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The relationship between a change of direction and vertical and horizontal reactive strength

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Gavin Frecklington

ABSTRACT

This study was to determine the relationship between a 45° and 90° change of direction (COD) and unilateral and bilateral (vertical and horizontal) reactive strength. Drop jumps involved stepping off a box onto one or two legs then jumping for maximum height or distance whilst minimising ground contact time (GCT). Reactive strength (RS) was measured by dividing jump displacement with ground contact time. COD tests involved subjects running at a predetermined speed (2ms⁻¹, 4ms⁻¹ or 6ms⁻¹) then turning at an angle of 45° or 90° as fast as possible. Twenty eight males (mean ± SD age, height, and mass of 22 ± 5 years, 181 ± 10 cm and 78 ± 11 kg respectively) took part in the study. A 90° COD at a medium speed reported a large relationship with RS on all drop jumps except one footed horizontal jumping. At a slow speed bilateral RS also shared a large relationship however unilateral RS saw a weaker association. However at a fast speed the relationship reduced but still showed a moderate correlation across all jumps. At an angle of 45° a weak to moderate relationship were reported. Results indicate RS is an important physical quality that shares a relationship with a COD task however as the angle become less acute there is a diminishing reliance on the skill.

CHAPTER ONE: INTRODUCTION

An important component in any multi-directional or evasive sport is the ability to be more agile than an opponent as a movement performed faster or slower may be the difference between gaining an advantage and conceding a disadvantage. Whilst research into the development of agility does exist, the information is generally ambiguous with an even bigger disparity in the area of the physical preparation of a COD (2,10,14). Agility is a multifactorial skill and thus needs to be trained accordingly, however, in order to do this more detailed research is needed to inform the strength and conditioning community of how to appropriately and effectively develop each part of the skill (14).

Many studies have set out to determine what physical qualities in an individual may best enhance agility but no consensus has been agreed amongst the literature (2,6,16). Previous research has concluded that in order to enhance agility, athletes should develop the cognitive components of the skill-set and whilst this may be applicable if the athletes' perception and decision making skills are the limiting factor, it may not lead to an overall improvement in agility if the athlete lacks the ability to move their body appropriately once a decision has been processed (12,20).

Whilst studies have found strong relationships between agility tests such as T-tests and L-drills and specific physical qualities; trying to extrapolate which of the physical qualities are responsible for actual COD is very difficult due to the methods used during the research (7,13,16). For example a T-test consists of different movements such as acceleration, deceleration, lateral shuffling and back pedalling so comparing this test with a group of physical qualities will only give general information about any relationship; meaning no specific inferences can be made. This suggests that in order to obtain information about an athletes' ability to change direction at an angle of 45 or 90° the movement needs to be evaluated

in a way that ensures other variables do not influence the outcome. This has been done in other gross movement deemed important to athletic performance such as linear top speed sprinting and decelerating (4,16).

One physical quality thought to have high importance in any specific COD cut is RS and whilst some studies have found moderate to high correlations between the two, the methodology of the testing could be challenged (13,21). For example the study by Peterson, Alvar, and Rhea did report a strong relationships between vertical/horizontal jumping and agility but the agility test was a T-test (13). Young, James and Montgomery concluded that RS has some importance in COD but it could be argued acceleration would have largely influenced their results (19). The possible explanation as to why other studies have not found a relationship between RS and COD could be that the skill was not tested in the specific manner in which it is used in a sports task (1,6). For example during a cut the task is completed unilaterally with ground force reactions being applied vertically, horizontally and laterally (2,3). Whereas studies that have attempted to establish a relationship have generally investigated bilateral RS and in the vertical direction (7,13). Literature that has tested jumping in the unilateral, vertical, horizontal and lateral planes of movements against COD have only discovered small to moderate correlations but again methodological oversights could be the limiting factor (6,10,11).

The main aim of the research was to design a study that assesses the relationship between a COD and RS whilst limiting other influencing physical qualities such as acceleration and deceleration. It is hypothesised there is likely to be a strong relationship between RS and a COD test at 45° and 90°. Specifically, it is thought that unilateral vertical RS will show the strongest relationship with a COD but horizontal reactive strength will also show a large relationship. The second hypothesis is that the faster the preceding approach speed and the more acute the turn the more reliant the subject will on RS due to the higher forces the subjects would have to overcome. This would show in the study by seeing subjects with greater RS not

only having a faster COD speed but also having a faster entrance velocity. A third hypothesis was that subjects with greater RS would require less GCT to overcome ground reaction forces, consequently leading to a faster COD speed due to less time on the floor.

CHAPTER TWO: METHODS

2.1 Experimental approach to the problem

The study investigated the relationship between a pre-planned COD at angles of 45° and 90° and bilateral and unilateral RS in the vertical and horizontal plane. The COD was completed at an individual's maximum speed, however, a linear run of 12m prior to the COD was controlled at a speed of 2, 4 and 6ms⁻¹. A straight line 5m sprint was performed to compare against the COD times in order to distinguish that the speed of the COD was the determining factor and not acceleration in the overall time to complete the task. The techniques involved in COD includes planting one foot outside an athlete's centre of mass, therefore it was deemed necessary to test unilateral jumping alongside bilateral jumping to determine if any relationship exists when looking at specific components (6). It was also decided that both vertical and horizontal directions should also be investigated as COD requires athletes to overcome forces from differing angles (11).

2.2 Subjects

Twenty eight males with an active (within two months) participation in a multi-directional sport were recruited for the study (mean ± SD age, height, and mass of 22 ± 5 years, 181 ± 10 cm and 78 ± 11 kg respectively). St Marys School of sport, health and applied sciences ethical review board approved the study design. The risks and benefits of the study was verbally explained to the subjects before participation and written informed consent was sought.

2.3 Procedures

Testing was completed on a sprung wooden indoor basketball court at the same time of the day 48 hours apart. Subjects were advised not to ingest any stimulating supplements or caffeinated drinks 24 hours and to refrain from any strenuous activity 48 hours prior to testing. The participants were encouraged to stay hydrated both before and during testing. A ten minute

standardised warm up consisted of general movements, activation and mobilisation of all the major joints in the body and potentiation of the specific tasks involved in the testing protocol. Subjects received an information sheet explaining the details of the research which included procedures and risks involved.

The first day of testing consisted of height and weight measurements and familiarisation of all required movements. Specifically, the different speeds were demonstrated, explained and practiced from slow to fast ($2,4,6\text{ms}^{-1}$) until each subject completed three correctly timed runs with each attempt separated by a 60sec rest. After a five minute rest the COD protocol was demonstrated, explained and practiced with 90secs rest until each subject completed three successful attempts. A successful attempt was determined by the subject entering into the turn at the correct speed with a leniency of 250ms. After a five minute rest the jumps were demonstrated and practiced until each subject completed three successful jumps. A successful jump was determined by the subject completing the jumps with the correct technique under agreement of both themselves and the tester.

The second testing day consisted of the same warm up with two practice runs of each of the COD tests. After a five minute rest twelve experimental COD tests were completed separated by a 90secs rest. The twelve runs consisted of two correct runs at the different speeds at an angle of 90° and this was repeated at the angle of 45° . The subjects also completed three experimental 5m sprints. The order and speeds were randomised.

The third testing day saw the subjects complete the warm up followed by practice of the jumps. After a five minute break each subject performed the twelve experimental jumps, separated by 90secs. The order of jumps was randomised.

2.3.1 Running speeds protocol

The speed was practiced by having subjects run a 24m straight line between evenly spaced out cones at the specific distances (2, 4 or 6m) with the aim of simultaneously passing the cone to the sound of a metronome (Metro timer application for Apple iPhone) set at 1sec. Practice was conducted from slow to fast with 60secs rest between runs.

2.3.2 Sprint protocol

Subjects maximally ran from a static athletic stance between two cones measured 5m apart. Participants performed three sprints with a 90sec rest between attempts and the best times were used for analysis.

