An Investigation into the Relationship
between the Reactive Strength Index
and Change-of-Direction Speed for
Soccer, GAA, and Rugby Union Players

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Submission Date: 26th April 2013
Submitted in part fulfilment of the requirements for the B.Sc. in Sports and Exercise Sciences at the University of Limerick
An Investigation into the Relationship between the Reactive Strength Index and Change-of-Direction Speed for Soccer, GAA, and Rugby Union Players


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Abstract

The ability to change direction while sprinting is considered to be crucial for successful performance in field-based team sports (Brughelli et al. 2008). Lower extremity power measures and jump tests have been used to predict change-of-direction (COD) ability. Measures of reactive strength are suggested to have a stronger relationship with COD speed than traditional strength and power measures due to the similarity of the stretch shortening cycle (SSC) component of the movement (Sheppard and Young 2006). The aim of this study was to investigate the relationship between bilateral reactive strength and COD ability for Soccer, Rugby Union and GAA players. Thirty-eight male subjects aged 20.4 ±5.8 years, and mass 76.9 ±14.3 kg, were recruited to participate in the study. COD ability was assessed using three trials of the L-run drill, sprint times were recorded using dual-beam electronic timing gates. Bilateral reactive strength was evaluated using a drop jump (DJ) from a dropping height of 0.3m, reactive strength index (RSI) was calculated with the Microgate Optojump optical measuring device. A Pearson correlation coefficient and 1-way ANOVA statistical analysis were performed. Results found a weak negative relationship (r = -0.110) between RSI and CODS. Statistically significant (p<0.05) differences were found between both the Soccer and Rugby Union group, and the GAA and Rugby Union group for CODS. No significant differences were found between the groups for RSI. It was concluded that bilateral reactive strength measures are poor predictors of COD ability. Investigation into unilateral reactive strength measures in both the lateral and forward direction is recommended for future research.

Key Words: Change-of-direction speed, COD, Reactive Strength, Reactive Strength Index, RSI, Drop Jump, Optojump, Soccer, GAA, Rugby Union


Declaration

I hereby declare that the work contained in this thesis is my own and was completed without collaboration or assistance, other than the counsel of my supervisor Dr Ian Kenny of the Physical Education and Sports Sciences Department, University of Limerick.

Signed: ___________________________  Date: ________________
Dedication

To my parents John and Carol, and also my fiancée Valerie who supported and encouraged me every step of the way. I couldn’t have done it on my own.

Thank You 😊.
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1.0 INTRODUCTION

1.1 Background
Change of direction speed (CODS) is one the underpinning components of agility performance (Cardinale et al 2011). In field based team sports, players perform high intensity running with changes of direction, and rapid acceleration and deceleration throughout the game. CODS differs from agility in that it does not involve a perceptual or decision making component, but it is a highly trainable closed skill that includes a rapid, whole-body change of direction or speed (Brughelli et al 2008). It has been argued that CODS ability is a determinant for successful participation in team sports. Such arguments are supported by studies in the literature that found that CODS ability can differentiate between soccer players of elite and amateur status (Reilly et al 2000). It is also used as a talent identification tool by coaches and scouts in the NFL Combine to assess players potential to succeed at professional level, statistically significant differences have been found between drafted and non-drafted players on CODS scores (Sierer et al 2008).

![Deterministic Model of CODS Performance, Young et al (2002)](image)

CODS ability is influenced by many factors, namely technique, leg muscle qualities such as strength and power capacity, and straight sprinting speed. Reactive strength is a component of leg muscle qualities, and is the ability to reverse eccentric muscle contraction into concentric muscle contraction. This eccentric-concentric muscle action is pertinent to change of direction performance, as the player must first apply an
eccentric force to decelerate before executing a concentric action to accelerate the body in a new direction (Gamble 2010). Thus, it is suggested that reactive strength measures may have a stronger relationship with change of direction performance than traditional strength and power measures, and targeted training interventions to enhance reactive strength may have the potential to enhance CODS (Young and Farrow 2006).

1.2 Aims of the Research
The aims of the study were:

- To investigate the strength of the relationship, if any existed, between reactive strength and CODS performance.
- To determine if any differences existed between reactive strength and CODS performance among players of different field based sports, Soccer, Rugby Union, and GAA.

1.3 Hypotheses

1.3.1 Null Hypothesis ($H_0$)
- No relationship exists between reactive strength and CODS performance.
- There is no difference between reactive strength and CODS performance among players of Soccer, Rugby Union, and GAA.

1.3.2 Alternative Hypothesis ($H_a$)
- A significant relationship exists between reactive strength and CODS performance.
- A significant difference exists between reactive strength and CODS performance among players of Soccer, Rugby, and GAA.

2.0 LITERATURE REVIEW

2.1 Introduction
The purpose of this review was to investigate the relevant literature in relation to CODS performance, and identify consistencies, contradictions, and gaps from the studies in this area. The review was structured around the main recurring themes noted from the accessible research papers. The electronic databases of Academic Search Complete, Cinahl, Medline, SPORTDiscus, Google Scholar, Journal of Strength & Conditioning Research, PubMed, and T & F Online were searched for peer reviewed articles written in the English language between the years of 1985-2013. The following key terms were

2.2 Straight Sprinting Speed and COD Performance

Straight sprinting speed is considered a determinant of CODS according to deterministic model of Young et al (2002). It is widely accepted that CODS ability is dependent on fast movement, but correlation studies into the relationship between straight sprinting speed and CODS have reported poor to moderate relationships. If straight sprinting speed is a true determinant of CODS then training to improve CODS should also improve straight sprinting speed, and vice versa.

2.2.1 Correlation Studies

The majority of studies between straight sprinting speed and CODS found moderate correlations ($r = 0.3 - 0.5$) (Brughelli et al 2008). Buttifant et al (1995) compared soccer players on a CODS test involving four COD over 20 metres, with performance on a 20 metre sprint test, and reported a moderate correlation ($r = 0.33$) between the tests. Comparable results ($r = 0.346$) were found in a study by Little and Williams (2005) on 106 professional soccer players when they investigated the strength of the association between 10 metre sprint times and a 20 metre zig-zag CODS test involving three 100° changes of direction. Both of the preceding studies employed similar methods and protocols, sprint and COD times were recorded using electronic timing gates, tests were completed in the same order, but Buttifant and colleagues (1995) performed their testing on grass with subjects wearing football boots in order to assure greater ecological validity, whereas Little and Williams (2005) conducted their testing indoors on a synthetic surface. Similar empirical research by Baker (1999a) and Young et al (1996) displayed consistent results, leading the authors to conclude that straight sprinting speed and CODS are distinct physical qualities. In their review on agility in 2006, Sheppard and Young declared that the strength of the relationship between straight sprinting speed and CODS reduces with an increase in the number of COD. This does not appear to be true, studies involving 1 COD carried out by Draper and Lancaster (1985) displayed correlations of $r = 0.055$, and $r = 0.495$ respectively, studies of 3 COD ($r = 0.346$) by Little and Williams (2005), and studies of 4 COD ($r = 0.55$) (Pauloe et al 2000) contradict the conclusion of Sheppard and Young (2006). These studies display low to moderate correlations regardless of the number of direction changes. The range of sprinting distances and number of COD applied in the various studies were chosen based on notational analysis and time-motion studies of the
movement demands of the sport in question, Section 2.5 covers this topic in more
detail.

