

TITLE

The effect of short-term in-season Isotonic vs. Isoinertial strength training on speed and power in elite young football players

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**The effect of short-term in-season Isotonic vs. Isoinertial
strength training on speed and power in elite young
football players**

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TABLE OF CONTENTS

	Acknowledgements	5
	Abstract	6
Chapter 1:	Introduction	7 - 11
Chapter 2:	Methodology	12 - 17
2.1	Experimental Approach to the Problem	12 - 13
2.2	Subjects	13 - 14
2.3	Testing Procedures	14 - 16
2.4	Training Intervention	16 - 17
2.5	Statistical Analysis	17
Chapter 3:	Results	18 - 22
Chapter 4:	Discussion	23 - 28
	References	29 - 37
	Appendices	38 -

LIST OF FIGURES

Figure 1: Scatter graph showing weak relationships in the 2 groups 21

LIST OF TABLES

Table 1: Mean anthropometric measures of the participants	14
Table 2: 6-week Intervention program for both groups	16
Table 3: Performance indices of the 2 groups from pre to post intervention	19
Table 4: Pearson correlation of Sprint time and 1RM squat	20
Table 5: Pearson correlation of CMJ and difference in C.S.A.	22

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ABSTRACT

The aim of this study was to compare the effect of isotonic and isoinertial strength training on speed and power over a short-term period during the in-season in elite young football players. Using a controlled study design, 19 players were randomly split up into 2 groups: ISOTONIC (n=10, age: 15 ± 0.36 years, height: 1.68 ± 0.53 m, body mass: 58.7 ± 4.5 kgs) and ISOINERTIAL (n=9, age: 15 ± 0.51 years, height: 1.69 ± 0.35 m, body mass: 59.2 ± 5.60 kgs). Both groups took part in a 6-week (12 sessions) intervention program consisting of either the barbell back squat (ISOTONIC) or the flywheel squat (ISOINERTIAL). Pre and post-tests were carried out on 1RM squat, thigh CSA (circumference surface area), CMJ (countermovement jump) and 15 m sprint. There was a significant interaction between pre/post tests and CSA ($p = 0.007$), with *post hoc* analysis revealing significant higher improvement in the ISOINERTIAL group (from 25.80 ± 6.99 cm² to 31.22 ± 6.83 cm²). There were no interactions from pre to post intervention ($p > 0.05$) in the 1RM squat, CMJ and 15m sprint. There was also no correlation ($p > 0.05$) between the performance (CMJ/15 m sprint) and morphological (CSA) or neurological (1RM squat) changes. The results of this study support results from other studies confirming that isoinertial training has a better impact on 15 m sprint and CMJ performance. However, this was only statistically significant in the CSA, and therefore we cannot conclude that one type of training is preferred over the other to improve speed and power over a short-term period.

KEY WORDS: Strength training, young, elite, athletic performance, neurological adaptations, morphological adaptations.

CHAPTER I

INTRODUCTION

Football is one of the world's most popular team sport amongst the young generation with more than 735 projects being held every year in developing the youth sector (18). Making it to the elite level demands the players to have a better level of speed and power when compared to sub-elite young players (43). In fact, studies have shown that there is a 0.12 s difference over a 15 m sprint (2.44 ± 0.07 s vs. 2.56 ± 0.12 s) and 5 cm difference in the standing vertical jump (55.80 ± 5.82 cm vs. 50.21 ± 7.58 cm) between elite and sub elite football players, confirming the key importance of speed and power (44). These differences become crucial in various situations of a match including: short sprints to gain possession of the ball, changing direction of movement, execute tackles, holding off players and also heading the ball during set pieces and free-kicks (43). One way of improving speed and power especially at youth elite level, is strength training (46). Due to its high level of dynamic correspondence in both the angles of force and the power produced at these angles, the squat exercise is one of the most common strength exercises utilized by many strength and conditioning coaches to improve the components of speed and power (26, 37, 53). Using different equipment, the same squat movement can be either an isotonic movement (barbell back squat) or an isoinertial movement (flywheel squat) (40).

Both types of movement (isotonic and isoinertial) have a positive impact on strength (8, 25, 50). Long-term isotonic training (60 to 80% of 1Repetition Maximum (RM)) improve the 1RM

squat to up to 123% in youth elite football players (46). Additionally, short-term studies following isotonic strength training also showed to have a positive impact of strength with participants displaying a 25% improvement in the 1RM squat (8, 50). Moreover, a short-term study (10 weeks – 3 sessions per week) comparing isotonic training with isoinertial training on a unilateral knee extension showed that the athletes who trained concentrically displayed a bigger improvement in the force produced during the 1RM squat (18.4%) than those who trained eccentrically (6.8%) even though both groups worked at the same load (10 reps x 3 sets) (25). However, subjects in this study used a kin-com dynamometer during their training which has a different movement plane when compared to the barbell squat and this might have effected the results of the 1RM squat (12). However, being a concentric contraction test of the quadricep muscle group, the barbell 1RM squat test seems to be more affected by isotonic training rather than by isoinertial training (25).