2.3.3 Drop jump protocol

Bilateral vertical drop jump data was collected by having subjects step off a 30cm box onto a force platform (PASCO, PS-2141, Dobbs Ferry, NY, USA) then immediately jumping and landing back on the plate. The same procedure was used to collect data for unilateral vertical drop jumping but a 10cm box was used and subjects jumped off one leg but had the option to land on one or both legs. The horizontal jumps were collected in the same way, however subjects jumped forward for maximal displacement.

2.3.4 Change of direction protocol

The subjects ran 12m in a straight line then turned at an angle of 45° or 90° in a predetermined direction of left or right as fast as possible past a cone 5m away. To determine that the correct entry speed was achieved two light gates (Brower TC gate, Utah, USA) were located at the start and end of the initial 12m. A leniency of 250ms was used and if the subjects were not travelling at the correct speed they were verbally informed to abort the attempt. A box measuring 20in square was marked on the floor at the point of direction change and the plant foot had to land in the box. During the 4ms⁻¹ trial a distance of 2m was given to slow down before the COD and for the 6ms⁻¹ trials a distance of 4m was given. The greater trochanter

was palpated and located on each subject and a mark was placed on it to use as a traceable marker during analysis. The order of runs was randomised. Figure one shows a schematic of the set up.

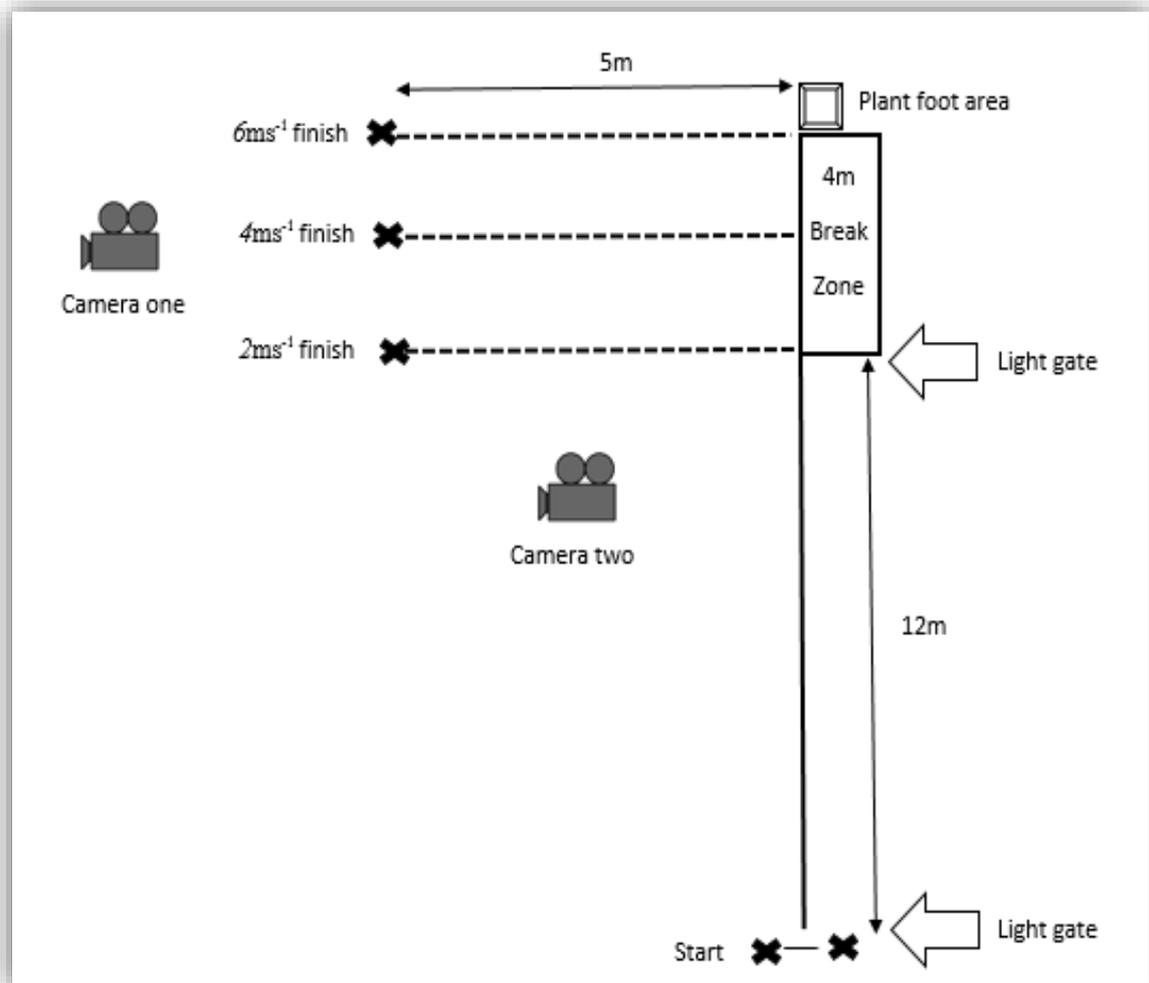


Figure 1. Schematic illustration of 90° COD setup

2.4 Data collection and analysis

2.4.1 Change of direction and acceleration trial

Two cameras (Apple, iPhone 7, California, USA) filming at 240 frames per second were used to film at two different angles involved with the COD. Camera one was positioned 6m away and perpendicular to the approach line and camera two was positioned 6m perpendicular to the

exit line. Both were used in combination with the software program Kinovea (V 0.8.15) to collect the following times:

1. Entrance velocity - 2m preceding the initiation of plant foot ground contact. Velocity was measured using the calculation: distance/time.
2. Total COD time - time from ground contact initiation of step before plant foot to crossing the finish line.
3. Exit velocity - time from plant foot to succeeding 2m. Velocity was measured using the calculation; distance/time.
4. Ground contact time of three steps - time of ground contact of step before plant foot, plant foot and step after plant foot. The time was calculated from initiation of any part of the foot making contact with the floor to the lift of.

2.4.2 Sprint trial

Two markers were set up 5m apart and a camera was positioned 6m perpendicular to that line. The time from a static start position to running the 5m distance was calculated and analysed with Kinovea software (V 0.8.15).

2.4.3 Horizontal drop jump trial

A camera (Apple) was positioned 5m away, perpendicular to the line of jump to capture horizontal displacement. The distance was analysed using Kinovea which was calibrated using a reference point marked in the floor along the path of the jump. This was used to measure the distance from toe on the take-off foot to the heel of the rearmost foot upon landing. Ground contact time was calculated from initial ground contact to take off.

2.4.4 Vertical jump trial

Kinetic data was collected using a force platform (PASCO) sampling at 1000Hz connected to a computer running SPARKvue software. Ground reaction force data was filtered at a cut-off frequency of 10Hz which is an assigned arbitrary threshold used to determine when a subject is on or off the platform. Vertical jump height was determined from flight time using the calculation: $(9.81 \times \text{flight time}^2) / 8$ (8).

Reactive strength index (RSI) was calculated by dividing jump height or distance with total ground contact time (5).

CHAPTER THREE: STATISTICAL ANALYSES

A Pearson product-moment correlation coefficient was used in order to establish if a relationship existed between RSI and GCT of three steps involved in the COD, total COD time and entrance and exit velocities. This analysis was also used to determine if a relationship existed between the total COD speed and sprint time. The results from the correlation coefficient were rated whereby 0–0.1 = trivial, 0.11–0.3 = small, 0.31–0.5 = moderate, 0.51–0.7 = large, 0.71–0.9 = very large, 0.91–0.99 = nearly perfect, and 1 = perfect. A repeated-measures t-test was used to analyse differences in speeds of 90° and 45° COD trials and an alpha level was set at $P < 0.05$ unless stated. The test was also used to determine if a relationship existed between GCT and the drop jumps.

CHAPTER FOUR: RESULTS

4.1 Relationships between COD and reactive strength indices

Significant inverse relationships ($p < 0.01$) were indicated between a medium speed COD of 90° and three of the four different types of jumps. At a slower speed significant inverse correlations ($p > 0.01$) were also observed but only with bilateral RS trials. Table 1 reports a correlation matrix to delineate the large relationships between the measures.