2.2.2 Training Studies
Two studies examined the transferability of sprint training to COD performance and
displayed contrasting results. Both used recreationally trained athletes. In the study by
Young et al (2001), 36 subjects were randomly assigned to either a sprint training
group, or COD training group. The subjects completed 2 sessions per week of 5-8
sprints over 6 weeks. At the end of the study, the sprint group showed significant
improvements (p<0.05) in sprint times (3% time reduction) but not COD times, and the
COD group significantly improved COD times (p<0.05) but not sprint times.

In a related study by Markovic et al (2007), a similar protocol was followed, but a
greater volume of training was carried out over a longer period of 10 weeks, with a total
of 30 sessions of 9-12 sprints. 30 subjects were assigned to either a sprint training
group, plyometric training group, or control group. At the end of the 10 weeks the sprint
training group significantly improved sprint times (3.1%), and also showed a significant
improvement in COD times (4.3%). This contradicts the work of Young et al (2001) who
concluded that straight sprinting and COD performance were separate qualities and
should be trained as such, and this is an area that warrants more research in well
trained athletes.

2.3 Leg Muscle Qualities and COD Performance
Leg strength, power, and reactive strength are qualities that are said to influence COD
performance. COD actions are characterised by a rapid deceleration during which the
knee and hip extensor muscles are subjected to high eccentric forces with unilateral leg
force expression exceeding 2000 Newtons (Simonsen et al 2000), closely followed by a
concentric contraction of the same muscle groups to accelerate the body in the new
direction. This eccentric-concentric action invokes the stretch-shortening cycle (SSC)
leading to the generation and application of high forces, and highlights the need for
high levels of lower limb strength for successful COD performance. As such,
quantification of the association between measures of leg muscle qualities and CODS
is necessary to enable researchers and coaches to prioritize the key performance
elements in order to optimize training program design.
2.3.1 CODS and Leg Muscle Strength and Power

Maximum strength and explosive power are considered to be key factors in enabling the athlete to overcome their own inertia and generate high velocity movements and COD (Gamble 2010). Increasing the force generating capacity of the muscles through traditional isoinertial strength training is thought to improve acceleration and high velocity COD performance on the field of play (Cronin and Hansen 2006). There is a distinct lack of research investigating maximal strength and CODS. A study by Markovic (2007) on 76 male PE students, correlated measures of leg extensor strength and power (1RM squat and squat jump), with performance on 3 different CODS tests. He found weak correlations ($r = -0.17$ to $-0.31$) and concluded that maximal leg extensor strength and power measures are poor predictors of CODS in young physically active men. These findings were consistent with previous research by Petersen and Colleagues in 2006 who examined lower body muscular strength (1RM squat) with performance on the T-Test for 54 male and female intercollegiate athletes. Petersen found correlations of $r = -0.169$ for males and $r = -0.408$ for females which corroborated the results of Markovic (2007). Further research is desirable however in order to substantiate the findings of these two studies.

Vertical jump height was the most commonly used measure of leg power in the literature. Studies of bilateral leg power and CODS consistently reported small to moderate correlations ($r = -0.01$ to $-0.49$). Young and colleagues (1996) investigated the relationship between a CMJ loaded with an external resistance of 50% of the subjects bodyweight, and performance on a 20 meter CODS test, and found a correlation of $r = 0.01$. They concluded that the external resistance was too great and represented a measure of strength rather than power, and repeated the experiment with an unloaded CMJ, observing a correlation of $r = -0.10$. A study into the relationship between hang power clean scores and CODS for professional Australian Rules Football Players were similarly unrelated (Hori et al 2008). It was found that hang power clean scores were more strongly related to CMJ height and 20 meter sprint ($r = 0.51$ and $r = -0.57$), than CODS ($r = -0.34$). It is apparent that the principle of specificity must be adhered to when training and testing for CODS performance. Bilateral sagittal plane power measures have proven to be poor predictors of CODS. Side-stepping cutting movements are the main characteristic of COD performance in team sports. These movements are generated primarily by medial-lateral rather than vertical ground reaction forces, and it is important to investigate whether strength and power measures in frontal plane movements might be better associated with CODS (Gamble 2010). No studies were found that investigated strength and power measures in the frontal plane,
and very few studies have been undertaken that explore the relationship between leg power measures from horizontal jumps for distance, and CODS. Such tests instinctively appear more specific to COD performance due to the direction of force application both horizontally and vertically, which closely resembles most running movements (Brughelli et al. 2008). Conflicting results have emerged from the studies carried out in this area. Markovic (2007) reported small correlations (r = -0.12 to -0.27) between bilateral broad jump and COD performance. Whereas, Petersen and colleagues (2006) found significant moderate and strong correlations for males (r = -0.613) and females (r = -0.713) when assessed on bilateral broad jump and COD performance. Similarly, Negrete and Brophy (2000) assessed unilateral broad jump distance and COD performance and reported a correlation of r = -0.65, however it must be noted that in this study the results of both males and females were pooled together and this may have affected the reliability of the results. Given these preliminary findings, it appears that horizontal jump scores are more strongly related to COD performance than vertical jump scores, and additional research with more robust study designs needs to be conducted to further our knowledge in this area.

2.4 Reactive Strength and COD Performance

Reactive strength tests and COD performance are expected to be strongly correlated due to the similarities of both actions to activate SSC mechanisms within the muscle which store elastic energy that can be subsequently utilized during the concentric action to maximise force production in a minimal amount of time (Ball and Zanetti 2012). Reactive strength is most commonly assessed using the drop jump, and measured with a contact mat or force plate (Cardinale et al 2011). This requires the athlete to step off a box, minimize ground contact time, and then jump for maximal height. The level of reactive strength is calculated using the reactive strength index (RSI) and is a measure of the amount of force generated and the time it takes to do so, it is calculated by the height jumped divided by the ground contact time.

\[
\text{Reactive Strength Index (RSI) = \frac{\text{Jump Height (m)}}{\text{Contact Time (sec)}}}
\]

Equation 2.4 - Reactive Strength Index

2.4.1 Bilateral/Unilateral Reactive Strength and CODS

Bilateral and Unilateral reactive strength measures have been said to assess different elements of SSC performance due to differences in ground contact times. Fast SSC actions (ground contact times of 100-250 ms) as commonly seen in the bilateral drop jump closely resemble the ground contact times associated with maximum velocity
running, whereas the slow SSC actions of the unilateral drop jump (250-500 ms) are likely to be better related to COD movements due to the longer foot contact times compared to sprinting (Gamble 2010, Schmidtbleicher et al 1992).

The association between bilateral drop jump and CODS has been investigated and researchers have been unable to come to a clear consensus on their findings. Djevalikian (1993) reported a statistically significant (P<0.05) association (r = 0.42) between bilateral depth jump and performance on a CODS test. These findings were supported by the moderate and significant (p<0.05) coefficients (r = -0.59) found for CODS and reactive strength by Young et al (2002), who concluded that the reactive strength of the leg extensor muscles were important for COD actions due to the similarity of the push-off actions required in both movements. More recently, Castillo-Rodriguez et al (2012) found statistically significant results similar to those of Young et al (2002) (p<0.001) (r = -0.48), but concluded that the drop jump was not an accurate predictor of COD performance because it was primarily a test of the ankle extensor muscles and did not sufficiently stress all of the muscles involved in hip and knee extension. In contrast to these statistically significant findings, research by Young et al (1996) found non-significant low correlations (r = 0.36) between CODS and drop jump performance.