The component of speed, another key component in elite young football, is affected by both isotonic and isoinertial strength training (11). A long-term study (2 years) on 15 year old elite football players have found that isotonic training during the season contributes to a 4% improvement over 15 – 20 m sprints (46). On the other hand, isoinertial strength training over a shorter period done with 18 year old football players resulted in a 1.5% improvement over a 20 m sprint (ES: 0.32) (11). The difference in the sprinting time improvement may be due to the duration of the study and the age of the subjects. Apart from the higher neural adaptations expected, a longer-period of training results in better running mechanics and therefore a better improved time irrelevant from the type of strength training done (46). Also, the age of the subjects vary from one study to the other. While in the long-term study, the subjects (aged 15 years) were growing up at a fast rate and grew by 3% in their standing height by the end of the study, those in the short-term study (aged 18 years) were already at 96% of their adult height

during the study (11). This means that those in the long-term study experienced a bigger difference in their body size, and stride length, contributing to a higher improvement in their sprinting times when compared to those in the short-term study (46). In fact, when comparing both types of strength training (isotonic and isoinertial) over a short-term period, subjects (aged 22 years) in both groups displayed no group x time interaction in their 20m sprinting time improvement ($p > 0.05$) confirming that both types of strength training have a positive impact on speed with no significant difference between the 2 (12). Nonetheless, sprinting times can be influenced by various factors including weather conditions, ground surface and running technique (22). In fact, various studies combine speed testing with power testing through the countermovement jump (CMJ) in order to measure the improvement of the participants.

Isotonic strength training (barbell squat) at moderate intensity (45-65% of 1RM) has resulted in a 6.3% improvement in the CMJ performance while isoinertial strength training done at 3-6 reps x 6 sets has improved the CMJ performance by 7.6% (11, 49). The better power improvement following isoinertial strength training is due to an increase in the force generated in the quadricep muscle group during the eccentric contraction phase which is then transformed into elastic strain energy and released during the stretch shortening cycle (SSC) (30, 33, 51). In fact, various studies have shown a 74% improvement in power following isoinertial strength training (42, 53). This confirms that although both types of training have a positive impact on the CMJ performance, isoinertial training tends to be preferred as it displays the bigger improvement.

This improvement in athletic performance namely strength, speed and power comes about through neurological and morphological changes following both isotonic and isoinertial strength training. Through neurological changes, the athlete is allowed to fully recruit the

prime movers and coordinate better the movement therefore applying more force in the specific movement (24). On the otherhand, due to an increase in the type II muscle fiber size through strength training, the athlete is able to produce more force in his movements and therefore perform better (24). Studies have shown that isoinertial training done over a short-term period results in a significant 6.2% increase in the thigh CSA when compared to a 5% increase following isotonic training (25, 35, 40). This is because during an eccentric contraction, there is a higher mechanical tension and muscle micro lesions which result in an insulin-like growth factor in order to repair muscle damage and work as a key factor for hypertrophy (25). Therefore, isoinertial training has shown to provide a better stimulus than isotonic training and increases the effect of resistance training through morphological changes.

Research has also shown that through an increase in electromyography (EMG), especially following the initial phases of training, neural adaptations occur even before morphological changes and, therefore, an improvement in strength could be observed before an increase in muscle size (19, 24). Neurological changes through strength training allows for a higher peak and rate of force, and therefore higher muscle activation (46). In fact, studies have shown that isoinertial strength training over a short-term period done on adult male subjects results in a significantly higher ($p > 0.05$) muscle force and peak torque improvement of 29% during eccentric contraction when compared to a 19% increase during a concentric contraction when tested on an isokinetic dynamometer (16, 29). This neural drive, which is so important to the speed and power athlete, comes about through an increase in the motor unit firing rate which is highly dependent on the type of muscle contraction (19, 24). In fact, studies have shown that there is a 15% increase in motor unit firing rate after a short-term strength program consisting of eccentric overloading of the quadriceps muscle group (28, 52). The motor cortex and spinal cord inflow, where neurological changes occur, are also greater following an eccentric

contraction rather than after a concentric contraction (1, 15). This is due to the concurrent modulation of the Ia afferent input which is derived by the lengthening muscle in order to reduce stretch reflex and muscle damage (1, 15). Another reason is due to the mental planning needed to perform an eccentric contraction when compared to a concentric contraction, being a more complex movement (1, 15).

In view of these considerations, this study aims to compare the effect isotonic and isoinertial strength training have on speed and power over a short period of time during the in-season of youth elite football players. The results of these tests will be analysed through the difference in other components: Thigh CSA and 1RM squat, to investigate whether performance change (if any) is brought about through morphological or neurological changes. Furthermore, this study hopes to give a clearer idea to strength and conditioning coaches, the type of strength training ideal to develop the components of speed and power. It is hypothesised that over a short period of time, isoinertial strength training is preferred over isotonic strength training, as it has a better impact on actions involving speed and power and also on muscle size and strength.

CHAPTER II

METHODOLOGY

2.1 Experimental approach to the Problem

Using a controlled study design, 19 participants took part in a training intervention program as a supplement to their normal training. The Graphpad Software available online (22) was used to randomly assign the participants to either an ISOTONIC group (n=10) or an ISOINERTIAL group (n=9). Pre and post assessments were carried out to investigate the effect of the 2 different intervention programs. The training intervention consisted of one of the following exercises: ISOTONIC group trained using the back squat exercise, and the ISOINERTIAL group trained using the Flywheel Desmotec D11 machine.