Table 1. Correlation matrix for 90° COD and RS

RSI = reactive strength index

	Correlation coefficients		
	2ms^{-1}	4ms^{-1}	6ms^{-1}
Bilateral horizontal RSI	-0.594*	-0.713**	-0.531**
Unilateral horizontal RSI	-0.208	-0.372	-0.456*
Bilateral vertical RSI	-0.610**	-0.661**	-0.453*
Unilateral vertical RSI	-0.456*	-0.633**	-0.543**

* Correlation is significant at the 0.05 level (2 tailed)

** Correlation is significant at the 0.01 level (2 tailed)

Significant inverse relationships ($p < 0.01$) were indicated between a COD of 45° however the relationships were generally weak to moderate. However a large inverse relationship, ($p < 0.001$) was indicated during a fast COD at 45° and bilateral vertical jumping. Table 2 offers a correlation matrix to delineate the weak to moderate relationships between the measures.

Table 2. Correlation matrix for 45° COD and RS

	Correlation coefficients		
	2ms ⁻¹	4ms ⁻¹	6ms ⁻¹
Bilateral horizontal RSI	-0.428*	-0.455*	-0.410*
Unilateral horizontal RSI	-0.200	-0.434*	-0.485**
Bilateral vertical RSI	-0.466*	-0.461*	-0.537**
Unilateral vertical RSI	-0.360	-0.525**	-0.480**

RSI = reactive strength index

* Correlation is significant at the 0.05 level (2 tailed)

** Correlation is significant at the 0.01 level (2 tailed)

4.2 Relationship between ground contact times of 45° and 90° COD trials

The GCT of the step before the plant step were similar between a COD at 45° and 90° across all speeds. However at 45° the GCT of the second (plant) and following step were significantly shorter ($p < 0.05$) than at 90°. Table 3 displays all of the GCT.

Table 3. Table shows ground contact times (the mean \pm SD) of the plant step and one step either side during all COD trials

Step	COD angle	Mean \pm SD ground contact time (seconds)		
		2ms ⁻¹	4ms ⁻¹	6ms ⁻¹
1	45°	0.217 \pm 0.07	0.178 \pm 0.05	0.152 \pm 0.04
	90°	0.215 \pm 0.10	0.174 \pm 0.05	0.158 \pm 0.04
2	45°	0.244 \pm 0.04*	0.229 \pm 0.03*	0.216 \pm 0.03*
	90°	0.271 \pm 0.04	0.262 \pm 0.03	0.254 \pm 0.05
3	45°	0.234 \pm 0.04*	0.227 \pm 0.03*	0.233 \pm 0.04*
	90°	0.265 \pm 0.05	0.264 \pm 0.04	0.277 \pm 0.05

Step one = step before plant, step two = plant foot, step three = step after plant

*Indicates significance at the 0.05 level

4.3 Relationship between ground contact time and COD speed

Significant moderate relationships ($p < 0.05$) were reported between the first step and total COD time at slow and medium but not fast speeds. Only small to trivial relationships existed between the second and third step and total COD speeds. Table 4 shows a correlation matrix of all relationships.

Table 4. Correlation matrix reporting relationships between total COD time and GCT of three steps involved in the turn

COD Speed	COD angle	Correlation coefficient		
		Step 1	Step 2	Step 3
2ms ⁻¹	45°	0.441*	0.056	0.308
	90°	0.503**	0.420*	0.124
4ms ⁻¹	45°	0.407*	0.020	0.115
	90°	0.491**	0.304	0.343
6ms ⁻¹	45°	0.307	0.223	0.209
	90°	0.288	0.113	-0.010

Step 1 = step before plant, step 2 = plant foot, step 3 = step after plant

* Correlation is significant at the 0.05 level (2 tailed)

** Correlation is significant at the 0.01 level (2 tailed)

4.4 Relationship between first step ground contact time and reactive strength index at slow and medium speed COD trials

The first step GCT and bilateral horizontal RSI reports a significant ($p < 0.01$) moderate relationship (-0.438) during a COD of 4ms⁻¹ at 90°. However all other GCT and reactive strength indices only reports a small too trivial relationship (-0.009 – -0.366).

4.5 Mean ground contact times of drop jumps

In both the vertical and horizontal direction the bilateral variation of the drop jump displayed a shorter GCT. Bilateral vertical drop jump was reported to have a significantly ($p < 0.05$) shorter GCT than the other jumps. The unilateral horizontal drop jump displayed the longest GCT. Table 5 shows all drop jump GCT (mean \pm SD).

Table 5. Table shows the ground contact time (mean \pm SD of each of the drop jumps

Mean \pm SD ground contact time (seconds)			
Bilateral horizontal	Unilateral horizontal	Bilateral vertical	Unilateral vertical
0.301 \pm 0.060	0.328 \pm 0.054	0.237 \pm 0.046	0.304 \pm 0.045

4.6 Relationship between drop jumps

Vertical bilateral and unilateral RSI showed a very large significant correlation ($P < 0.01$) whereas horizontal bilateral and unilateral RSI only indicated a large relationship ($P < 0.001$). Table 6 shows relationship between drop jumps.

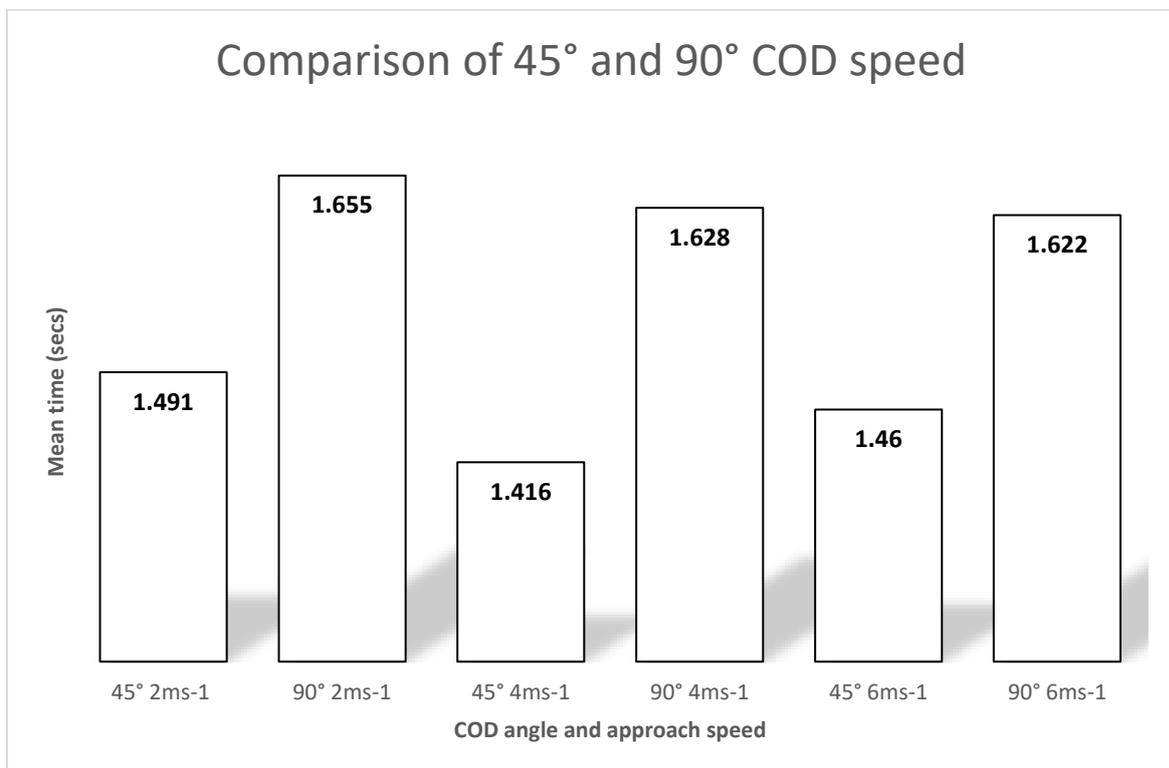
Table 6. Correlation matrix to show relationship between drop jumps

Correlation coefficients				
	Bilateral horizontal RSI	Unilateral horizontal RSI	Bilateral vertical RSI	Unilateral vertical RSI
Bilateral horizontal RSI	1.000			
Unilateral horizontal RSI	0.680**	1.000		
Bilateral vertical RSI	0.617**	0.349	1.000	
Unilateral vertical RSI	0.599**	0.601**	0.781**	1.000

**correlation is significant at the 0.01 level (2 tailed)

4.7 Difference between speed and entrance velocity of 45° and 90° COD trials

All COD trials at 45° were performed significantly ($p < 0.05$) faster and had a faster entrance velocity than COD at angles of 90°. Figure 2 graphically represents the difference in time between the COD angles.