Given that the cutting actions of COD movements are performed on one leg, it is surprising to note the scarcity of studies using unilateral drop jumps and COD tests. Only one study assessed these qualities (Young et al 2002), and found that differences in reactive strength between left and right legs influenced COD performance, with the subjects significantly slower when changing direction off the weaker leg. This highlights the requirement for specificity in testing and training, as Djevalikian (1993) found no significant differences in CODS off either leg when imbalances were found for concentric strength measures. Based on these findings, reactive strength appears to be a more accurate predictor of CODS than traditional strength and power measures, however more research is required in order to validate these claims.

2.5 CODS Assessment
CODS tests typically involve timed maximum effort sprints over a pre-planned course in order to measure the ability of the player to change direction rapidly. Many of the CODS tests have been specially designed to simulate the demands of the sport being assessed. The T-Test was most commonly used test observed from the literature, this test which involves backward running and side-shuffling, was designed specifically to replicate the movement demands of tennis, basketball, and volleyball (Cardinale et al
In order to identify or develop appropriate CODS tests for any sport, it is important to consult time-motion studies to classify the movement patterns and energy requirements that characterize the sport. Time-Motion analysis of field based team sports has revealed that 80%-90% of game time is spent in low to moderate intensity activity zones (Bloomfield et al. 2006), but that high intensity running activities were more likely determine the outcome of the game (Roberts et al. 2008). Soccer, Rugby Union, and GAA display similar movement demands, the majority of high intensity efforts last from 1-3 seconds, and cover distances of 1.8-17 meters (Dwyer and Gabbett 2012, Little and Williams 2005). Bloomfield and colleagues (2006) studied the movement demands of FA Premier League soccer players over the course of a full season. They found that 727 ± 203 changes of direction occurred during the course of play, with the majority of turns between 0°-90°, and approximately 90-100 turns of between 90°-180°. This data is consistent with findings from similar studies on other codes, Deutsch et al. (2007) studied the physical demands of elite rugby union and reported that high intensity COD running lasted between 2.5-3.1 seconds, and Reilly and Collins (2008) concluded that the demands of GAA and Soccer were similar, with high intensity bouts averaging 5.7 seconds.

Of the COD tests reported in the literature, only nine studies reported on the reliability of the tests. The reliability of the tests is important, especially for training studies to enable the researcher to determine whether the intervention has brought about meaningful change (Brughelli et al. 2000). Of these studies, the L-run and T-test were most commonly used. Gabbett (2006) found an intra-class correlation of 0.90, and a typical error of measurement of 2.8% for the L-run COD test. Similarly, McBride et al. (2002), described the T-test as having an intra-class correlation of 0.94, with a typical error of measurement of 2.09%, indicating that both tests are highly reliable. While both tests have proven to be reliable, the L-run is deemed more appropriate for measuring the demands of field sports due to its duration (~5-7 seconds) and utilization of 90° and 180° turns, which represent the movement demands that were observed in the time-motion studies (Brughelli et al. 2008).

### 2.6 Summary of the Literature

It can be concluded from the literature review that the factors that influence COD ability are not yet fully understood. There is a substantial body of evidence supporting the claim that straight sprinting speed and CODS are separate unrelated physical qualities, and should be trained as such. Measures of reactive strength have typically shown stronger correlations with CODS than traditional strength measures. Further research is warranted into these strength qualities, and should include jumps both bilaterally and
unilaterally in the horizontal and lateral direction. In terms of training studies, traditional sagittal plane strength and power exercises have not proven to be effective at eliciting improvements in CODS. COD movements occur largely in the frontal plane, and require rapid eccentric-concentric type muscle contractions. Future intervention studies should aim to address these movement demands. Finally, CODS tests should be chosen on the basis that they closely resemble the movement patterns, distances, durations, and bioenergetic demands of the sport as much as possible.

3.0 METHODOLOGY

3.1 Experimental Approach to the Problem

A cross-sectional study design was applied to determine the relationship between reactive strength and COD sprint performance. Competitive amateur GAA, Soccer, and Rugby Union players were assessed and compared on measures of reactive strength and CODS. Testing took place over three days and was conducted on location at team training sessions. Each subject completed the testing in one session. Reactive strength was evaluated using the drop jump from a height of 0.3 m. This height has been cited in previous studies measuring the same construct and has been deemed a safe height for well-trained athletes when tested in a non-fatigued state (Flanagan et al 2008, Flanagan and Comyns 2008). CODS was assessed using a 20 metre sprint with three pre-planned changes of direction (2 x 90° and 1 x 180°). The subjects performed three repetitions of each test and all trials were included for analysis. Drop jump scores were obtained using Microgate Optojump testing equipment and software, and CODS scores were attained using Microgate dual-beam electronic timing gates.

3.2 Subjects

Thirty-eight male subjects aged 20.4 ±5.8 years, and mass 76.9 ±14.3 kg, volunteered to participate in the study. All subjects were recruited from teams in the Limerick and Clare area and were active participants in competitive amateur leagues and championships. Subjects had a minimum of six years training and playing experience, consisting of no less than two 1-hour training sessions and one competitive fixture per week during competition season. Ethics approval was granted by the ethics committee of the faculty of Education and Health Sciences at the University of Limerick. All subjects/guardians were provided with an information sheet (see Appendix A1) outlining details of the study plus possible risks and benefits. The subject/guardian completed a pre-test questionnaire and signed an informed consent form prior to participating in the study (see Appendices A2 & A3).
3.3 Instrumentation

3.3.1 Jump Testing
Drop jump performance parameters were acquired using the Optojump optical measuring system (Microgate, Bolzano, Italy). The Optojump device consists of transmitter and receiver bars which are placed parallel on the floor. The bars communicate continuously through the light emitting diodes (LEDs) located on each bar. Any interruption of the signal between the two bars is detected by the system and the duration is calculated by the software. This makes it possible to determine contact time and flight time for the drop jump from which the reactive strength index (RSI) may be derived. Previous research has concluded that Optojump displays strong concurrent validity with an interclass correlation (ICC) of almost 1 ($r^2 = 0.997$) in comparison to force plate measures (Quattro Jump, Kistler, Winterthur, Switzerland). Test-retest reliability of Optojump displayed high interclass correlation ($r^2 = 0.985$) and low coefficient of variation (CV = 2.7%) (Glatthorn et al 2011), flight time and contact time measurements are deemed to be accurate to 1/1000 seconds.

3.3.2 CODS Testing
The CODS of the players was assessed using Microgate dual beam electronic timing gates (Polifemo, Microgate, Bolzano, Italy). The dual beam timing system has greater reliability over single beam systems in that both beams must be broken simultaneously to trigger the start/stop. Thus, false scores triggered by a leading arm or leg breaking a single beam are eliminated. CODS was measured to the nearest 1/100 seconds, and previous research utilising the same equipment found a low coefficient of variation (CV = 1.7%) and high interclass correlation (ICC = 0.91) (Garcia-Pallares et al 2011) deeming this equipment both valid and reliable.

3.4 Testing Protocol

3.4.1 Anthropometric Data
Anthropometric data were gathered prior to the assessment of RSI and CODS and the subjects’ age, mass, and height were recorded on the subject record sheet provided (see Appendix A4). Height was measured using Seca 217 standalone stadiometer and the value was recorded to the nearest 0.1 cm. Body mass was measured to the nearest 0.1 kg using a Seca 876 mobile flat scale.

