivation and confidence were measured using the Physical Activity Questionnaire (PAQ). This also included The Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA) questionnaire was also used to evaluate confidence and motivation.

Daily PA behaviour data was also objectively gathered with the use of Garmin Vivo Fit Junior pedometers that the children were asked to wear for seven days. Self reported data of daily PA behaviour was also gathered indirectly using the PAQ and crossed referenced against pedometer data.

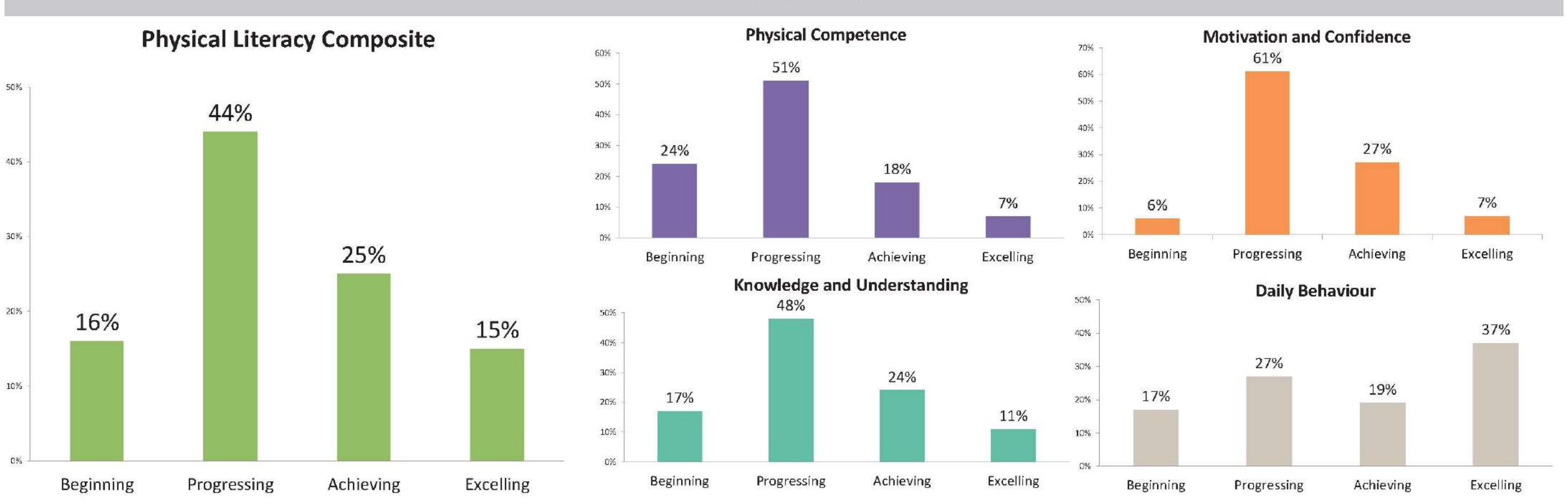
DATA ANALYSIS

Microsoft Excel was used for this interim analysis.

Overall, 60% of children were not deemed to have met the physically literate benchmark, with the highest proportion (44%) of children achieving the progressing category. 40% of children achieved the benchmark or above, and 15% were shown to be excelling.

The key contributory domains affecting the overall composite score were physical competence and motivation and confidence with 75% and 67% respectively not achieving the domain bench mark set by the CAPL. The knowledge & understanding and the daily behaviour domain identified 65% and 44% respectively of children not achieving the domain bench mark set by the CAPL.

RESULTS



DISCUSSION

The CAPL fills a need for the holistic assessment for children's PL. It allows educators, coaches, and researchers to make informed decisions about PA programming and investment based on normative values. It also provides unique insight into some of the contributory factors alluding to the decline of physical activity trends and general athletic qualities in children. This is also extremely valuable in looking at factors relating to long term athlete development planning.