90 = 90° COD angle; 45 = 45° COD angle

Figure 2. Graph displaying the difference in COD times between 45° and 90°

4.8 Relationship between 5m sprint and total COD speed

Small to moderate relationships were seen between all COD trials and a 5m sprint tests except one trial ($p < 0.05$). At a slow speed and at an angle of 45° a large significant ($p < 0.01$) relationship is reported with a 5m sprint test. Table 7 shows correlation between 5m sprint time and total COD time.

Table 7. Table displays correlation coefficients between total COD and 5m sprint time

Correlation coefficients						
	2ms⁻¹ 90	2ms⁻¹ 45	4ms⁻¹ 90	4ms⁻¹ 45	6ms⁻¹ 90	6ms⁻¹ 45
Sprint time	0.251	0.632**	0.456*	0.426*	0.458*	0.316

*correlation is significant at the 0.05 level (2 tailed)

**correlation is significant at the 0.01 level (2 tailed)

CHAPTER FIVE: DISCUSSION

The results demonstrated that a strong relationship exists between RS and a 90° COD at slow and medium speeds. Specifically, the best correlations were bilateral jumping in both vertical and horizontal directions ($r = -0.713$ and $r = -0.661$) respectively, although unilateral vertical jumping ($r = -0.633$) also displays a good relationship. Within the literature the best correlations found between a COD task and jumping have been documented as $r = -0.79$ for a bilateral horizontal jump and $r = -0.71$ for vertical unilateral RS (13,21). Although higher relationships have already been found, methodological issues within both papers have to be scrutinised to determine if the associated variables are indeed COD and jumping skills. Peterson et al. (13) used a COD which involved a T-test that includes many skills such as acceleration, deceleration and lateral shuffling; making any inference about the specific COD turn very difficult. So although there appears to be a strong connection, under closer scrutiny the relationship between the actual turns involved with the T-test and jumping are largely unknown. A study by Young et al. (21) was methodologically similar to the current research however it failed to control the influence of acceleration on the COD times. Although this could appear trivial the strongest correlations were seen at COD of 20° which was similar to straight line sprinting and saw a diminishing relationship as the angle became more acute. This was contrary to the current study that showed an increased relationship between a COD and 5m sprint as the angle became more acute. However the results only reported a weak to moderate correlation ($r = 0.251 - 0.458$) during all tests except a 2ms^{-1} COD of 45°. When collectively considering the other literature with the current study it can be thought that the current study managed to extrapolate the relative contribution of a COD by reducing other variables suggesting the results are a more accurate representation of the actual relationship between the two tasks.

It was thought that a stronger relationship would be seen when completing the jump trials on one leg and when the speed of the turn increased but the results did not support this predication. However it is possible the reason for the equivocal results could potentially lie within methodological issues rather than a true lack of relationship. An important factor to consider when selecting the testing battery was how familiar the movement would be to the subjects to eliminate the chances of a subject not maximising their physical capacity due to insufficient technique. Whilst familiarisation training took place it is thought that subjects were not competent enough with unilateral horizontal jumping which could have potentially affected an important factor that largely influences RS.

The mean GCT for a unilateral horizontal jump was the longest (0.328 seconds) of jumps performed, indicating the subjects needed longer time on the floor to overcome the force from the drop or because they were not in the most efficient position upon landing, which again would increase the time to get off the floor (18). The long GCT could suggest the subjects were trying achieve a large displacement by increasing the rate of force development at the compensation of a short contact time however the mean distance was still shorter when compared to a study involving rugby players (mean \pm SD jump cm, $198 \pm 28 - 225 \pm 18$), respectively (6). The longest mean GCT of the steps during a slow and medium speed COD was 0.271secs which are statistically shorter than that during the unilateral horizontal jump (0.328secs). The mechanisms involved within the stretch shortening cycle between the two movements is likely to be different due to the large discrepancy in the time of rates of force development suggesting the mechanical qualities being utilised will also be different which could have contributed to the poor correlation (17). A strong relationship between both types of horizontal jumps (bilateral and unilateral) did exist however it was not as high as the correlation seen between the two types of vertical jumps. Another plausible reason for the extended GCT during the one legged horizontal jump could be that the box may have been two

high for the subjects, creating too high a force for them to overcome causing an increased contact time with the floor (17). This theory was unlikely to be what was observed in this instance as subjects displayed competency during the vertical derivative which used the same height box with the same load.

The relationship between unilateral vertical and horizontal jumps was $r = 0.601$ whereas in other literature it has been reported as $r = 0.74$ (6). The relationship was therefore expected to be higher and in line with other studies which again further suggests that the techniques of the vertical jump were not carried over to the horizontal jumps in the current study (6). Therefore it can be concluded that the reason why unilateral horizontal RS did not show any relationship with a COD was not because a relationship does not exist but because the subject's technical competency during the task was insufficient.

It was predicted that a relationship between a COD and RS would be more significant as the speeds increased especially during the 90° due to the higher forces acting upon the body, however, the results saw a decreased correlation. It is possible that the lack of relationship could be explained by the way in which the study was conducted which casts doubts over whether the results were a true reflection of reality. During a slow COD the speed was controlled until the first step and during the medium speed trial the subjects had 2m 'break zone' however during the fast trial the subjects had a 4m 'break zone' which was an extra third added to the approach run. Due to the lack of control of the actual speed it would very difficult to know how the subjects prepared themselves for the COD but it was thought that subjects with lower RSI would break earlier than their stronger peers. Although the entrance velocities were measured it did not show any relationships with the COD speed nor offer any insights as to what changed in the 'break zone' that could have caused the lack of correlation. Having such a large uncontrolled zone could be an oversight in the experiment which could potentially suggest that entering a 90° COD at a speed of 6ms^{-1} could simply have been too fast for the

population in the experiment. The sound rational applies and without sufficient control it would be difficult to determine if indeed RS does play a role at high speeds.

Overall a COD of 45° showed to have a weak to moderate relationship with RS which was also significantly weaker than the relationship seen with a 90° angle. This was unexpected as other studies had demonstrated a greater relationship between a COD at less acute angles than sharper (21). It is thought that many factors could have contributed to the lack of relationship but the speed at which the turn was completed and consequently the GCT of the three steps involved with the COD are likely to be strongly influencing factors (17). The main difference between the two different COD tests was the speed at which the subjects completed the trials. The 45° COD were completed significantly faster than the 90° trial which was possible by a reduced deceleration prior to the turn. This was observed not only in the total COD time but also when comparing the entrance velocities of the medium and fast trials which showed a significantly faster approach into the turn. It is not possible to compare this data to other studies as the only known literature that measured the specific COD contribution did so under reactive rather than pre-planned conditions (6). Travelling at faster velocities also saw a significant reduction in the GCT of the second and third step between a 45° and 90° cut. During slow and medium speeds the GCT of the second and third steps were statistically shorter (0.227 – 0.244ms) during the 45° turn when compared to the 90° turn (0.262 – 0.271ms). It could be that lack of relationship is a result of the speed and contact times in which the 45° COD were completed as it is again likely that the mechanisms that are involved within the stretch shortening cycles are different. For example during top speed sprinting the velocity in which an athlete is moving is high and the GCT is short but during acceleration tasks the velocity of the athlete is slow and GCT are long. This demonstrates the speed of movement is likely to influence the times available for rates of force development much like what is observed between sprinting and accelerating. A faster COD such as the 45° trial is likely to be utilising

the mechanisms involved with a short stretch shortening mechanism and the 90° trials utilising a long stretch shortening cycle mechanism (8). Although overall RS displayed weak to moderate correlations the strongest relationship was seen between bilateral vertical jumping (-0.537) which had the shortest GCT (0.237ms) which is not too indifferent from the GCT used during a 45° COD (0.227-0.244). It could therefore be inferred that one of the reasons why bilateral vertical jumping displayed the strongest correlation with a 45° COD was because of the similarities between the GCT and the influence that has on the stretch shortening mechanisms. If the drop jumps were individualised and controlled in terms of GCT by manipulating the box height to achieve a shorter contact time it is thought a stronger relationship could have been seen (17).