3.4.2 Warm-Up
Prior to testing each group completed a 12-minute standardized warm-up which was based on the structure used by Meylan and colleagues (2009) and Sporis et al (2010).
but was tailored to meet the specific demands of the assessment. It was composed of a general warm-up lasting five minutes comprised of light jogging and skipping activities (see Appendix A5). This proceeded onto a series of dynamic stretches (leg swings, multidirectional lunges, squats, and single-leg Romanian deadlifts), which was then followed by a progression of acceleration/deceleration drills performed at gradually increasing intensities (2 x 10 metre sprints at 50%, 75%, and 100% of max speed), and concluded with a number of jumping and bounding activities. After the warm-up the subjects completed three warm-up trials for each assessment (Drop Jump and L-run).

3.4.3 Drop Jump
Correct drop jump technique was demonstrated and explained to all subjects prior to the assessment. The subjects were instructed to place their hands on their hips and to maintain this position at all times during the jump for control purposes (Walsh et al. 2004). Next, the subjects were directed to initiate the drop jump by rising up onto the toes of the supporting leg and to lean forward to take-off from the box. Upon ground contact the subjects were directed to minimize ground contact time and to jump vertically for maximum height while ensuring hip and knee flexion did not occur after leaving the ground. In order to help minimise ground contact time, verbal cues such as ‘imagine the ground is hot’, and ‘try to rebound off the ground’ were given. The testing protocol followed the procedures of previous work by Flanagan et al (2008). Three trials were performed with a one minute recovery period between each trial. Means, standard deviations, coefficient of variation, interquartile range, minimum, and maximum of the three trials were calculated for analysis.

3.4.4. L-run
CODS was assessed using the L-run CODS drill (see Appendix A6 for schematic diagram) and measured with Microgate dual-beam electronic timing gates (Polifemo, Microgate, Bolzano, Italy). Three agility poles were placed in the shape of an ‘L’ with the poles placed five metres apart. The 3-4-5 metre triangle method (see Appendix A6) was applied to ensure an exact 90° angle was present between the poles, this was measured independently by two different investigators in order to confirm accuracy. The running route was demonstrated to the subjects and they were instructed to complete the course as fast as possible without knocking over any of the poles. Testing procedures followed a similar protocol to that used by Sporis and colleagues (2010). Three trials were recorded and two minutes recovery was permitted between each trial to mitigate the effects of fatigue.
Figure 3.1 Drop jump testing set-up and assessment

Figure 3.2 Layout and running route of L-run CODS test
3.5 Statistical Analysis

IBM SPSS Version 20 for Windows was used to perform the statistical analysis. Standard statistical parameters (mean, standard deviation, coefficient of variance, and interquartile range) were calculated for each test. A Pearson's correlation was used to establish the strength of the relationship between RSI and CODS. Correlations of less than 0.1 indicate a very weak relationship, whereas correlations of 0.9 or above indicate a very strong relationship (0.1-0.3 = weak, 0.3-0.5 = moderate, 0.5-1 = strong) (Hopkins 2011). A one-way Analysis of Variance (ANOVA) was applied to compare the differences between the means of the groups (Soccer, Rugby Union, and GAA) for RSI and CODS measures. A Bonferroni post-hoc test was applied in order to correct against the chance of a systematic Type I error occurring.

4.0 RESULTS

4.1 Descriptive Statistics

The purpose of this study was to determine the strength of the relationship between reactive strength index (RSI) and change of direction speed (CODS) for Soccer, Rugby Union, and GAA players. Other variables of interest were Jump Height (cm) and Contact Time (sec). Table 4.1 shows the mean and standard deviation for age, mass, and height of the entire subject group (n=38), and also for each individual subgroup.

Table 4.1 Mean ± SD for Age, Mass, and Height

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yrs)</th>
<th>Mass (kg)</th>
<th>Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Subjects (n=38)</td>
<td>20.4 ± 5.8</td>
<td>76.9 ± 14.4</td>
<td>177.9 ± 6.9</td>
</tr>
<tr>
<td>Soccer (n=10)</td>
<td>15.8 ± 0.3</td>
<td>61.7 ± 4.9</td>
<td>172.2 ± 5.9</td>
</tr>
<tr>
<td>Rugby Union (n=16)</td>
<td>17.7 ± 0.8</td>
<td>80.3 ± 15.4</td>
<td>179.4 ± 6.8</td>
</tr>
<tr>
<td>GAA (n=12)</td>
<td>27.9 ± 4.7</td>
<td>84.9 ± 7.2</td>
<td>180.6 ± 5.2</td>
</tr>
</tbody>
</table>

Quantification of variability within the entire subject group for RSI, CODS, and Jump Height is outlined in Table 4.2. Absolute measures of variability are represented by the Min, Max, and Standard Deviation values. Normalized measures of variability are represented by the Coefficient of Variance and Interquartile Range.
Table 4.2 Mean ± SD, Minimum, Maximum, Interquartile Range, and Coefficient of Variation for RSI, CODS, and Jump Height, for all subjects.

<table>
<thead>
<tr>
<th>All Subjects (n=38)</th>
<th>RSI</th>
<th>Jump Height (m)</th>
<th>CODS (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>0.98 ± 0.28</td>
<td>0.25 ± 0.06</td>
<td>5.93 ± 0.34</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.21</td>
<td>0.05</td>
<td>5.42</td>
</tr>
<tr>
<td>Maximum</td>
<td>1.78</td>
<td>0.43</td>
<td>7.28</td>
</tr>
<tr>
<td>Interquartile Range</td>
<td>0.42</td>
<td>0.07</td>
<td>0.39</td>
</tr>
<tr>
<td>Coefficient of Variation (%)</td>
<td>29.1</td>
<td>24.6</td>
<td>5.8</td>
</tr>
</tbody>
</table>

4.2 Group Comparisons for RSI, CODS, Jump Height, and Contact Time

The results for comparisons between the means of the groups for RSI, CODS, Jump Height, and Contact Time are displayed graphically in Figure 4.1.

Figure 4.1 (a) Mean RSI scores, (b) Mean CODS scores, * = significant (p<0.05) differences between Soccer and Rugby Union, and GAA and Rugby Union, (c) Mean Jump Height Scores, (d) Mean Contact Time Scores
Figure 4.1 (a) shows the mean RSI scores for each group. As can be seen from the chart, the GAA group displayed the highest score (RSI =1.01), slightly higher than the Rugby Union group (RSI =0.99), and the Soccer group had the lowest score (RSI =0.92). However none of the differences were statistically significant. Figure 4.1 (b) compares the groups for CODS. Statistically significant differences (p<0.05) were found between both the Soccer and Rugby Union groups, and the GAA and Rugby Union groups, but no significant difference was found between the Soccer and GAA group. Figures 4.1 (c) and 4.1 (d) display the results for jump height and contact time respectively. While it can be seen from the graph that the GAA group displayed the highest scores for jump height there were no statistically significant findings between the groups. Similarly, for contact time the findings were not significant between the groups.

Tables 4.3 and 4.4 present the results of the statistical analysis for RSI and CODS for the subject groups. Statistically significant differences can be seen between both the Soccer and Rugby Union group, and the GAA and Rugby Union group for measures of CODS.