The majority of children in this study are achieving scores within the progressing category with few meeting the achieving or excelling categories. The data would suggest that a renewed emphasis on physical competence and motivation & confidence within Jersey is necessary to improve overall physical literacy scores of KS1 children and below.

Jersey mirrors similar sized jurisdictions with the UK with regard to obesity, declining sport and physical activity participation and FMS acquisition. As such this data could up be easily scaled to larger jurisdictions and prove useful for comparison.

Future studies should investigate appropriate messaging to children, educators, coaches, and policy makers as to what is necessary to leverage higher levels of physical competence and motivation and confidence within KS1 children and below, in order to enhance physical activity engagement and the foundations of athleticism.

ACKNOWLEDGEMENTS

The authors would like to thank Jersey Sport, Canadian Assessment of Physical Literacy, Mount Royal University and the States of Jersey Education Department for their partnership and support in conducting the research.

A Study to Evaluate the Effects of a Neuromuscular Injury Prevention Programme (GAA15) in Adolescent Males Participating in Hurling

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1. Introduction

Adolescent involvement in organised sport has never been more popular in Ireland. However, this increased level of activity has reportedly caused concern regarding the potential risk and severity of sporting injuries (1).

Previous research into adolescent injury incidence in multidirectional sports have established a decline in injury rates following the implementation of injury prevention programmes (2).

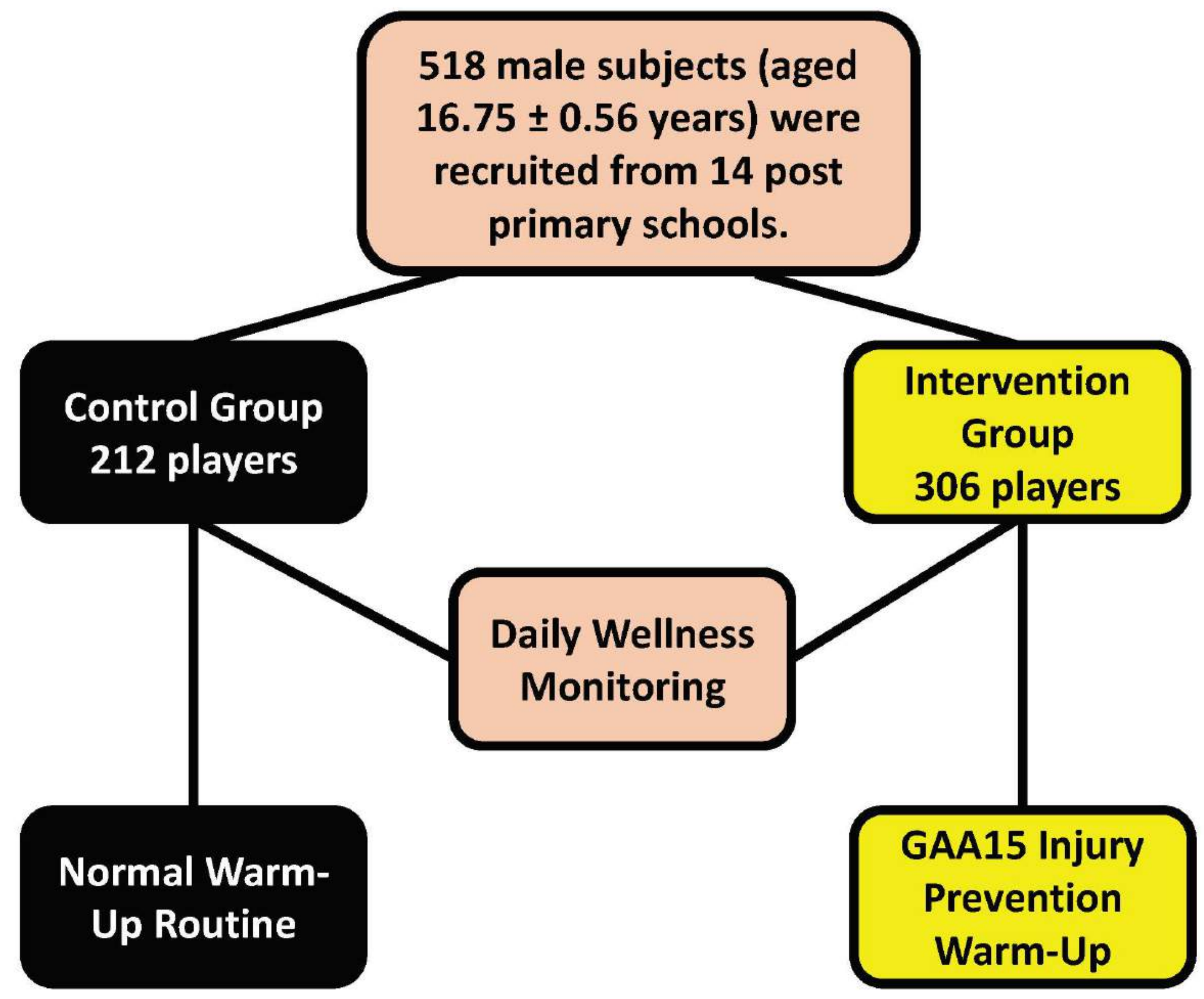
Hurling can be described as a fast, high intensity, running, contact sport that involves phases of continuous physical activity, including unpredicted, explosive and multidirectional movements with player-to-player physical contact.