The second hypothesis was subjects with better RS would require less time on the floor to overcome the forces especially at higher speeds and sharper angles. The first step GCT during both 45° and 90° COD tests at slow and medium speeds showed a moderate relationship with total COD speed. However the relationship between RSI of all jumps and GCT of the first step only showed a weak to moderate relationship suggesting RS is not likely to be the mechanism contributing to the short GCT. Figure 3 shows the first step of the two main techniques used by subjects which were a stutter step and long stride approach. The stutter step approach is likely to have resulted in a faster COD time because it technically requires less GCT than the stride approach and because this technique allowed the subject to change direction closer to the turn resulting in less distance to cover. At fast speeds there appears to be no relationship with the first step and COD performance which could be explained by inability of the subject to appropriately manipulate their foot position to get close to the COD turn because of the speed in which they were travelling. This shows that although a relationship exists between the first step and a COD it is unlikely to be a result of RS.



Figure 3. Differences between a stutter step technique (top three) and long stride technique (bottom three). All images show the first step in COD.

There was no relationship between all COD total time trials and the GCT of the second step (plant foot) or next step, suggesting that the RS of an athlete does not affect the rate of force development during a COD task. Interestingly subjects with poorer RS did not compensate for lack of ability to overcome high forces by spending more time on the ground to utilise a longer stretch shortening cycle mechanism, as demonstrated by a constant GCT between ‘stronger’ and ‘weaker’ athletes. It was thought that in weaker athletes’ GCT would increase resulting in a reduced RSI much like what is observed during depth jumps when a box height becomes too high; however this was not the case (18). Because there appears to be a strong relationship between a COD task and RS but GCT did not differ between weaker and stronger subjects it is thought the reason for the faster total COD times observed in subjects with a greater RS was

not because the subject spent less time on the floor but because they produced a higher magnitude of force during plant foot mechanics to accelerate faster out of the turn (15). This finding is in line with the current literature surrounding the GCT seen in sprinting and during counter movement jumps. For example GCT during a countermovement is approximately <250ms and during top speed sprinting it is approximately 100ms (9,19). It is widely accepted in order to increase these skills one should aim to increase the magnitude of force within specified GCT dictated by the skill rather achieve the same force in less time by increasing the rate of force development (9,13,19).

The current study does support the notion that horizontal and vertical reactive strength is an important physical quality in the execution of a COD at 90° at slow and medium speeds, however due to methodological flaws it is largely unknown what the relationship is during faster speeds. The GCT of a COD task remains within a constant time (0.262 – 0.271ms) so in order to induce improvements the amount of force developed within this time frame is thought to be of high importance. A stronger relationship between bilateral RS and a COD task has led to the conclusion that this type of strength is more important than unilateral RS however a relationship does still exist suggesting development within a training plan is still warranted. It was shown that as the angle of COD became less acute there was a diminished importance on RS. The current study has shown RS can explain 50% of the variance within a COD task of 90° with the remaining 50% likely to come technique and postural components and other physical qualities such as relative, concentric and eccentric lower body strength (6,16).

The results suggest that RS is important for athletes competing in sports that involve sharp COD at slow and medium speeds and an improvement of this physical quality would likely lead to an improvement in an athletes agility when combined with cognitive and technical components.

CHAPTER SIX: PRACTICAL APPLICATION

Developing unilateral and bilateral (horizontal and vertical) RS is likely to lead to an improvement in COD tasks that are sharp in angles ($< 90^\circ$) and preceded by a slow to medium approach speed. Exercises that focus on bilateral RS completed in the horizontal and vertical plane should be prioritised in order to see best development. To ensure specificity between an exercise and a COD task; movements that encourage a long GCT of around 260ms are recommended to ensure a similar stretch shortening mechanism is developed.

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APPENDIX

1. Ethics application

St Mary's University

Ethics Sub-Committee

Application for Ethical Approval (Research)

This form must be completed by any undergraduate or postgraduate student, or member of staff at St Mary's University, who is undertaking research involving contact with, or observation of, human participants.

Undergraduate and postgraduate students should have the form signed by their supervisor, and forwarded to the School Ethics Sub-Committee representative. Staff applications should be forwarded directly to the School Ethics Sub-Committee representative. All supporting documents should be merged into one PDF (in order of the checklist) and clearly entitled with your **Full Name, School, Supervisor**.

Please note that for all undergraduate research projects the supervisor is considered to be the Principal Investigator for the study.

If the proposal has been submitted for approval to an external, properly constituted ethics committee (e.g. NHS Ethics), then please submit a copy of the application and approval letter to the Secretary of the Ethics Sub-Committee. Please note that you will also be required to complete the St Mary's Application for Ethical Approval.

Before completing this form:

- Please refer to the **University's Ethical Guidelines**. As the researcher/ supervisor, you are responsible for exercising appropriate professional judgment in this review.
- Please refer to the Ethical Application System (Three Tiers) information sheet.
- Please refer to the Frequently Asked Questions and Commonly Made Mistakes sheet.
- If you are conducting research with children or young people, please ensure that you read the **Guidelines for Conducting Research with Children or Young People**, and answer the below questions with reference to the guidelines.

Please note:

In line with University Academic Regulations the signed completed Ethics Form must be included as an appendix to the final research project.

If you have any queries when completing this document, please consult your supervisor (for students) or School Ethics Sub-Committee representative (for staff).

St Mary's Ethics Application Checklist

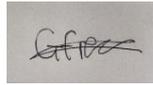
The checklist below will help you to ensure that all the supporting documents are submitted with your ethics application form. The supporting documents are necessary for the Ethics Sub-Committee to be able to review and approve your application.

Please note, if the appropriate documents are not submitted with the application form then the application will be returned directly to the applicant and may need to be resubmitted at a later date.

Document	Enclosed? (delete as appropriate)		Version No
	Yes	Not applicable	
1. Application Form	Mandatory		
2. Risk Assessment Form	Yes		
3. Participant Invitation Letter	Yes		
4. Participant Information Sheet	Mandatory		
5. Participant Consent Form	Mandatory		
6. Parental Consent Form		N/A	
7. Participant Recruitment Material - e.g. copies of Posters, newspaper adverts, website, emails		N/A	
8. Letter from host organisation (granting permission to conduct the study on the premises)	Yes		
9. Research instrument, e.g. validated questionnaire, survey, interview schedule		N/A	
10. DBS (to be sent separately)		N/A	
11. Other Research Ethics Committee application (e.g. NHS REC form)		N/A	
12. Certificates of training (required if storing human tissue)		N/A	

I can confirm that all relevant documents are included in order of the list and in one PDF document (any DBS check to be sent separately) named in the following format: **Full Name, School, Supervisor.**

Signature of Applicant:



Signature of Supervisor:



Ethics Application Form

1) Name of proposer(s)	Gavin Frecklington
2) St Mary's email address	135217@live.smuc.ac.uk
3) Name of supervisor	Dr Daniel Cleather

4) Title of project Relationship between change of direction and unilateral vertical and horizontal reactive strength
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5) School or service	St Mary's University
6) Programme (whether undergraduate, postgraduate taught or postgraduate research)	MSc – Strength and Conditioning
7) Type of activity/research (staff/undergraduate student/postgraduate student)	MSc student

8) Confidentiality

Will all information remain confidential in line with the Data Protection Act 1998?	YES
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9) Consent