The effect of the training intervention was assessed using both gym based and field-tests mostly relevant to football: speed and power (7). A familiarization session was done 1 week prior to the pre tests where subjects had the chance to get accustomed both with the experimental procedures: CMJ and 15 m sprint and also with the intervention procedures: barbell back squat and flywheel. The experimental procedures took place at the beginning of the second half of the competition season, on 2 different days with at least 48 hours interval between them. Both testing days took place in the morning (9.00 – 11.00 hrs) in an indoor facility on parquet wood surface and under similar conditions (temperature 20.0 ± 1.2 °C). Participants were asked to refrain from any physical activity for up to 48 hours prior each testing day and use the same running shoes throughout the whole study. They were also asked to avoid any food

consumption up to 2 hours prior testing but could sip on water prior and during the testing procedures. Participants were tested one at a time. Participants were instructed and shown each test and were verbally encouraged to give their best effort. Testing was initiated by a standardized 10 minute warm up following the RAMP protocol (27). Participants worked over a distance of 10m and started off with a light jog to raise the body temperature. Muscle activation through low knees, high knees, straight leg skip, A skip, B skip and back kicks was done followed by joint mobility exercises of the shoulders, hip, knees and ankles. Warm up was finished off by potentiating the lower limb muscles through calf jumping, lunges and high knee jumping. At the end, participants completed a few short sprints to prepare their body for maximal intensity.

The training intervention consisted of 2 training sessions per week over a period of 6 weeks. Each session was completed in the morning (10.00 hrs), during school hours, just before their football session consisting mainly of technical and tactical activities. All participants followed similar weekly schedules except for the intervention exercise (isotonic or isoinertial). The intervention program started 1 week after the pre testing and ended 1 week prior to the post testing procedures. All intervention sessions were supervised by a qualified strength and conditioning coach and the duration of each session for both groups was kept similar.

2.2 Subjects

19 elite male young football players were recruited to take part in this study. Table 1 shows their mean descriptive data. All subjects were biologically similar (92 ± 3 % of their adult height) based on the Khamis-Roche model (31). All subjects were part of the National football squad and attended the National Sport School in Malta. All subjects signed a written consent form while their parents (since they were all under 18) signed a written assent form after being

thoroughly explained the purpose and the potential risks of taking part in this study and explained that participation is on a voluntary basis and that all training and testing procedures will be conducted by qualified personnel and in line with the World Medical Association declaration of Helsinki (55). Approval by the Ethical subcommittee board at St Mary's University Twickenham was obtained. All participants had been training for at least 7 years and were training 4 times a week in the morning at school, 3 times a week in the evening with their respective club and another 2 times a week with the National team in the evening. Each training session lasted 1.5 hours. All participants were injury free and involved in a competitive match once a week.

	ISOTONIC (n=10)	ISOINERTIAL (n=9)
Age (years)	15 ± 0.36	15 ± 0.51
Height (m)	1.68 ± 0.53	1.69 ± 0.35
Weight (kg)	58.7 ± 4.5	59.2 ± 5.60

Table 1. Mean anthropometric measures of the participants.

2.3 Testing Procedures

Testing day 1 started with the assessment of the subjects' body height and weight. The height was measured using an electronic stadiometer (Seca, Ontario, CA,) and the weight using digital weighing scales (ES200L; Ohaus Corporation, Pine Brook, NJ, USA). The height was taken to the nearest cm while the weight was taken to the nearest hundred of a kg. The cross sectional area (CSA) of the right thigh was also measured on testing day 1 together with the 1RM squat of the subjects. On testing day 2, subjects were tested on their CMJ and the 15 m sprint.

The CSA of the right thigh was found by measuring the circumference of the thigh at mid point (between the lateral condyle of the femur and greater trochanter) using a measuring tape and the subcutaneous adipose tissue of the same circumference point, both anterior (QAT) and posterior (HAT), using a skinfold calliper. The results were then put in the following formula: $\left[\frac{r-(QAT + HAT)}{2} \right]^2$ and the cross sectional area in cm^2 was calculated (4).

The back squat was the exercise used to determine the maximal strength of the subjects. Since they were not used to carrying heavy weights, the 1RM was measured indirectly by working on 5RM having a coefficient variation (CV) of 3% (20) and then multiplying the result by 1.2 to calculate the 1RM (21). Subjects were given verbal feedback by the researcher throughout. After warming up with a 20 kgs barbell, the researcher subjectively estimated the initial load and then progressed by 5 to 10 kgs initially and 2.5kgs when reaching their maximum until the 5RM max was obtained in less than 3 trials. Subjects failing to lift the 5th repetition were given a second chance before recording their result. Subjects were given a period of 3 to 5 minutes rest between each set. A squat was determined as a valid one when the subject's thigh was parallel to the ground without rounding of the trunk or without the heels rising off (22). These were assessed by the strength and conditioning coach conducting the test.