Former investigations into injury incidence and rates within the Gaelic Athletic Association (GAA) has primarily focused on elite adult players, with a lack of data on the adolescent cohort (3).

While injury prevention research and strategies are progressing at adult level within the GAA, there is a lack of similar strategies at adolescent level. Previous research is compelling and underlines the necessity to reduce the incidence of injury in this adolescent cohort. Adolescents are at risk in terms of overload and growth related injuries in sport, with hurling and the GAA no exception to this.

The aim of the current investigation was to assess and critically analyse the application and implementation of a neuromuscular injury prevention warm-up programme (GAA15) in adolescent (age 13 – 18.5 years) boys participating in hurling.

2. Methodology



3. Injury Classification

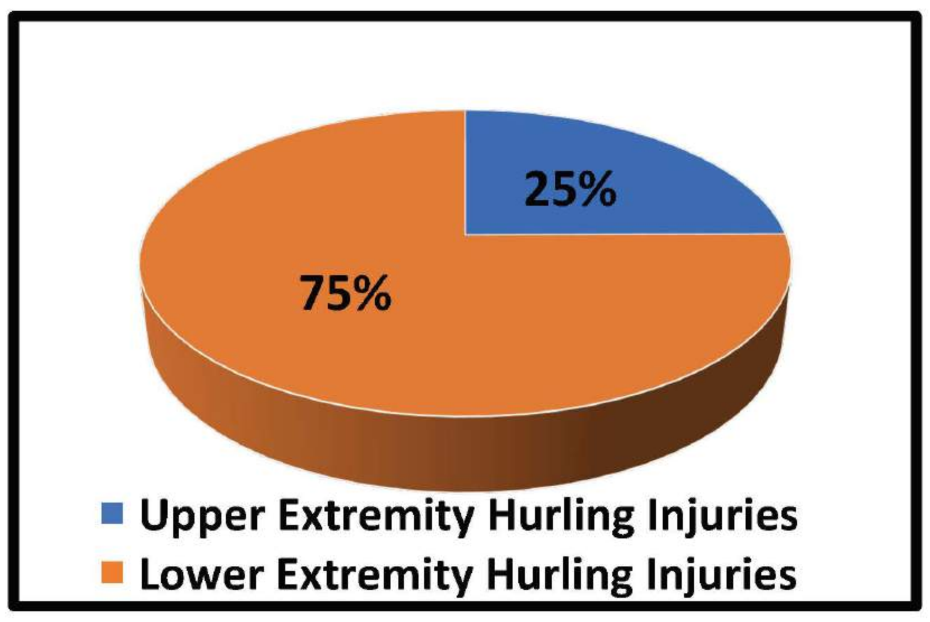


Figure 1. Total hurling injury classification.