Will written informed consent be obtained from all participants/participants' representatives?	YES
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10) Pre-approved protocol	
Has the protocol been approved by the Ethics Subcommittee under a generic application?	YES/NO/Not applicable Date of approval: not yet

11) Approval from another Ethics Committee	
a) Will the research require approval by an ethics committee external to St Mary's University?	NO
b) Are you working with persons under 18 years of age or vulnerable adults?	NO

12) Identifiable risks	
a) Is there significant potential for physical or psychological discomfort, harm, stress or burden to participants?	NO
b) Are participants over 65 years of age?	NO

c) Do participants have limited ability to give voluntary consent? This could include cognitively impaired persons, prisoners, persons with a chronic physical or mental condition, or those who live in or are connected to an institutional environment.	NO
d) Are any invasive techniques involved? And/or the collection of body fluids or tissue?	NO
e) Is an extensive degree of exercise or physical exertion involved?	NO
f) Is there manipulation of cognitive or affective human responses which could cause stress or anxiety?	NO
g) Are drugs or other substances (including liquid and food additives) to be administered?	NO
h) Will deception of participants be used in a way which might cause distress, or might reasonably affect their willingness to participate in the research? For example, misleading participants on the purpose of the research, by giving them false information.	NO
i) Will highly personal, intimate or other private and confidential information be sought? For example sexual preferences.	NO
j) Will payment be made to participants? This can include costs for expenses or time.	NO

k) Could the relationship between the researcher/ supervisor and the participant be such that a participant might feel pressurised to take part?	NO
l) Are you working under the remit of the Human Tissue Act 2004?	NO

13) Proposed start and completion date
<p>Please indicate:</p> <ul style="list-style-type: none"> • When the study is due to commence. • Timetable for data collection. • The expected date of completion. <p>Please ensure that your start date is at least 3 weeks after the submission deadline for the Ethics Sub-Committee meeting.</p>
<p>Recruitment for the study will begin February 2017 after ethical approval.</p> <p>It is anticipated that data collection will begin in February/March 2017 and be completed by the March 2017. This project will be submitted for marking in May 2017</p>

14) Sponsors/Collaborators
<p>Please give names and details of sponsors or collaborators on the project. This does not include your supervisor(s) or St Mary's University.</p> <ul style="list-style-type: none"> • Sponsor: An individual or organisation who provides financial resources or some other support for a project. • Collaborator: An individual or organisation who works on the project as a recognised contributor by providing advice, data or another form of support.

Collaborators on this project are going to be Reading Rockets basketball club and John Madejski academy who have kindly agreed to provide the facilities and athletes for data collection.

15. Other Research Ethics Committee Approval

- Please indicate whether additional approval is required or has already been obtained (e.g. the NHS Research Ethics Committee).
- Please also note which code of practice / professional body you have consulted for your project.
- Whether approval has previously been given for any element of this research by the University Ethics Sub-Committee.

N/A

16. Purpose of the study

In lay language, please provide a brief introduction to the background and rationale for your study. *[100 word limit]*

- Be clear about the concepts / factors / performances you will measure / assess/ observe and (if applicable), the context within which this will be done.
- Please state if there are likely to be any direct benefits, e.g. to participants, other groups or organizations’.

Agility and change of direction (COD) is a commonly used skill in many sports and while research on the development of the cognitive component is well established the research on the physical qualities that underpin the skill is not (Paul, Gabbett, & Nassis, 2015; Young & Farrow, 2006). I propose to assess any correlations between unilateral reactive strength using reactive strength index as a measure, ground contact times and a change of direction of 45 and 90 degrees. The study will be conducted within a sports hall with subjects that are familiar with rapid changes of direction. A benefit to the athletes taking part will be they will receive a report on their performance and a summary of the findings.

References

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17. Study Design/Methodology

In lay language, please provide details of:

- a) The design of the study (qualitative/quantitative questionnaires etc.)
- b) The proposed methods of data collection (what you will do, how you will do this and the nature of tests).
- c) You should also include details regarding the requirement of the participant i.e. the extent of their commitment and the length of time they will be required to attend testing.
- d) Please include details of where the testing will take place.
- e) Please state whether the materials/procedures you are using are original, or the intellectual property of a third party. If the materials/procedures are original, please describe any pre-testing you have done or will do to ensure that they are effective.

The design of the proposed study will be quantitative whereby I aim to collect data from subjects performing multiple jumps, 5m straight line accelerating and running at a specified speed then performing a pre-planned change of direction at either 45 or 90 degrees in an indoor sports hall.

Prior to any testing the subjects will be taken through ten minutes movement specific warm up led by a UKSCA accredited coach. Subjects will be advised not to ingest any stimulating supplements or caffeinated drinks 24 hours before testing and will be asked to refrain from any strenuous activity 48 hours before testing. The participants will be encouraged to stay hydrated with the consumption of water both prior and during testing.

I plan to have three testing days which will include familiarisation of specific running speeds, jump technique and change of direction test and data collection of all the tasks. Testing days will be conducted at the same time of the day 48 hours apart.

Day one will consist of data collection of anthropometric (weight and height) familiarisation of the correct running speeds and jumping techniques.

Day two will consist of data collection of sprint test and all jumps (12 total) and then familiarisation change direction tests at an angle of 45 degrees and 90 degrees.

Day three will consist of data collection of the change of direction tests (18 total).

Running speeds protocol

Participants will change direction immediately after traveling at a predetermined speed of 2m, 4m and 6m per second. To teach the participants how to run at the specified speeds they will practice running a 24m straight line between evenly lined out cones at the specific distances (2,4 or 6m) with the aim of simultaneously passing the cone to the sound of a metronome set at one second. Practice will be conducted from slow to fast.

5 meter sprint protocol

In order to test the participants' acceleration they will complete a 5m sprint test. Testing procedures will have the subjects starting from a static position in an athletic stance between two light gates which will be set at 5 meters apart. Participants will perform three maximum sprints with a 180 second rest between attempts and the best times will be used for analysis.

Jump protocol

Data of bilateral and unilateral vertical and horizontal jumps will be collected to assess the participants' reactive strength. In order to collect data to assess for the bilateral vertical jump participants will perform a depth jump off a 30cm box onto a force plate then immediately jump.

In order to establish the reactive strength index the flight time and contact time will be used. The same procedure will be used to collect data for the unilateral vertical jump however subjects will use a 10cm box and will land and jump off one leg. To collect data for horizontal jumps the subject will follow the same procedure as above for both bilateral and unilateral jumps but will jump forward for maximal distance. To establish a reactive strength index for horizontal jumping data will use contact time and

distance covered. The distance will be measured from the end of the toe to the back of the heel of the back foot. Jumps will be completed in a randomized order and three jumps per direction will be attempted with 120 seconds rest between jumps and the best reactive strength index will be used for comparison. The order of jumps will be randomised.

Change of direction protocol

The subjects will be required to perform a linear 12m run at a specified speed then change direction at an angle of 45 degrees and 90 degrees as fast as possible and accelerate a further 5m as fast as possible. The subjects will travel in a direction of their choice and the time it takes them to travel the last 5m will be used for analysis.

The subjects will run the 12m straight line between three light gates located at the start, middle and end to monitor that the subjects are travelling at the specified speed. The participants must be travelling at a constant speed before they change direction and there will be a leniency of 250ms of the specified speeds and times outside of this will not be used for analysis.

A box measured 20 inches square will be marked on the floor at the 12m mark and the subjects must perform the change of direction within that box. The time it takes from the initiation of the plant foot (outside foot) to completion of the 5m sprint will be collected and used for comparison.