The lower limb explosive strength was measured by the countermovement jump (CMJ) using the infrared-light platform built into the OptoJump system (Microgate Next 2008, Bolzano, Italy). Having a CV of 3.4%, this is reliable way to measure the height of a CMJ (6). After warming up, the subjects were given 2 trials and 3 experimental trials and the best-recorded jump in centimetres (cms) was taken (38). Participants were asked to prepare for the jump by moving the knee extension down to a 90° flexion and then without pausing, jump as high as they could. Subjects were also asked to keep their hands on their hips to isolate the movement

of the CMJ and record solely the lower limb power. Subjects were given up to 90 seconds rest between each experimental trial.

The speed of the subjects was measured by the 15m sprint test using the dual-beam electronic timing gates (Race time 2 Light Radio System; Microgate, Bolzano, Italy) being a reliable piece of equipment to test speed with a CV of 1.3% (53). The electric gates that were placed 1.0m above the ground, were used to calculate the distance and record the running time of the subjects. Subjects were given 2 maximal sprint trials and the best recorded time in s was taken. They were asked to start from a 3-point start position and the starting point was standardized to -0.5 m from the starting gate. Participants were encouraged to run as fast as they could past the 2nd set of gates. 3 minutes of passive rest was given to each subject between the 2 trials.

2.4 Training intervention

All subjects in both the ISOTONIC and ISOINERTIAL groups performed the training exercise twice a week for a period of 6 weeks to a total of 12 sessions. The criteria for exclusion was set on missing 2 sessions throughout the 6 weeks. Each group had a specific protocol to follow as shown in Table 2. Working with 6-8RM has shown to improve both power and speed and, therefore, both exercises followed this principle as explained in the paragraphs below (9, 10).

ISOTONIC – Back squat (n = 10)	ISOINERTIAL – Flywheel (n=9)
Week 1 to 3: 3 x 8RM/ 2mins rec.	Week 1 to 6: 3 x 8/ 2mins rec.
Week 4 to 6: 3 x 6RM/ 1min rec.	

Table 2. Training interventions for both groups over the 6-week period.

ISOTONIC Group: Training consisted of 3 x 8RM back squat. This was changed to 3 x 6RM after 3 weeks. Participants were asked to descend in a controlled manner to a 90° angle in each squat and ascend from the squat as fast as they could.

ISOINERTIAL Group: Training consisted of 3 x 8reps on the flywheel Desmotec D11 machine for the whole duration of the program. Participants were asked to perform the squats with their hands on their hips. They were asked to ascend as fast as they could in each repetition but descend in a controlled manner. Good squatting style was maintained and reinforced throughout the whole program mainly: maintaining a flat back and chest up throughout the whole movement, flexion/extension of the hips, knees and ankles remains smoothly and constantly during descend and ascend, heels remain on the floor throughout and thighs come parallel to the ground at midpoint squat (22).

2.5 Statistical analysis

The analysis was performed using the IBM SPSS statistics 22. All values are expressed as means \pm standard deviation. Assessment to determine normality for all variables was performed using the Kolmogorov-Smirnov test. Comparisons between ISOTONIC and ISOINERTIAL groups were performed using factorial analysis of variance (ANOVA) (2 x 2 design, time x training intervention). Threshold values for Cohen's d statistics were > 0.2 (possibly), > 0.6 (likely), > 1.2 (very likely) and > 2.0 (very very likely) (47). Significant interactions were followed-up using *post hoc* tests with Bonferroni adjustments for multiple comparisons. In addition, correlations between changes in CMJ and 15 m sprint with changes in 1RM squat and CSA within the groups were calculated using the Pearson correlation coefficient. For all performances indices, p value of < 0.05 was taken as the level of significance.

CHAPTER III

RESULTS

There were no significant differences in the anthropometrical characteristics between the ISOTONIC and ISOINERTIAL groups ($p > 0.05$) (See Table 1). There were also no significant differences between the performance testing variables between the 2 groups at baseline ($p > 0.05$).

No significant group by time interaction was observed for the 1RM squat ($F_{1,17} = 3.45$; $p = 0.08$). However, comparisons within the groups showed a significant time effect (pre to post intervention) ($F_{1,17} = 128.56$; $p = 0.00$) (See Table 3). Group effect between subjects was not significant ($F_{1,17} = 0.00$, $P = 0.99$).

The CSA results show a significant group by time interaction ($F_{1,17} = 9.39$; $p = 0.00$). Comparisons within the groups also showed a significant time effect ($F_{1,17} = 34.39$; $p = 0.00$). Though, there was no significant group effect between the subjects ($F_{1,17} = 0.94$; $p = 0.34$), *Post hoc* analysis revealed that there was a significant higher improvement in the ISOINERTIAL group when compared to the ISOTONIC group ($p = 0.007$) (See Table 3).

The results of the CMJ testing for both groups as displayed in Table 3 show no significant group by time interaction ($F_{1,17} = 1.21$; $p = 0.29$). However, within-group comparisons showed a significant time effect from pre to post training intervention ($F_{1,17} = 50.58$; $p = 0.00$). No significant group effect was revealed ($F_{1,17} = 0.06$; $p = 0.81$).