**Table 4.3 Statistical Analysis of RSI scores between groups**

<table>
<thead>
<tr>
<th></th>
<th>Soccer</th>
<th>Rugby Union</th>
<th>GAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soccer</td>
<td></td>
<td>p = 0.376</td>
<td>p = 0.568</td>
</tr>
<tr>
<td>Rugby Union</td>
<td>p = 0.376</td>
<td></td>
<td>p = 1.000</td>
</tr>
<tr>
<td>GAA</td>
<td>p = 0.568</td>
<td>p = 1.000</td>
<td></td>
</tr>
</tbody>
</table>

**Table 4.4 Statistical Analysis of CODS scores between groups**

<table>
<thead>
<tr>
<th></th>
<th>Soccer</th>
<th>Rugby Union</th>
<th>GAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soccer</td>
<td></td>
<td>p = 0.000 *</td>
<td>p = 1.000</td>
</tr>
<tr>
<td>Rugby Union</td>
<td>p = 0.000 *</td>
<td></td>
<td>p = 0.000 *</td>
</tr>
<tr>
<td>GAA</td>
<td>p = 1.000</td>
<td>p = 0.000 *</td>
<td></td>
</tr>
</tbody>
</table>

* = The mean difference is significant at p<0.05 level.

**4.3 Distribution of the Data for RSI and CODS**

Figure 4.2 shows a five point summary for the spread of the data for CODS. The minimum and maximum times are represented by the bars above and below the rectangle. The interquartile range where the middle 50% of the data lies is represented by the rectangle between the upper and lower quartile, and the median is represented...
by the line in the rectangle above the lower quartile. What is important to note are the outliers represented by the circles above the max value bars. These outliers were given special consideration in relation to the correlation analysis and were removed if they were $\pm 2$ standard deviations away from the mean.

Figure 4.2 Box Plot displaying the distribution of the data for CODS

Figure 4.3 provides a graphical representation of the spread of the data amongst all subjects for RSI scores. Similar to Fig 4.2, outliers are displayed both above and below the max and min whiskers. These outliers were removed were they found to be $\pm 2$ standard deviations from the mean.
4.4 Correlation Analysis

The results of the correlation analysis between RSI and CODS for the entire subject group are displayed in Figure 4.4. A Pearson's correlation coefficient ($r$) was applied to measure the strength of the association between RSI and CODS. The result of the analysis found a weak negative relationship ($r = -0.110$) between RSI and CODS. The resulting $x,y$ scatter plot diagram and best fit line is displayed below.

Fig 4.4 Relationship between RSI and CODS for the entire subject group
The results of the Pearson's correlation analysis for Soccer, Rugby Union, and GAA are displayed in Figure 4.5. The strongest negative relationship was found for the Soccer group ($r = -0.307$), and can be seen in Figure 4.5 (a). Similarly, the Rugby Union group, Fig 4.5 (b), also displayed a negative relationship albeit weaker than the Soccer group ($r = -0.146$). In contrast to both the Soccer and Rugby Union groups, the GAA group seen in Fig 4.5 (c), showed a weak positive relationship between RSI and CODS ($r = 0.220$).

5.0 DISCUSSION

5.1 Relationship between RSI and CODS

The main finding of the current study observed that a weak negative relationship ($r = -0.110$) exists between Reactive Strength Index (RSI) and Change of Direction Speed (CODS). The magnitude of the correlation is consistent with what has typically been found by previous research studies of a similar nature (Young et al 1996, Petersen et al 2006, Markovic et al 2007), although these findings are not unanimously supported in the literature (Young et al 2002, Djevalikian 1993).
The nature of field-based team sports places demands on the player to rapidly decelerate and change direction in response to the movements and actions of teammates, the ball, and the opposition. Reactive strength describes this eccentric-concentric coupling action, and this strength quality is considered to underpin CODS performance. While the drop jump has shown to have a stronger statistical relationship to CODS performance than traditional strength and power measures (Sheppard and Young 2006), the results of this current study show that it is still a poor predictor of COD ability in field sport players. Unilateral horizontal and lateral side-stepping and evasive movements are traits which characterize field-based team sports. These movements are initiated through the generation of medio-lateral ground reaction forces to accelerate the body laterally in a cutting manoeuvre. The drop jump is a bilateral exercise occurring in the sagittal plane, with force primarily generated from the extensor muscles of the hip and knee as well as the plantarflexors of the ankle, these are the primary muscles recruited for maximum velocity straight-line sprinting. The muscles involved in hip abduction which moves the femur laterally, namely the gluteus medius, gluteus minimus, and tensor fasciae latae, are not optimally recruited in the drop jump (Thompson and Floyd 2004). The findings of this empirical investigation demonstrate that bilateral sagittal plane measures of reactive strength are poor predictors of CODS performance as force is produced predominantly in the vertical direction. This confirms that the specificity of the testing exercise does not accurately assess the reactive strength component characteristic as it would occur during match-play. The base of support from which the exercise is performed, unilateral or bilateral, as well as the direction of force application should be given special consideration, and should mimic as closely as possible the demands placed on the player during the course of play (Gamble 2012). Movement specificity research requires further emphasis in the field. Despite the fact that the majority of movements observed in team sports are comprised of lateral movements and changes of direction performed on one leg (Bloomfield et al 2006, Roberts et al 2008, Dwyer and Gabbett 2012), there is a lack of emphasis in the literature on the assessment of CODS using methods to analyse reactive strength in both the horizontal and lateral direction. The bilateral drop jump does not have the capacity to predict performance in COD activities, modifications to traditional testing methods are suggested to employ unilateral variations to assess reactive strength in both the lateral and forward directions.
5.2 Relationship between RSI and CODS for Soccer, Rugby Union, and GAA

5.2.1 Relationship between RSI and CODS for Soccer and Rugby
Both the Soccer \((r = -0.307)\) and Rugby \((r = -0.146)\) groups displayed negative correlations between RSI and CODS. Both of these groups were assessed on an Astroturf surface with the players wearing their football boots in order to increase the ecological validity of the tests. The moderate relationship (Hopkins 2011) observed in the Soccer group was the largest amongst the three groups. This is not surprising given analysis of GPS and time-motion studies into both codes. Total distances covered in soccer typically range from 10-11.5 km depending on position this is much greater than the distances reported for rugby union of 5.5-6.2 km (Roberts et al. 2008, Bloomfield et al. 2006, Bradley et al. 2009). When these distances are broken down further and assessed for the total distances covered at sprinting speeds, soccer players manage to cover 1.8-3.2 km sprinting, whereas the rugby union players cover 0.45-0.30 km at high-intensity sprinting. Soccer players also make a substantially greater number of high-intensity changes of direction in comparison to rugby union players (264 vs. 78), thus highlighting the increased mobility and agility characteristics of the soccer player which corresponds with the findings of this study (Bloomfield et al. 2006, Duthie et al. 2006).

5.2.2 Relationship between RSI and CODS for GAA
In contrast to both the Soccer and Rugby Union group, and also in contrast to what is widely reported in the literature (Sheppard and Young 2006), the GAA group displayed a weak positive correlation between RSI and CODS \((r = 0.220)\). This meant that as the subjects RSI increased, so too did the time to complete the CODS task. This was an unexpected finding. Given that the movement demands per minute during match-play of GAA are similar to Soccer, a weak to moderate negative correlation was expected (Reilly and Collins 2008). Unlike the testing procedures for the Soccer and Rugby Union groups which was conducted on Astroturf with the players wearing the appropriate footwear, facility restrictions meant that the GAA group were tested indoors on a basketball court with the players wearing running shoes, and this may have affected the results. It was noted during the testing procedure that a number of the players had a tendency to slip when rounding the agility poles during the CODS assessment. A possible reason for this could be due to a low coefficient of friction between the sole of the running shoe and the surface of the basketball court. When compared to specialized indoor court shoes such as basketball and squash footwear, running shoes are made from harder less deformable material which is optimal for producing a high traction coefficient between the shoe and outdoor terrain (Shorten et
Friction is dependent on the types of surfaces that are in contact with each other. Thus, greater friction can be developed between the court surface and the soft rubber soles of squash and basketball shoes than can be developed between the court surface and the sole of the running shoe. When the coefficient of friction between the shoe and the court is low, it requires only a small normal contact force to be applied before sliding or slipping will occur between the surfaces. Therefore, a possible explanation behind the direction of the correlation between RSI and CODS for the GAA players is that the players with the larger RSI were able to generate greater normal contact forces when changing direction, this larger normal contact force coupled with a low coefficient of friction may have resulted in reduced traction which impaired their performance on the test. This rationalization is supported by findings in the literature that noted that the time to complete an agility task can be affected by up to as much as 0.5 seconds over a distance of 8 meters depending on the coefficient of friction between the shoe and the surface (Pedroza et al 2010). It would be interesting to re-test this group under the same conditions as the Soccer and Rugby Union groups in order to confirm or refute the proposed justification behind the direction of the correlation.