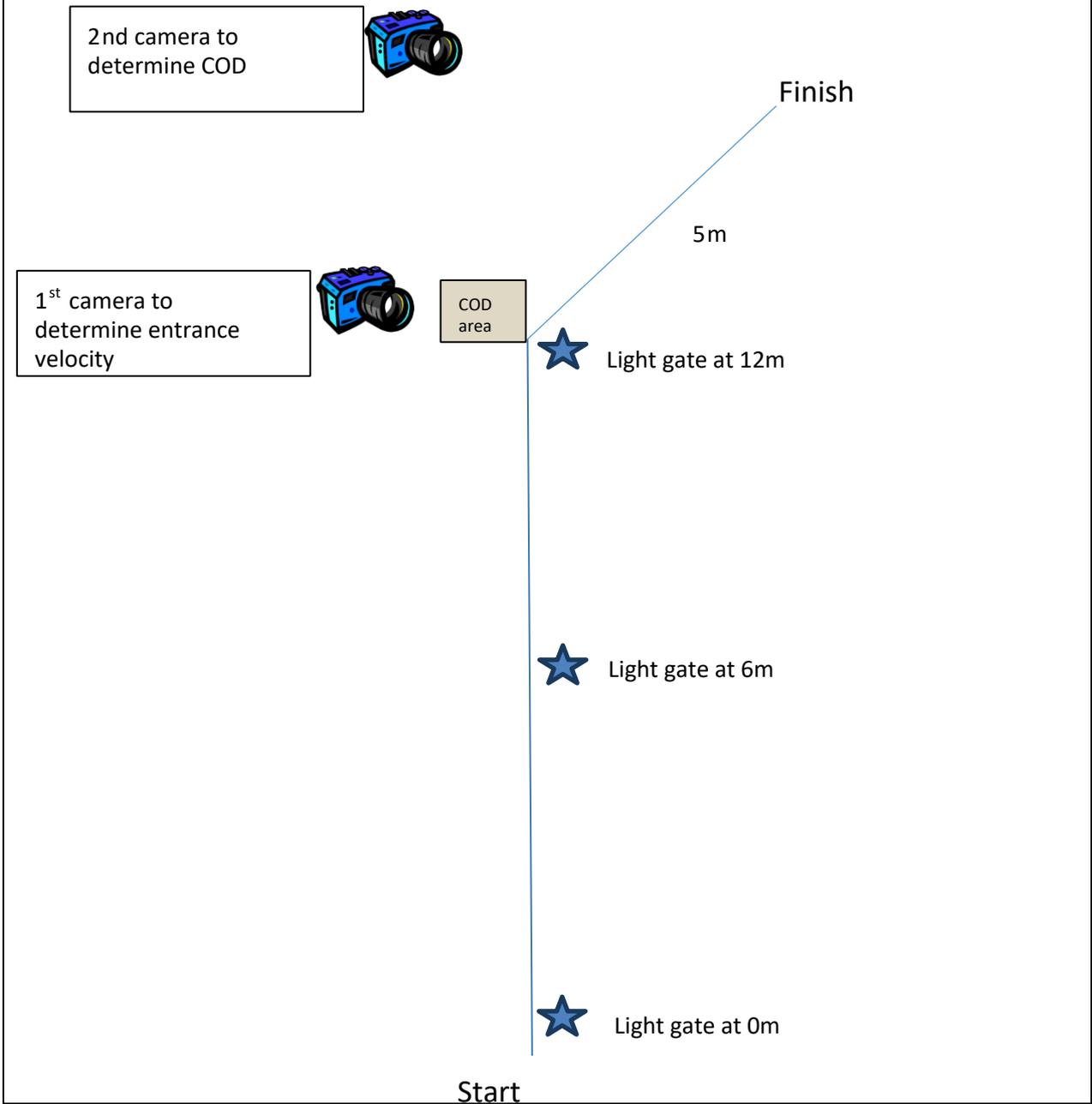
The subjects will perform two change of direction runs at each of the specified speeds so they will run twice at 2m per second, twice at 4m per second and twice at 6m per second then cut at an angle of 45 degrees and the same will be repeated at an angle of 90 degrees. This means each individual will perform 12 change of direction runs in total. The order of entry speed and cutting angle will be randomised. Each individual will have a rest period of 120 seconds between attempts. For each failed run due to incorrect entry speed the subject will have a 120 rest then retake the run.

The direction (left or right) that the individuals perform will be predetermined and decided by themselves during the familiarisation phase and they be encouraged to choose the direction they are most comfortable with and one that allows them the best performance.

Slow motion camera analysis

Slow motion cameras will be used to collect the time it takes the participants to change direction. The time from the plant foot (outside foot) striding down within the box at the 12m mark to the time the individual passes the 5m mark will be used for analysis. As well as the total time to complete 5m I will collect the ground contact times of the first three steps. The camera will be located so the 5m stretch can clearly be visible. An additional camera will be used and focused on the area on and just before the change of direction box to calculate the entrance velocity.

Change of direction of 45 degrees set up example



18. Participants

Please mention:

- a) The number of participants you are recruiting and why. For example, because of their specific age or sex.
- b) How they will be recruited and chosen.
- c) The inclusion/exclusion criteria.
- d) For internet studies please clarify how you will verify the age of the participants.
- e) If the research is taking place in a school or organisation then please include their written agreement for the research to be undertaken.

- a) I will recruit 30 participants. They will be recruited on the basis that they already have developed the required skill to complete the test automatically which should reduce variables during analysis.
- b) Participants must be healthy adult males aged 18-45 and free of injury. They must be physically active and participate in multidirectional sports a minimum of two times per week and have done for more than 12 months. The subject will be recruited from basketball teams, rugby teams and chosen based on the above criteria.
- c) The participants must be able to competently complete all the tests required with good techniques. If a subject is unable to competently complete any of the testing to a level that is deemed acceptable by the supervising strength and conditioning coach then the subjects will be excluded from the study. Subjects will also be excluded if they display any injuries or inability to maximally exert themselves.

19. Consent

If you have any exclusion criteria, please ensure that your consent Form and Participant Information Sheet clearly makes participants aware that their data may or may not be used.

- a) Are there any incentives/pressures which may make it difficult for participants to refuse to take part? If so, explain and clarify why this needs to be done
- b) Will any of the participants be from any of the following groups?
 - Children under 18
 - Participants with learning disabilities
 - Participants suffering from dementia
 - Other vulnerable groups.
- c) If any of the above apply, does the researcher/investigator hold a current DBS certificate? A copy of the DBS must be supplied **separately from** the application.
- d) How will consent be obtained? This includes consent from all necessary persons i.e. participants and parents.

- a) NO
- b) NO
- c) N/A
- d) All participants must sign and return back a consent and Physical Activity Readiness Questionnaire form prior to the first day. They will also be given an information sheet which will explain everything they need to know about the research.

20. Risks and benefits of research/ activity

- a) Are there any potential risks or adverse effects (e.g. injury, pain, discomfort, distress, changes to lifestyle) associated with this study? If so please provide details, including information on how these will be minimised.
- b) Please explain where the risks / effects may arise from (and why), so that it is clear why the risks / effects will be difficult to completely eliminate or minimise.
- c) Does the study involve any invasive procedures? If so, please confirm that the researchers or collaborators have appropriate training and are competent to deliver these procedures. Please note that invasive procedures also include the use of deceptive procedures in order to obtain information.
- d) Will individual/group interviews/questionnaires include anything that may be sensitive or upsetting? If so, please clarify why this information is necessary (and if applicable, any prior use of the questionnaire/interview).
- e) Please describe how you would deal with any adverse reactions participants might experience. Discuss any adverse reaction that might occur and the actions that will be taken in response by you, your supervisor or some third party (explain why a third party is being used for this purpose).
- f) Are there any benefits to the participant or for the organisation taking part in the research (e.g. gain knowledge of their fitness)?

- a) Participants will experience moderate physical stress during the study. However the level of stress should not be indifferent from the stress and forces that act upon the subjects during participation of their sports.
- b) There are minimal risks involved in the testing as subjects will undergo strict familiarisation training under the supervision of a UKSCA accredited coach. The same coach will also be supervising the trial and if they feel any of the subject's safety is compromised through insufficient technical competency then the subject will be excluded. If the subjects are unable to technically complete the desired task during familiarisation training they will also be exempt from trial.
- c) NO
- d) NO
- e) If any of the subjects are injured as result of taking part in the study an onsite first aided will be called to assist in administering support to the participant and deciding whether medical treatment is needed.
- f) The subjects will be provided with verbal feedback of their test results but any information is initially unlikely to benefit them however they will be provided with a summary of findings which will give them an insight to their reactive strength and change of direction abilities.