VARIABLE	ISOTONIC (N=10)				ISOINERTIAL (N=9)			
	Pre	Post	Cohen's d	Qualitative Assessment	Pre	Post	Cohen's d	Qualitative Assessment
CSA	30.58 ± 5.72	32.28 ± 7.18	0.26	Possibly	25.80 ± 6.99	31.22 ± 6.83 **	0.78	Likely
1RM SQUAT	87.90 ± 12.25	107.85 ± 14.39	1.49	Very likely	90.67 ± 14.21	105.00 ± 18.73	0.86	Likely
CMJ	35.32 ± 4.75	37.11 ± 5.19	0.36	Possibly	34.41 ± 5.37	36.86 ± 5.11	0.46	Possibly
15 M SPRINT	2.62 ± 0.09	2.42 ± 0.06	2.6	Very very likely	2.57 ± 0.14	2.34 ± 0.22	1.25	Very Likely

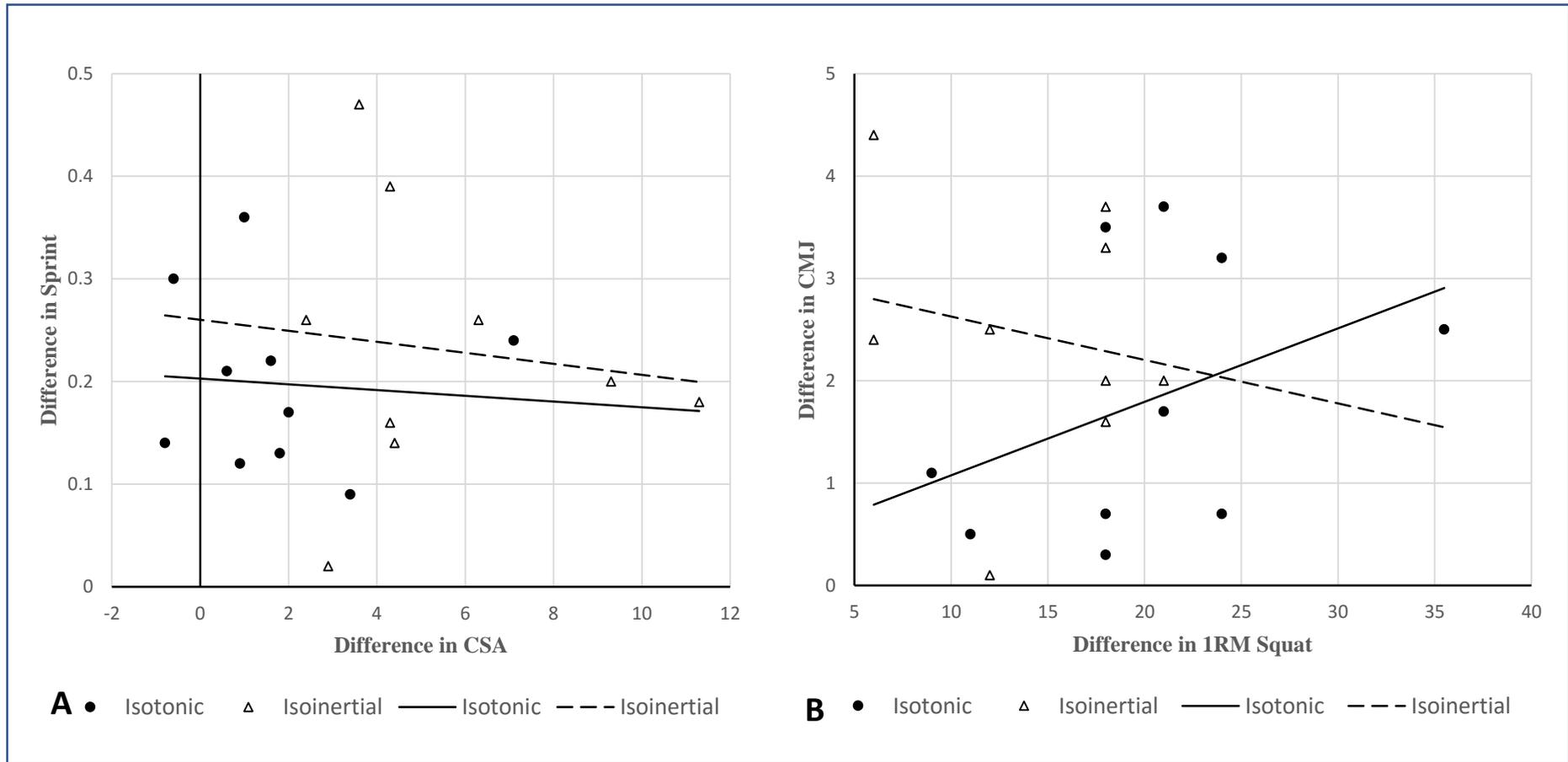
Table 3: Performances indices of the CSA, 1RM squat, CMJ and 15m sprint of the 2 experimental groups at baseline (pre-intervention) and after the training intervention (post-intervention). Asterix (*) indicate significant difference ($p < 0.05$) in the CSA from Pre to Post intervention between the 2 groups

The group by time interaction for the 15m sprint was also not significant ($F_{1,17} = 70.26$; $p = 0.53$). Yet, time effect within-groups was shown to be significant ($F_{1,17} = 70.26$, $p = 0.00$) while the group effect between the subjects was also not significant ($F_{1,17} = 1.04$; $p = 0.32$). The results for both groups from pre to post-training intervention are displayed in Table 5.