\[ F_s = \mu_s R \]

*Equation 5.1 Static Friction (McGinnis 2005)*

\[ F_d = \mu_d R \]

*Equation 5.2 Dynamic Friction (McGinnis 2005)*

Fs = Static Friction Force
µs = Coefficient of Static Friction
µd = Coefficient of Dynamic Friction
R = Normal Contact Force

### 5.3 Comparison of RSI Scores Between Groups

No significant differences were found between the means of the groups following comparison of RSI scores. The RSI is the ratio between ground contact time and jump height and displays the ability of the subject to develop maximum force in a minimum amount of time (Cardinale et al 2011). An individual’s RSI has been described as a measure of their ‘explosive’ capabilities. This describes the ability to quickly transition between eccentric to concentric muscle contraction (Young 1995).
It is important to note that the contact time for all groups was indicative of slow SSC function (>250 ms). Bilateral drop jumps typically elicit a fast SSC action (<250 ms) normally associated with maximum velocity straight-line sprinting. The average drop jump ground contact time for the entire subject group (270 ms) is in the slow SSC range (<250 ms) which is associated with COD activities (Gamble 2010, Schmidtbleicher 1992). Possible explanations behind this longer than usual ground contact time are whether the subjects are trained or untrained in plyometric type drop jump training, and the influence of the dropping height (0.3m) used. Athletes accustomed to this type of activity can typically elicit a fast SSC response from drop jump heights of up to 0.6m (Flanagan and Comyns 2008). The drop jump height selected was chosen because it was a commonly used height in previous studies using similar subjects (Jones et al 2009, Salonikidis and Zafereidis 2008). It may have been more effective to perform an incremental assessment (e.g., 20,25,30 cm) for each subject in order to identify the optimal drop jump height, beyond which the fast SSC component capability becomes compromised, as this would give an indication of the eccentric loading capacity for each subject. The height used (0.3 m) may have exceeded the optimal eccentric loading capability of the subjects, and resulted in a compromised capacity to transition effectively from eccentric to a forceful concentric contraction. The protective inhibitory effect of the Golgi Tendon Organ (GTO) is proposed as the possible mechanism behind this performance decrement. The GTO becomes activated as the muscle tension increases the stretch in the attached tendon. The discharge of the GTO increases as the tension in the muscle increases, and as the eccentric loading stimulated by the drop jump comes close to a level that could potentially damage the muscle-tendon complex, the reflexive inhibition of the GTO causes the muscle to relax and temporarily reduces the concentric contractile capacity of the muscles (Flanagan and Comyns 2008, Baechle and Earle 2008).

Had each individual performed an incremental assessment in order to obtain the optimal jump height to elicit maximum RSI, then it is possible that the results may have been different.

The information gathered from this testing session is also of benefit to the strength & conditioning staff of the teams tested as it was determined that the jump height used presented a sub-optimal stimulus for the players, and that this height presented an increased injury risk to the players because of the high impact forces generated upon landing (Bobbert et al 1987). This information is of important practical significance when considering the design and implementation of a plyometric training program.
5.4 Comparison of CODS Scores Between Groups

When the groups were compared for CODS scores significant differences were found between the Soccer and Rugby Union groups (p<0.05), and the GAA and Rugby Union groups (P<0.05), but no significant difference was found between the Soccer and GAA groups (p=1.000).

Unsurprisingly, given the similarity of the movement characteristics of both Soccer and GAA, no significant difference exists between the groups for measures of CODS. The duration (5-7 sec), the distance (20 m), and number and degree changes of direction of the L-run CODS test applied in this study accurately reflect the activities of both codes (Keiner et al 2013, Bloomfield et al 2007, Reilly and Collins 2008).

The Rugby Union group, as expected, was the slowest out of the three groups assessed. This can be attributed to the large differences in positional demands between the backs and the forwards. In rugby union it has been noted that as much as 80% of sprints do not involve a change of direction (Duthie 2004), backs cover greater distances at high intensity running than forwards due to the fact that they have greater open space to run into than the forwards who are commonly in close proximity to the opponent. While the backs cover more distance at high speeds, these sprints are most often initiated from flying starts (Roberts et al 2008). Forwards commence more sprints from a standing start with less than 7% of their sprints occurring from a striding start (Duthie 2004), but the majority of their high-intensity activity is performed in periods of static exertion such as rucks, scrums, and mauls (Deutsch et al 2007, Cahill et al 2012, Duthie 2004). Due to the close proximity of the opponents, forwards tend to run with the ball straight ahead in an attempt to make territorial gains, the backs in contrast complete sprints of greater distances with a higher proportion of changes of direction in order to expose gaps that appear in the opposition defence (Duthie et al 2006, Duthie 2004). When all of this is taken into consideration it is logical to conclude that the L-run CODS test does not provide a truly accurate representation of the CODS abilities of the rugby union players as would occur during match conditions. It may be more appropriate to devise a novel test to more accurately represent the CODS demands for both rugby union backs and forwards.
6.0 CONCLUSION

6.1 Hypothesis

- In consideration of the presence of a relationship, albeit weak \((r = -0.110)\), between RSI and CODS the null hypothesis \((H_0)\) is rejected in favour of the alternative hypothesis \((H_a)\).
- No significant differences existed between measures of RSI among the Soccer, Rugby Union, and GAA groups, thus the null hypothesis \((H_0)\) is accepted for this variable.
- Significant differences existed between the groups on measures of CODS, therefore the null hypothesis \((H_0)\) is rejected in favour of the alternative hypothesis \((H_a)\) for this construct.

6.2 Practical Significance of the Findings

- The results of the study indicate that the RSI score attained from the vertical drop jump is poorly related to CODS performance. When using jump tests to predict COD ability, special consideration should be given to the base of support and direction of force application required for successful participation in the sport. However it is important to note that correlation analysis only provides a relationship between the variables, it does not imply cause and effect (Brughelli et al 2008).
- The Optojump optical measuring device provides a valid practical and portable solution for assessing RSI in an applied setting. Instant feedback is provided detailing the ground contact time and jump height for the drop jump, and an indication of the type of SSC activity (slow or fast) can be determined (Glatthorn et al 2011).
- Depending on the goal of training, different exercises should be selected to elicit the appropriate SSC mechanism in accordance with the demands of the sport.
- The time duration, distance, and number of changes of direction provided by the L-run correspond to the movement demands on Soccer and GAA. A novel test should be designed in order to cater for differences in the demands between rugby union backs and forwards.
6.3 Strengths & Limitations of the Study

6.3.1 Strengths of the Study
- Testing for both the Soccer and GAA group was conducted under conditions similar to what the players would experience during matches (Sporis et al 2010).
- Repeat trials (n = 3) were conducted in order to give a more accurate indication of the subjects performance.
- Dual-beam electronic timing gates were used, these have shown to have greater reliability over single-beam systems (Garcia-Pallares et al 2011).