21. Confidentiality, privacy and data protection

a) What steps will be taken to ensure participants' confidentiality?

- Please describe how data, particularly personal information, will be stored (all electronic data must be stored on St Mary's University servers).
- Consider how you will identify participants who request their data be withdrawn, such that you can still maintain the confidentiality of theirs and others' data.

b) Describe how you will manage data using a data a management plan.

- You should show how you plan to store the data securely and select the data that will be made publically available once the project has ended.
- You should also show how you will take account of the relevant legislation including that relating data protection, freedom of information and intellectual property.

c) Who will have access to the data? Please identify all persons who will have access to the data (normally yourself and your supervisor).

d) Will the data results include information which may identify people or places?

- Explain what information will be identifiable.
- Whether the persons or places (e.g. organizations) are aware of this.
- Consent forms should state what information will be identifiable and any likely outputs which will use the information e.g. dissertations, theses and any future publications/presentations.

- a) All data and personal information will be stored on St Mary's university servers and will only be accessible by the research group. All participants will not be referred to by name throughout the study and will be assigned a numbered code that will only be known by the research group to protect the identity and associated information. If anyone withdraws from the study all their information and data that has been collected for that individual will be destroyed. All information will be disposed of after 5 years.
- b) All information will be protected by a password on St Mary's servers and the password will be known by the research group. The individuals information will be number coded to ensure no individuals information will be directly associated to their name. Only the numbered code will be made public when the project is made public to protect the identity of the individual's results.
- c) Gavin Frecklington, Dr Daniel Cleather
- d) No

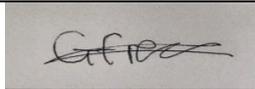
22. Feedback to participants

Please give details of how feedback will be given to participants:

- As a minimum, it would normally be expected for feedback to be offered to participants in an acceptable to format, e.g. a summary of findings appropriately written.
- Please state whether you intend to provide feedback to any other individual(s) or organisation(s) and what form this would take.

Feedback will be offered to the participants as a summary of findings appropriately written. Feedback will not be provided to any other individuals or organizations.

The proposer recognises their responsibility in carrying out the project in accordance with the University's Ethical Guidelines and will ensure that any person(s) assisting in the research/teaching are also bound by these. The Ethics Sub-Committee must be notified of, and approve, any deviation from the information provided on this form.

Signature of Proposer(s)	Date: 31/12/16
	

Signature of Supervisor (for student research projects)

A handwritten signature in black ink, consisting of a stylized 'J' followed by a horizontal line and a small flourish.

Date:

10/01/17

2. Approval form

Name of applicant: Gavin Frecklington

Name of supervisor: Daniel Cleather

Programme of study: MSc in Strength and Conditioning

Title of project: Relationship between change of direction and unilateral vertical and horizontal reactive strength

Supervisors, please complete section 1 or 2. If approved at level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

SECTION 1

Approved at Level 1

Signature of supervisor (for student applications).....

Date.....

SECTION 2

Refer to School Ethics Representative for consideration at Level 2 or Level 3

Signature of supervisor..... 

Date.....10/01/17.....

SECTION 3

To be completed by School Ethics Representative

Approved at Level 2

Signature of School Ethics Representative.....

Date.....

SECTION 4

To be completed by School Ethics Representative. Level 3 consideration required by the Ethics Sub-Committee (including all staff research involving human participants)

Signature of School Ethics Representative.....

Date.....

Level 3 approval – confirmation will be via correspondence from the Ethics Sub-Committee

3. Participant information sheet

Participant information sheet

Section A: The Research Project

Title of project

Relationship between change of direction and unilateral vertical and horizontal reactive strength

You are being invited to take part in a research project. Please read this information sheet to familiarise yourself with the requirements and procedures involved and please feel free to discuss anything with us if you have any questions. Thank you for reading:

Purpose and value of study

Agility and change of direction are very important physical qualities when playing sport yet very little is known about what physical qualities need to be developed to improve this skill. The aim of this study is determine if reactive strength can help develop the ability of an athlete to change direction which can carry over to tasks such as evading a defender.

Invitation to participate

You have been chosen to participate in this study because you are a healthy male aged 18-45 who is physically fit and participates in a multidirectional sport regularly.

Who is organising the research

The research is being organised by Gavin Frecklington (MSc strength and conditioning student) under the supervision of Dr Daniel Cleather (St Mary's University MSc strength and conditioning course director)

What will happen to the results of the study?

After the study is complete you will be given a summary of finding which will explain what the project found and concluded. You will not receive other participant's results nor will your results be given to other organisations.

Source of funding for the research

There is no external funding for this study

Contact for further information

To find any further information please contact Gavin Frecklington
(135217@live.smuc.ac.uk)

Section B: Your Participation in the Research Project

Can you refuse to take part?

You are under no obligation to take part in this research and if you initially agree to take part then decide not to no questions will be asked and you will not be penalised.

Can you withdraw from the project at any time, and how?

You are free to withdraw from the study at any time and all you will be required to do is inform any members of the research team or email the above address.

What will happen if you agree to take part (brief description of procedures/tests?)

There will be three testing days which will include familiarisation of specific running speeds, jump and change of direction techniques and then data collection of the tests. The testing days will be embedded within your technical training sessions or strength and conditioning training so will not require additional time commitments from you.

Day one will consist of data collection of anthropometric (weight and height) familiarisation running at speeds of 2m, 4m and 6m per second and both single and double leg jumping in vertical and horizontal directions.

Day two will consist of data collection of a 0-5 meter sprint and all jump tests (12 total) and then familiarisation of running with a change direction at an angle of 45 degrees and 90 degrees.

Day three will consist of data collection of change of direction tests which requires you to run at a constant speed then change direction as fast as possible at an angle of 45 degrees and the same thing will be repeated for 90 degrees.

Are there any risks involved (e.g. side effects) and if so, what will be done to ensure your wellbeing/safety?

Any physical participation will involve an element of risk however the risk should be no higher than participation in your sport. All necessary precautions will be implemented to reduce the risk of injury occurring and your safety throughout the investigation is priority to the researcher who is an accredited strength and conditioning coach by the UK Strength and Conditioning Association and first aid qualified.

Are there any special precautions you must take before, during or after taking part in the study?

You are asked not ingest any stimulating supplements or caffeinated drinks within 24 hours of testing. Also please refrain from participation within any strenuous activity for 48 hours prior to study. Please stay hydrated with the consumption of water both before and during testing.

What will happen to any information/data/samples that are collected from you?

All data and personal information and data collected will be password protected and stored on St Mary's university servers and will only be accessible by the research group. Your identity will not be made public and any personal information after the study will be destroyed. The researchers will comply with the Data Protection Act (1998).

Are there any benefits from taking part?

Although there may not be any initial benefits from taking part in the study you will gain an insight into your own reactive strength and change of direction abilities especially compared to your peers. However any findings will help support and shape the way your strength and conditioning coach chosen to prepare you for your sport.

How much time you will need to give up to take part in the project/

You will not be required to dedicate any extra time outside of your own technical or strength and conditioning training as the research will be embedded within your allocated times.

St Mary's University information

Address: Waldegrave Road, Strawberry Hill, Twickenham, London, TW1 4SX

Telephone: 020 8240 4000

Fax: 020 8240 4255

YOU WILL BE GIVEN A COPY OF THIS FORM TO KEEP TOGETHER WITH A COPY OF YOUR CONSENT FORM

4. Participant consent form

Name of Participant: _____

Title of the project: Relationship between change of direction and unilateral vertical and horizontal reactive strength

Main investigator and contact details: Gavin Frecklington (135217@live.smuc.ac.uk), Daniel Cleather (daniel.cleather@stmarys.ac.uk)

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: Relationship between change of direction and unilateral vertical and horizontal reactive strength

I WISH TO WITHDRAW FROM THIS STUDY

Name: _____

Signed: _____ Date: _____