There is a very weak non significant negative relationship between the difference in sprinting time and the difference in the CSA for both the ISOTONIC and ISOINERTIAL groups (See Figure 1A). On the other hand, a weak positive relationship is observed between the sprinting time and the 1RM squat for both the ISOTONIC and ISOINERTIAL groups (See Table 4). However, since both p values exceed the 0.05 level of significance, these relationships are also not significant.

		Difference in Squat
Diff. in sprint time (ISOTONIC)	Pearson Correlation	0.010
	P-value (1-tailed)	0.977
Diff. in sprint time (ISOINERTIAL)	Pearson Correlation	0.306
	P-value (1-tailed)	0.424

Table 4: The Pearson correlation of sprint time in relation to the difference in 1RM squat from pre to post intervention for the 2 groups (ISOTONIC and ISOINERTIAL) .



When comparing the difference in the CMJ performance and the difference in the CSA results from pre to post intervention, one can notice that for the ISOTONIC group there is a weak positive relationship while for the ISOINERTIAL group there is a weak negative relationship (See Table 5). Nonetheless, all p values exceed the 0.05 level of significance meaning that the relationships are not significant.

		Difference in CSA
Diff. in CMJ (ISOTONIC)	Pearson Correlation	0.191
	P-value (1-tailed)	0.597
Diff. in CMJ (ISOINERTIAL)	Pearson Correlation	-0.116
	P-value (1-tailed)	0.766

Table 5: The Pearson correlation of the CMJ in relation to the difference in C.S.A. from pre to post intervention for the 2 groups (ISOTONIC and ISOINERTIAL).

A weak positive relationship can be observed between the mean score differences of the CMJ and the 1RM squat from the pre to post assessment in the ISOTONIC group (See Figure 1B). On the other hand, there is a weak negative relationship between the CMJ and 1RM squat in the ISOINERTIAL group (See Figure 1B). However, both relationships are not significant as the p values exceed the 0.05 level of significance.

CHAPTER IV

DISCUSSION

This study compared the effect of short-term ISOTONIC vs. ISOINERTIAL strength training on 1RM squat, CSA, 15 m sprint and CMJ in elite young football players. It also aimed to investigate whether there is a relationship between improvement in the 15 m sprint/CMJ and the 1RM squat/CSA. Results have shown that the only significant improvement between the two groups was displayed in the thigh CSA with the ISOINERTIAL group improving more than the ISOTONIC group.

Being a concentric contraction test of the quadriceps muscle group, the 1RM squat is expected to be more effected by isotonic training than by isoinertial strength training (25). In fact, long duration studies (2 years) have shown an improvement of $123 \pm 38.5\%$ in the 1RM squat following isotonic strength training (46) while short-term studies done on football players (aged 17 – 19 years) showed improvement of 25% on the 1RM squat following isotonic training (8, 49). The improvement displayed by the ISOTONIC group in this study compares very well with that shown in short-term studies (22.6%), however, it differs drastically when compared with longer studies. This is because a longer strength training program, allows better improved neural adaptations which increase specific tension and, therefore, a better improvement in the 1RM squat result (25). Meanwhile, isoinertial strength training over a short-period done with adults showed a significant improvement of 25% in the 1RM squat (17). This differs from that found in this study where the ISOINERTIAL group displayed a 16.5% improvement in their 1RM squat. This difference can be explained through the age difference of the participants

since studies have shown that adults tend to have a higher muscle activation when compared to adolescent persons (3) and also a higher motor neuron activation (5, 41, 46). Moreover, the participants in the ISOINERTIAL group complained of pain in their upper back where the bar was resting during the 1RM squat test as they were not used to it. This might have interfered with the loading they were comfortable of putting on their backs.

Due to a greater mechanical tension in the muscle fibres, isoinertial training has shown to have a bigger impact on the thigh CSA when compared to isotonic training (25). In fact, various studies have displayed double the improvement in muscle hypertrophy following isoinertial training when compared with isotonic strength training, however, no study had such a considerable improvement as that shown in this study where the ISOINERTIAL group improved significantly more than the ISOTONIC group (21% vs 5%). This could be due to the different gender and age of the participants. One study focused on adult women rather than male youths (25) and therefore, the anabolic hormone (testosterone) responsible for muscle growth was much less when compared with male youths (34). Another reason could be the gravitational issue as other studies (12, 25, 40) have used a gravity independent flywheel mechanism rather than a gravity dependent flywheel squat. Moreover, results from studies working with an isotonic exercise showed an improvement similar to this study (3% and 5%) (14, 25). Therefore, the results obtained here are similar to those obtained in other studies and it confirms that isoinertial strength training is preferred to isotonic strength training for muscle hypertrophy.