6.3.2 Limitations of the Study
- A major limitation was that the GAA group were not tested under the same underfoot conditions as the Soccer and Rugby Union groups.
- The dropping height used for the drop jump provided a sub-optimal stimulus and may have provided an increased injury risk to the subjects (Flanagan and Comyns 2008, Bobbert et al 1987).

6.4 Recommendations for Future Research
- Future studies should implement both bilateral and unilateral drop jump variations in both the forward and lateral directions to mimic the force production and type of SSC activity as it would occur in side-stepping actions.
- Pre-screening of the subjects optimal dropping height for eliciting the greatest RSI response should be performed in order to more accurately assess their reactive strength capacity.
- Researchers should analyse the movement demands for both rugby union backs and forwards in order to come up with novel assessments for replicating the COD demands of the different positions.
- All groups should be assessed under the same conditions to rule out any inconsistencies or inaccuracy that may arise from testing on different surfaces.
BIBLIOGRAPHY


Title: Strength, speed and power correlates

What is the project about?

The aim of this research is to investigate if there is a relationship between strength, speed and power performance in field based sport players. Speed, strength and power are all components of training for field based sports players. However, each component's relationship to another and to movement performance is not widely known. How player strength correlates to their sprint speed, power and reactive performance will be assessed.

What will you have to do?

You will be asked to dress in short and t-shirt for physical activity and provide signed consent. Testing will require two one hour sessions over two days at the University of Limerick.

Day one

- You will be taken through a 10 minute dynamic warm up to include light jog followed by 3 hops, 3 bounds and 3 shuttle runs.

- You will perform three repetitions of the following, with 1 minute between reps and 10 minutes between different tests:
  - Hand grip dynamometer maximal strength of non dominant arm.
  - Countermovement jump on a force platform
  - Drop Jump on a force platform
  - Con-Trex leg strength test
  - 1 Repetition maximum bench press with a standard warm-up 50%

- Cool down

Day two
- You will be taken through a 10 minute dynamic warm up to include light jog followed by 3
  hops, 3 bounds and 3 shuttle runs.

- You will perform three repetitions of the following, with 1 minute between reps:
  - 10 metre maximal sprint through timing gates

**What are the benefits to you?**

Participation in the study will further our understanding of the relationships between the
training components of speed, strength and power. One component may be found to be more
relevant to speed performance than another. This understanding will help your coach to
develop interventions and strategies for high performance training.

**What are the risks?**

Muscle soreness and fatigue are possibilities as a result of taking part in this study. However,
these risks are no greater than that which might result from your normal exercise or training
session. Risks are minimal, and none that outweigh the risks involved in normal training
situation.

**What if I do not want to take part?**

Should you feel at any stage that you want to discontinue being a participant then this is dealt
with in an unhesitating and confidential manner where you have the option of pulling out
without the risk of information being disclosed.

**What happens to the information?**

The information retrieved from will be dealt with and handled in complete confidence
whereby results of the participants as well as their confidentiality are the first priority of the
researchers carrying out the experiment. After the completion of the study data will be kept
electronically on the principal investigator’s password-protected computer.

**Who else is taking part?**

In all there will be approximately 15 participants taking part from local rugby, soccer and
football clubs.

**What if something goes wrong?**

In the unlikely event that something goes wrong, the testing procedure will immediately cease
and the PESS department emergency procedures will be followed.
What happens at the end of the study?

At the end of the study the information will be used to present results but the information here will be completely anonymised. All subject detail/information and data will be held by the principal investigator for up to 7 years in a password-protected computer at UL.

What if I have more questions or do not understand something.

If you do not understand any aspect of the experiment we would urge you to come forward to myself the researcher, or indeed the principal investigator. It is important that the participant feels completely at ease throughout the experiment.

What if I change my mind during the study?

Should the you feel at any stage that you want to discontinue being a participant then you are free to stop and take no further part.

Project Investigator Contact Details:

Principal Investigator
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Undergraduate Student
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This study has been approved by the ethics committee of the faculty of Education and Health Sciences. If you have any concerns about this study and wish to contact someone independent, you may contact The EHS Research Ethics Contact Point of the Education and Health Sciences Research Ethics Committee, Room E1003, University of Limerick, Limerick.

Tel: (061) 234101 / Email: ehsresearchethics@ul.ie
Title: Strength, speed and power correlates

What is the project about?
The aim of this research is to investigate if there is a relationship between strength, speed and power performance in field based sport players. Speed, strength and power are all components of training for field based sports players. However, each component's relationship to another and to movement performance is not widely known. How player strength correlates to their sprint speed, power and reactive performance will be assessed.

What will you have to do?
Your child will be asked to dress in short and t-shirt for physical activity and provide signed consent. Testing will require two one hour sessions over two days at the University of Limerick.

Day one
- Your child will be taken through a 10 minute dynamic warm up to include light jog followed by 3 hops, 3 bounds and 3 shuttle runs.
- Your child will perform three repetitions of the following, with 1 minute between reps and 10 minutes between different tests:
  - Hand grip dynamometer maximal strength of non dominant arm.
  - Countermovement jump on a force platform
  - Drop Jump on a force platform
  - Con-Trex leg strength test
  - 1 Repetition maximum bench press with a standard warm-up 50%
- Cool down

Day two
- Your child will be taken through a 10 minute dynamic warm up to include light jog followed by 3 hops, 3 bounds and 3 shuttle runs.

- Your child will perform three repetitions of the following, with 1 minute between reps:
  - 10 metre maximal sprint through timing gates

What are the benefits to you?
Participation in the study will further our understanding of the relationships between the training components of speed, strength and power. One component may be found to be more relevant to speed performance than another. This understanding will help your child’s coach to develop interventions and strategies for high performance training.

What are the risks?
Muscle soreness and fatigue are possibilities as a result of taking part in this study. However, these risks are no greater than that which might result from your child’s normal exercise or training session. Risks are minimal, and none that outweigh the risks involved in normal training situation.

What if I do not want to take part?
Should you feel at any stage that you want your child to discontinue being a participant then this is dealt with in an unhesitating and confidential manner where you have the option of pulling out without the risk of information being disclosed.

What happens to the information?
The information retrieved from will be dealt with and handled in complete confidence whereby results of the participants as well as their confidentiality are the first priority of the researchers carrying out the experiment. After the completion of the study data will be kept electronically on the principal investigator’s password-protected computer.

Who else is taking part?
In all there will be approximately 15 participants taking part from local rugby, soccer and football clubs.

What if something goes wrong?
In the unlikely event that something goes wrong, the testing procedure will immediately cease and the PESS department emergency procedures will be followed.

What happens at the end of the study?
At the end of the study the information will be used to present results but the information here will be completely anonymised. All subject detail/information and data will be held by the principal investigator for up to 7 years in a password-protected computer at UL.

What if I have more questions or do not understand something.

If you or your child does not understand any aspect of the experiment we would urge you to come forward to myself the researcher, or indeed the principal investigator. It is important that the participant feels completely at ease throughout the experiment.

What if I change my mind during the study?

Should you feel at any stage that you want your child to discontinue being a participant then you are free to stop and take no further part.