75% of all injuries recorded were to the lower extremity with 25% to the upper limbs.

The hamstring was the most frequently injured body part followed by the knee, calf, and quadriceps muscles.

4. Results

Hurling training injury rates of 15.83/1000 hrs (95% CI:9.4-22.3) and 8.78/1000 hrs (95% CI:5.2-12.4) were recorded for the control and intervention groups respectively.

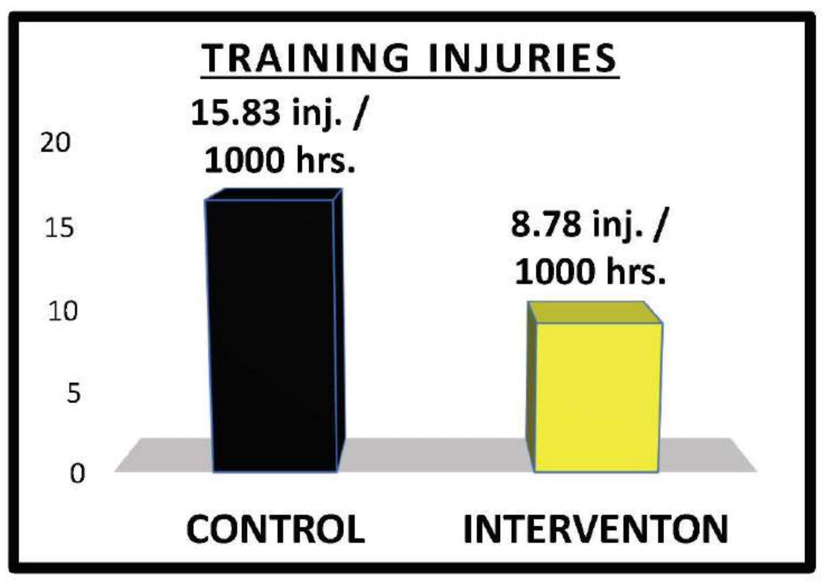


Figure 2. Rate of hurling training lower-extremity injuries.

Hurling match injury rates of 36.32/1000 hrs (95% CI:21.1-51.5) and 25.62/1000 hrs (95% CI:16.9-34.4) were reported for the control and intervention groups.

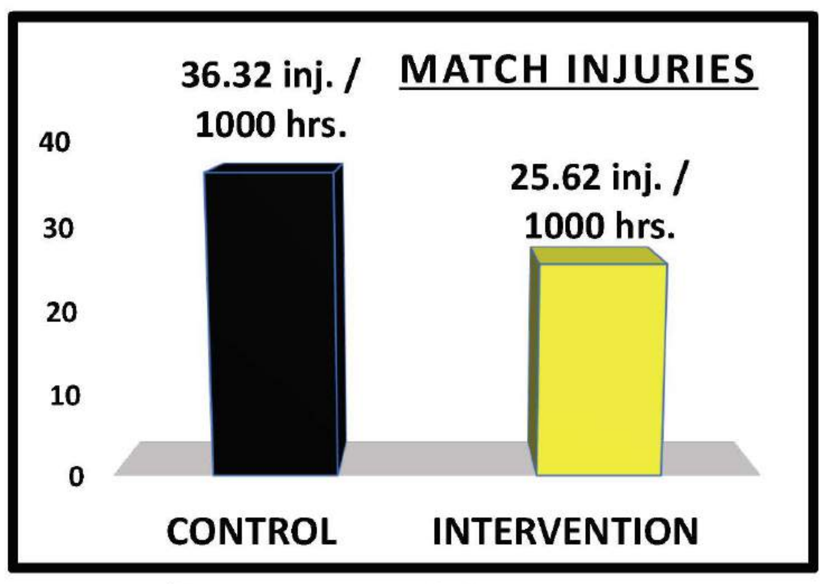


Figure 3. Rate of hurling match lower-extremity injuries.