Although sprinting can be influenced by various weather factors and running technique, studies have shown that both isotonic and isoinertial strength training have a similar impact on speed with no significant difference between the two (12, 46). In fact, this was confirmed in this study

where both groups (ISOTONIC and ISOINERTIAL) obtained similar improvement in the 15m sprint (7% vs 8%). However, these results differ considerably with those found in another study where those working isotonicly showed an improvement of 5.23% and those working isoinertially obtained an improvement of 3.4% (12). The difference in the results could be due to the age difference of the participants (adolescents vs adults). Following resistance training, adolescent persons can experience up to 14.2% improvement in anaerobic power (45) when compared to 12% in adults (39). Therefore, the difference in the improvement between the two studies is justified. Another short-term study done on young elite football players using the barbell back squat showed a 5.5% improvement over a 10m sprint (33). However, this study was done during the Pre-season period where athletes are highly loaded with training and emphasis is more on strength rather than power. Also, less focus is given to speed and sprinting mechanics during the pre season when compared to the in season and hence the difference in the percentage improvement (13). Comparing this study's results with previous studies, one can state that the findings are similar and that both isotonic and isoinertial strength training have a positive effect on speed with no significant difference between the two.

Through a better elastic strain energy stored, isoinertial strength training has a better effect on CMJ than isotonic strength training (30, 32, 32). Although, results in this study showed no significant differences in the CMJ improvement between the 2 groups (ISOINERTIAL – 7%, ISOTONIC – 5%), the improvements obtained are very similar to those obtained in other studies. In fact, other short term studies working isotonicly at moderate intensity (45-65% of 1RM) showed an improvement of 4.4% in the CMJ (33, 37). Moreover, De Hoyo et al. (13) showed a 7.6% improvement in the CMJ by U17 football players following isoinertial strength training, which is rather the same as that found in this study. This confirms that even though group by time comparisons showed no significant differences, isoinertial training has shown to

have a better effect on the CMJ performance due to the greater force generated in the quadriceps muscle group which is transformed into elastic strain energy and released during the SSC (30, 33, 51).

Analysing the relationship between the improvement in the 15 m sprint and CMJ of the ISOTONIC group in comparison to the improvement in the 1RM squat and CSA, one can conclude that both the 15 m sprint and CMJ improvement came about through neurological adaptations (1RM squat) ($r = 0.399$) rather than through morphological changes (CSA) ($r = 0.191$). In fact, this positive correlation between sprinting/jumping and 1RM squat was also confirmed by Mc Bride et al. (36) where participants had a 0.544 correlation between sprinting time and 1RM squat. This is because through the improved neurological pathways, the participant is able to fully activate his prime movers and improve the coordination of the activated muscles needed during high force production activities such as sprinting and jumping (45). However, the relationship in this study is not statistically significant and this could be due to the small sample size.

The results for the ISOINERTIAL group show that there is a positive correlation between the improvement in the 15 m sprint and the improvement in the (1RM squat) ($r = 0.306$). This shows that the improvement in speed came about through neurological changes rather than morphological changes as studies have shown that after a short-term strength training program, the neurological changes are bigger than morphological changes during eccentric contraction due to a bigger muscle force produced (24). Moreover, since neural adaptations happen before morphological changes, there is a higher muscle recruitment and firing rate during high intensity muscle contractions such as during sprinting (19). On the other hand, the improvement in the CMJ came about through an improvement in the CSA (morphological changes) ($r =$

0.63). This correlation is in line with a study by Secomb et al. (48) where they found a correlation of 0.46 - 0.73 between the vastus lateralis muscle group and the peak force during CMJ in a group of 30 junior participants. This correlation confirms that there is a positive relationship between muscle thickness and dynamic strength. However, even for this group, both relationships are very weak and not statistically significant.

There were some limitations to this study. Primarily, the sample size was small and this has effected the results as most findings would have been statistically significant with a bigger sample and therefore better conclusions on which type of training (isotonic or isoinertial) is ideal to improve the components of speed and power. Furthermore, a longer study would have produced more solid results due to the induced adaptive potential produced with long term strength training especially at the age of the subjects (46). Lastly, increasing the number of exercises for each training group rather than limiting them to 1 strength exercise would have produced clearer results.

PRACTICAL IMPLICATIONS

Considering the difference in the amount of studies done on isotonic training when compared to isoinertial strength training, it is evident that further research on the benefits of isoinertial strength training especially on the younger generation is required. This study has showed that the only significant benefit isoinertial strength training has on isotonic strength training is hypertrophy. Although the ISOINERTIAL group did better in the CMJ and 15 m sprint following 6 weeks of training and the ISOTONIC group did better in the 1RM squat, the improvements made between the groups were not significant and, therefore, we cannot conclude that one type of training is better than the other one. Furthermore, since correlations between performance (CMJ and 15m sprint) and neurological/morphological changes (CSA

and 1RM squat) were not significant between the groups, we also cannot conclude that a particular group improved its performance through neurological or morphological changes. However, having a bigger sample and a longer intervention program might have led to more significant results.

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APPENDICES

Appendix 1:

Ethics Approval sheet



St Mary's
University
Twickenham
London

3 January 2017

Unique Ref: SMEC_2016-17_045

Angie Mangion (SHAS): "The effect of short term in season isotonic vs isoinertial strength training on speed and power in youth elite soccer players".

Dear Angie

University Ethics Sub-Committee

Thank you for submitting your ethics application for the above research.