Project Investigator Contact Details:

Principal Investigator
Dr. Ian Kenny, PESS Dept. University of Limerick, Tel (061) 234308
Email: ian.kenny@ul.ie

Other investigators
Paul Harman
Undergraduate Student
PESS Department
086 2397656
0701878@studentmail.ul.ie

Declan Noonan
Undergraduate Student
PESS Department
087 1302402
09006538@studentmail.ul.ie

This study has been approved by the ethics committee of the faculty of Education and Health Sciences. If you have any concerns about this study and wish to contact someone independent, you may contact The EHS Research Ethics Contact Point of the Education and Health Sciences Research Ethics Committee, Room E1003, University of Limerick, Limerick.

Tel: (061) 234101 / Email: ehsresearchethics@ul.ie
Appendix A2

Pre-Test Questionnaire
University of Limerick

OLLSCOIL LUIMNIGH

SUBJECT PRE-TEST QUESTIONNAIRE

NAME ............................................  Ref. No. .................
Date of Birth ................................. Age: ..................

Test procedure .................................

As you are to be a subject in this laboratory/project, would you please complete the following questionnaire. Your cooperation in this is greatly appreciated.

Please tick appropriate box

YES  NO

Has the test procedure been fully explained to you?

Any information contained herein will be treated as confidential

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

2. Do you feel pain in your chest when you do physical activity?

3. In the past month, have you had chest pain when you were not doing physical activity?
4. Do you lose your balance because of dizziness or do you ever lose consciousness?

5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

6. Is your doctor currently prescribing drugs for your blood pressure or heart condition?

7. Do you know of any other reasons why you should not undergo physical activity? This might include severe asthma, diabetes, a recent sports injury, or serious illness.

8. Have you any blood disorders or infectious diseases that may prevent you from providing blood for experimental procedures?

• If you have answered NO to all questions then you can be reasonably sure that you can take part in the physical activity requirement of the test procedure

I ………………………………… declare that the above information is correct at the time of completing this questionnaire Date ……/……/…….
Please Note: If your health changes so that you can then answer YES to any of the above questions, tell the experimenter/laboratory supervisor. Consult with your doctor regarding the level of physical activity you can conduct.

- If you have answered **YES** to one or more questions:
  
  Talk with your doctor in person discussing with him/her those questions you answered yes.
  
  Ask your doctor if you are able to conduct the physical activity requirements.

Doctor's signature ........................................... Date ....../....../......

-----------------------------------------------

Signature of Experimenter............................... Date ....../....../......

-----------------------------------------------
PRE-TEST QUESTIONNAIRE

Completed by a Parent/Guardian of Child

NAME OF CHILD ............................................................................................................

CHILD DATE OF BIRTH ......................... CHILD’S AGE: ........

As your child is to be a participant in this project, would you please complete the following physical activity readiness questionnaire for your child.

Please tick appropriate box

Has the test procedure(s) that your child will participate in been fully YES  NO explained to you?

Any information contained herein will be treated as confidential

1. Has your doctor ever said that your child has a heart condition and that your child should only do physical activity recommended by a doctor?

2. Does your child ever experience chest pain during physical activity?

3. Does your child ever lose balance because of dizziness or do they ever lose consciousness?

4. Does your child have a bone or joint problem that could be made worse by a change in their physical activity participation?
5. Does your child have uncontrolled asthma (i.e. asthma that is not easily controlled by an inhaler?)

6. Is your doctor currently prescribing any medication for your child’s blood pressure or a heart condition?

7. Do you know of any other reasons why your child should not undergo physical activity? This might include diabetes, a recent injury, or serious illness.

If you have answered NO to all questions then you can be reasonably sure that your child can take part in the physical activity requirement of this project.

I ………………………………. declare that the above information is correct at the time of completing this questionnaire on date ……/……/…….

Please note: If your child’s health changes so that you can answer YES to any of the above questions, notify the investigators and consult with your doctor regarding the level of physical activity that your child can participate in.

If you answered YES to one or more questions:

Talk to your doctor in person discussing with him/her those questions you answered yes.

Ask your doctor if your child is able to participate in the physical activity requirements of the project.

Doctor’s Name…. ………………………………. Date …………………………….

Doctor’s Signature ……………………………….

Signature of Investigator …………………………. Date …………………………….

A2
Appendix A3

Informed Consent Form
Title of study: Strength, speed and power correlates

- I understand what the project is about, and what the results will be used for.
- I have completed the pre-test questionnaire.
- I am fully aware of all of the procedures involving myself, and of any risks and benefits associated with the study.
- I know that my participation is voluntary and that I can withdraw from the project at any stage without giving any reason.
- I am aware that my results and video footage will be kept confidential.

Volunteer’s name

Volunteer’s signature

Witness’ signature

Date

Experimenter’s signature
Appendix A4

Subject Record Sheet
University of Limerick

Subject Record Sheet

Name: ________________  Height (cm): ________________
Date of Birth: __________  Weight (kg): ________________
Club: ________________

**Drop Jump**

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<th>Jump Height</th>
<th>Reactive Strength Index</th>
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**Change of Direction Speed (L-run)**

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<td>3</td>
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**Straight Sprinting Speed (10 meters)**

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</thead>
<tbody>
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Appendix A5

Warm-Up Protocol
University of Limerick

FYP Warm-Up Protocol

General Warm-Up

- Jog 30m x 4 (Length of basketball court)
- Jog Knees up x 30m, Jog heels up x 30m
- Side Skip right x 30m, side skip left x 30m
- Carioca x30m, Jog x 30m
- Mountain Climbers x 30 seconds

Dynamic Stretching

- Leg Swings, Forward/Back x 10 each leg, Side/Side x 10 each leg
- Walking Knee Hug - Forward Lunge - RDL x 30m
- Squat to Stand x10
- Spiderman Climb x10

Specific Warm-Up

- Deceleration Drill
  - Run at 50% max, stop within 3 steps when whistle blows x2
  - Run at 75% max, stop within 5 steps when whistle blows x2
  - Run at 100% max, stop within 7 steps when whistle blows x2
- Skater Hops x 10
- CMJ x5
- Lean, Fall, & Go for 10m x2
- Drop And Go for 10m x2 – Partner applies support by putting both hands on the athletes shoulder, athlete leans forward to 45 degrees, on the signal the partner lets go and the athlete accelerates out.
• Push – Push Drill for 10m x2 - The partner gives heavy resistance with the hands on the front of the shoulders for 5 steps to force triple extension before releasing to allow 10m sprint.
Appendix A6

L-run Set-Up
Figure A1 3-4-5 metre triangle set-up

Figure A2 Schematic Diagram of the L-run set-up
Appendix A7

SPSS Analysis Tables
### Table A1 - Statistical analysis multiple comparison of group means for RSI and CODS

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### Table A2 – SPSS descriptives minimum and maximum

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### Table A3 – SPSS ANOVA table

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## Post Hoc Tests

### Table A4 – Bonferroni post-hoc test 1

#### Multiple Comparisons

**Bonferroni**

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### Table A5- Bonferroni post-hoc test 2

**Multiple Comparisons**

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* The mean difference is significant at the 0.05 level.
**Table A6** - Pearson's Correlation Coefficient between RSI and CODS for entire subject group

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<td></td>
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**Table A7** - Pearson's Correlation Coefficient between RSI and CODS for Soccer group

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Table A8  Pearson’s Correlation Coefficient between RSI and CODS for Rugby Union group

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Table A9  Pearson’s Correlation Coefficient between RSI and CODS for GAA group

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