5. Discussion

During the 2015/16 post primary school hurling season, this investigation found that, hurling training injuries were reduced by 45% in the intervention group compared to the control group following the implementation of the GAA 15 neuromuscular injury prevention warm-up.

Hurling match injuries were also reduced by 30% in the intervention group when compared to the control group during the same time period.

6. Conclusion

Following this investigation, it can be concluded that positive outcomes can be achieved from the implementation of a neuromuscular injury prevention warm-up, namely the GAA 15, to reduce lower extremity injuries in adolescent males participating in hurling.

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ISOMETRIC FORCE-TIME CHARACTERISTICS OF REGIONAL ACADEMY NETBALL PLAYERS

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Introduction

Anthropometric and physical qualities develop across age categories in English regional academy netball players (Thomas et al., 2016a). Moreover, stronger netball athletes have been shown to demonstrate superior sprint, change of direction speed and vertical jump performance compared to weaker athletes (d = 0.9-1.7) (Thomas et al., 2016b). However, it is unknown how isometric force-time characteristics differ between age categories within this population. Strength profiling of athletes via the isometric mid-thigh pull (IMTP) can provide valuable information regarding the rapid force contractile properties of athletes to inform future training and monitoring. The purpose of this study was to evaluate isometric force-time characteristics of English regional academy netball players by age category.

Experimental design and Methods

- Fifty regional academy netball players from three age categories: U15s (n=17), U17s (n=17) and U19s (n=16) performed three IMTPs at each posture on a force platform (Kistler, Winterthur, Switzerland, Model 9286AA, SN 1209740) sampling at 1000 Hz.
- Body mass (Seca Digital Scales, Model 707), standing and seated height (Stadiometer; Seca, Birmingham, United Kingdom), were measured to the nearest 0.1 kg and 0.1 cm and used to estimate maturity offset (Mirwald et al., 2002).
- Athletes were positioned in their self-preferred mid-thigh pull position (relative knee and hip angles of 130-150˚) (Comfort et al., 2015).
- PF was defined as the maximum force generated during the five second maximum effort IMTP. Time-specific force values at 100, 150 and 200 ms and rate of force development (RFD) at predetermined time bands (0-100, 0-150 and 0-200 ms) were also calculated (RFD = Δforce/Δtime).
- Absolute and relative PF and time-specific force values were also calculated.
- The onset of the contraction was determined when vertical ground-reaction force deviated 5 SD of body weight (Dos'Santos et al., 2017).
- The combined residual force and body weight were calculated as the average force over a 1 second stationary weighing period (in mid-thigh pull position posture) prior to the initiation of the IMTP (Dos'Santos et al., 2017).
- If the differences between the three trials exceeded 250 N then another trial was performed.
- The mean of three trials were used for statistical analysis.

Statistical Analyses

- Differences in IMTP kinetics between age categories were assessed using a series of one way analysis of variance.
- Where significant differences were found, Bonferroni post hoc analyses were used to detect differences between age categories with Hedges' g effect sizes to assess the magnitude of differences.
- The criterion for significance was set at $p \leq 0.05$.

Results

- U19s produced significantly greater absolute time-specific force values than U15s and U17s ($p \leq 0.039$, g = 0.76-1.21).
- Significantly larger absolute PF and RFD were demonstrated by the U19s compared to the U15s ($p \leq 0.003$, g = 1.20-1.33), whereas non-significant moderate differences were observed in absolute PF and RFD when compared to U17s ($p \geq 0.059$, g = 0.76-0.90).
- Trivial to small non-significant differences in absolute PF and absolute time-specific force values were demonstrated between U15s and U17s ($p \geq 0.537$, g = 0.11-0.44), whereas non-significant moderate differences in RFD were observed ($p \geq 0.113$, g = 0.58-0.84).
- Small non-significant differences in relative PF and relative time-specific force values were demonstrated between age categories, although the highest values were produced by the U19s ($p \geq 0.315$, g = 0.31-0.56).
- Maturity offset significantly increased across age categories ($p \leq 0.033$, g = 0.96-2.42). Significantly greater body mass was observed in the U19s compared to U15s (p = 0.07, g = 0.74), with non-significant moderate differences found compared to U17s (p = 0.20, g = 0.81).