I can confirm that your application has been considered by the Ethics Sub-Committee and that ethical approval is granted.

Yours sincerely

A handwritten signature in black ink, appearing to read 'Conor Gissane'.

Prof Conor Gissane
Chair of the Ethics Sub-Committee

Cc Stephen Patterson

Appendix 2:

Information sheet

A research project investigating the effect of short-term in season isotonic vs isoinertial strength training on speed and power in youth elite soccer players.

Introduction

I would like to invite you to participate in this project, which is concerned with the effect short term isotonic and isoinertial strength training has on speed and power.

Why am I doing the project?

The project is part of my final year for my Masters degree course at St Mary's University College, Twickenham, London. It is hoped that this project could provide further knowledge to strength and conditioning coaches and soccer coaches alike, the ideal quadriceps strength training exercise in order to improve speed and power during the soccer season.

What will you have to do if you agree to take part?

Return the consent form and parental consent form to me in the envelope provided so that I know you are interested.

1. I will let you know the date when the research will start and the group you will form part of for the intervention program.

2. You will be asked to present yourself for testing on 2 different days in the same week. After that you will start the intervention program which will be held twice a week during school hours (isotonic – back squat or isoinertial – flywheel). After the 6th week of training, you will be asked to report for the 2nd bout of testing which will be held in the same week.

3. When I have completed the study I will produce a summary of the findings which I will be more than happy to send you if you are interested.

How much of your time will participation involve?

The total research will last 8 weeks. The table below explains exactly what will happen in each week.

Week number	Day	Test/training
1	Monday and Wednesday	Test day 1 and 2
2 to 7	Monday and Wednesday	Traning
8	Monday and Wednesday	Test day 1 and 2

Will your participation in the project remain confidential?

If you agree to take part, your name will not be recorded on the test results and the information will not be disclosed to other parties. Your results will be used for the purpose of this project only. You can be assured that if you take part in the project you will remain anonymous.

What are the advantages of taking part?

Apart from gaining knowledge on how to perform a squat, it also helps you make improvements in speed and power. Once the study is finished, it will provide a better idea on the type of strength training exercise ideal in order to become faster and more powerful during the soccer season.

Are there any disadvantages of taking part?

If guidelines provided by me are followed, there will be no distadvantages of taking part in this study.

Do you have to take part in the study?

No, your participation in this project is entirely voluntary. You are not obliged to take part, you have been approached as one of the U17 soccer players at the National Spors School, Pembroke

Malta. However, this does not mean that you have to take part. If you do not wish to take part you do not have to give a reason and you will not be contacted again. Similarly, if you do agree to participate you are free to withdraw at any time during the project if you change our mind.

What happens now?

If you are interested in taking part in the study you are asked to complete the attached consent forms and return them to me in the envelope provided. Once I have received the forms, I will let you know the start of the research. You will then need to present yourself at school for testing during school hours. No lessons will be missed for testing or training. All tests and training will be done during the mainsport sessions at school. If you decide you would rather not participate in this study you need to return the bottom part of the consent form stating that you do not wish to participate in this study.

Researcher: Angie Mangion

Postgraduate student, St Mary's University College Twickenham, London

Supervisor: Dr Stephen Patterson

Senior lecturer – Sport Science

Sport, Health and Applied Science

Appendix 3:

Participant Consent Form



St Mary's
University
Twickenham
London

Name of Participant: _____

Title of the project: The effect of short term in season isotonic vs isoinertial strength training on speed and power in youth elite soccer players.

Main investigator and contact details: Angie Mangion Email: angiemangion@gmail.com

Members of the research team:

1. I agree to take part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I provide will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant (print).....

Signed.....

Date.....

If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.

Title of Project: _____

I WISH TO WITHDRAW FROM THIS STUDY

Name: _____

Appendix 4:

Parental Consent Form



**St Mary's
University
Twickenham
London**

Name of Participant: _____

Title of the project: The effect of short term in season isotonic vs isoinertial strength training on speed and power in youth elite soccer players.

Main investigator and contact details: Angie Mangion Email: angiemangion@gmail.com

Members of the research team:

1. I agree to my child taking part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my child's role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw my child from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I and my child provides will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I and my child have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of parent (print).....

Signed.....

Date.....

If you wish to withdraw your child from the research, please complete the form below and return to the main investigator named above.

Title of Project: _____

I WISH TO WITHDRAW MY CHILD FROM THIS STUDY

Name of Participant: _____

Name of Parent _____

Appendix 5:

Participant Personal Details Application Form



The effect of short term in season isotonic vs isoinertial strength training on speed in youth elite soccer players.

Researcher: Angie Mangion

Fill up Form

Personal information

Name and Surname: _____

Age: _____ Years _____ months

Date of birth: _____

Training

Name of registered club: _____

Years of training: _____

Are you in the National Team? ___ Yes ___ No

Number of training sessions per week: _____ National Team
_____ Club level

Duration of each session: _____

Currently following a strength program? ___ Yes ___ No

Injuries

Have you had any injuries in the past year? ___ Yes ___ No. If yes,

Injury type: _____

Duration of injury: _____

Are you back to full training now: ___ Yes ___ No