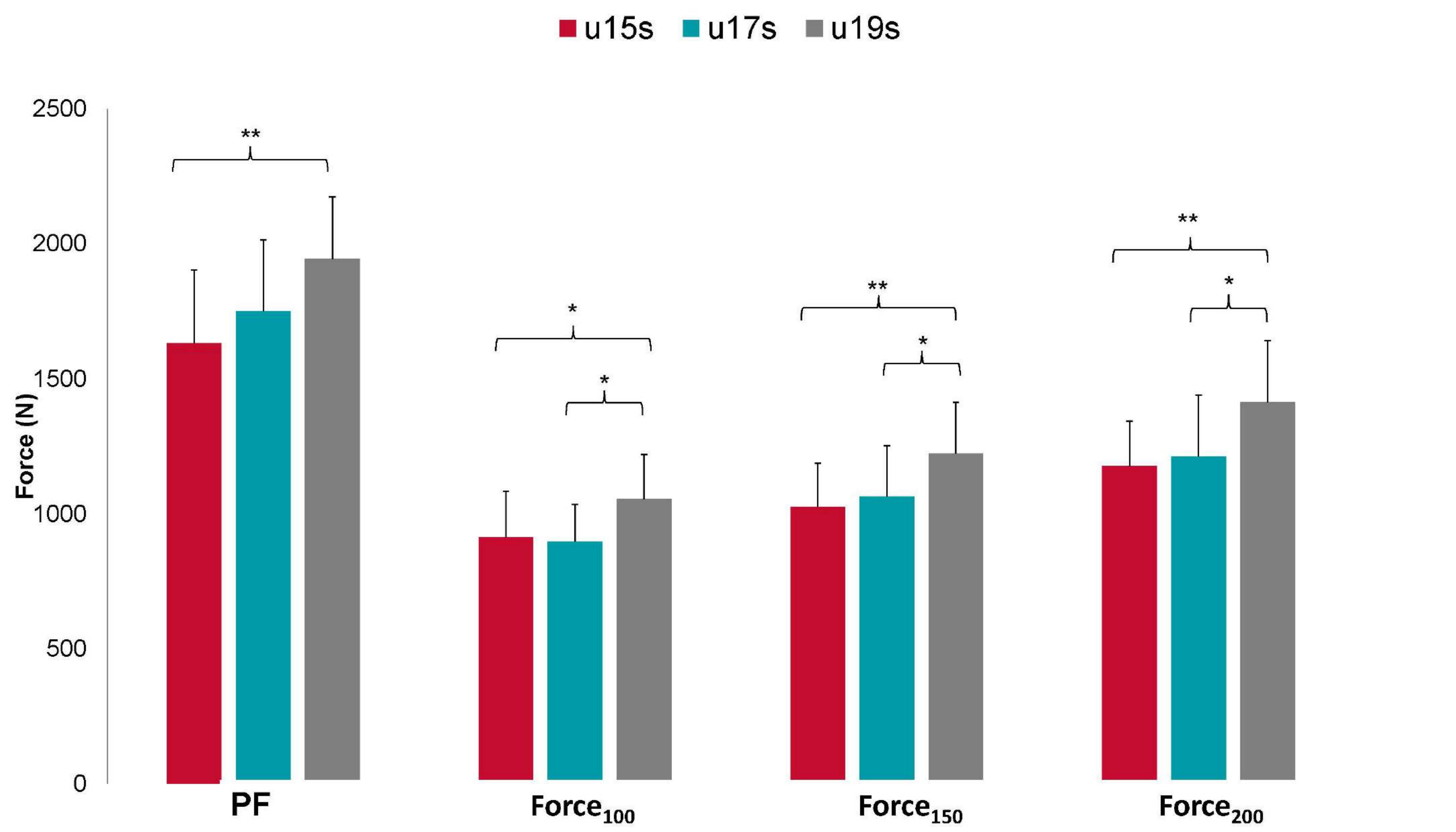

Figure 1. IMTP absolute PF and time–specific force values comparisons between age categories
** p ≤ 0.01; * p ≤ 0.05

Table 1. Anthropometric and IMTP force-time characteristics of regional academy netball players by age category

	U15s (n = 17)		U17s (n = 17)		U19s (n = 16)		U15s vs U17s		U15s vs U19s		U17s vs U19s	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	*p*	*g*	*p*	*g*	*p*	*g*
Age (years)	14.7	0.5	15.5	1.2	16.6	0.9	0.021	-0.91	<0.0001	-2.62	0.004	-1.01
Height (cm)	169.8	7.9	170.5	5.9	173.3	5.5	0.999	-0.09	0.41	-0.50	0.65	-0.49
Mass (kg)	62.0	9.7	63.3	5.8	68.0	5.7	0.999	-0.16	0.07	-0.74	0.21	-0.81
Maturity offset (years post PHV)	2.4	0.4	3.0	0.7	3.7	0.6	0.033	-0.96	<0.0001	-2.42	0.01	-1.04
PF (N)	1633	272	1753	262	1945	229	0.537	-0.44	0.003	-1.21	0.107	-0.76
$Force_{100}$ (N)	914	170	897	139	1056	165	0.999	0.11	0.039	-0.83	0.018	-1.02
$Force_{150}$ (N)	1028	161	1065	189	1225	190	0.999	-0.21	0.009	-1.09	0.043	-0.82
$Force_{200}$ (N)	1178	168	1214	229	1416	227	0.999	-0.18	0.006	-1.16	0.024	-0.87
RFD_{100} (N/s)	1821	929	2286	600	3275	1386	0.564	-0.58	<0.0001	-1.20	0.059	-0.90
RFD_{150} (N/s)	1971	770	2641	787	3307	1149	0.113	-0.84	<0.0001	-1.33	0.126	-0.66
RFD_{200} (N/s)	2228	792	2726	797	3435	1014	0.306	-0.61	0.001	-1.29	0.071	-0.76
Rel PF ($N \cdot kg^{-1}$)	26.6	4.3	27.8	4.4	28.7	3.7	0.021	-0.91	<0.0001	-2.62	0.004	-1.01
Rel $Force_{100}$ ($N \cdot kg^{-1}$)	14.8	2.4	14.2	2.3	15.6	2.3	0.999	-0.09	0.41	-0.50	0.65	-0.49
Rel $Force_{150}$ ($N \cdot kg^{-1}$)	16.8	2.9	16.9	3.0	18.1	3.0	0.999	-0.16	0.07	-0.74	0.21	-0.81
Rel $Force_{200}$ ($N \cdot kg^{-1}$)	19.3	3.4	19.2	3.5	20.9	3.6	0.033	-0.96	<0.0001	-2.42	0.01	-1.04

Key: PF: Peak Force; RFD: Rate of force development; $Force_{100}$: Force at 100 ms; $Force_{150}$: Force at 150 ms; $Force_{200}$: Force at 200 ms; RFD_{100}: RFD 0-100 ms; RFD_{150}: RFD 0-150 ms; RFD_{200}: RFD 0-200 ms; Rel: Relative; U: Under

Summary and Conclusion

The results from this study indicate that absolute PF, time-specific force values and RFD develop with age and maturation, with the greatest differences in force-time characteristics observed between U15s and U19s. However, when expressed relatively the differences in PF and time-specific force values are reduced when compared between age categories. This study provides normative data for isometric force-time characteristics which can be used to establish identification criteria and for monitoring purposes. Strength and conditioning coaches should consider developing their netball athlete's absolute strength and rapid force production capabilities as they progress to the next age category or squad.

Acknowledgments

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