Testing the constrained action hypothesis – the impact of internal and external cues on vertical jump and change of direction performance in trained and sedentary populations.

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## Acknowledgements

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completion of this piece of work.

Abstract

The impact of internal (INT) and external (EXT) cues on vertical jump (VJ) and change of direction (CoD) performance was examined in contrasting groups. Fourteen subjects participated, divided into two groups. Group one (n=8, age:27±5 years; body mass 78.4±8.0kg) were experienced athletes. Group two (n=6, age:27±4 years; body mass 74.7±13.6kg) were sedentary. Subjects performed 9 VJ and 12 CoD trials following INT, EXT and neutral (CONT) cues. Ground reaction forces were gathered by force plates for all performances. No interaction between experience and condition in VJ was found ($F_{(10,3)}=4.396$; $p=0.13$). Comparisons revealed velocity, power and impulse were greater in EXT compared with INT ($p\leq0.05$) for all subjects, with no difference for height or force ($p>0.05$). An interaction between experience and condition was found for time to maximum force on left CoD turns ($F_{(2,24)}=4.118$; $p=0.02$), with it significantly longer for sedentary performers. Comparisons for all subjects revealed EXT produced quicker trials than CONT ($p<0.01$). CONT produced lower impulse than INT ($p=0.01$). Time to maximum force on left turns was faster in EXT than INT ($p=0.03$). The study supports the constrained action hypothesis, but questions the role of automaticity. Instead, it would beneficial to examine cognitive demand, considering additional influencing factors.


Key Words: coaching practices, verbal instructions, attention focus

**Testing the constrained action hypothesis – the impact of internal and external cues on vertical jump and change of direction performance in trained and sedentary populations.**

Research investigating vertical jump (VJ) (Ford et al., 2005; Wulf & Dufek, 2009; Wulf, Dufek, Lozano, & Pettigrew, 2010) and change of direction performance (CoD) (Porter, Nolan, Ostrowski, & Wulf, 2010) suggests the use of cues focussing attention on external (EXT) factors positively impact performance compared with cues generating internal (INT) focus. However, universal application of this effect appears assumptive, as highlighted by a range of counter arguments to currently published research (Maurer & Zentgraf, 2007; Mullen, 2007; Toner & Moran, 2007; Weigelt, Schack, & Kunde, 2007; Wrisberg, 2007).

A common theme in these counter arguments is the lack of consideration given to individual differences between subjects (McPherson, 2000; Perkins-Ceccato, Passmore, & Lee, 2003). Whilst differences are potentially numerous, a factor of importance to the coach is prior experience in the chosen activity. The majority of work examining this area has used untrained populations, whom have limited experience; largely overlooking that experience of the athletic population may impact upon cue effectiveness (Wulf and Su, 2007).

Much research refers to the constrained action hypothesis (CAH) as an explanation for improved outcomes achieved in the presence of EXT cues (Wulf, 2007). This theory suggests that INT cues interfere with automaticity of performance by inhibiting coordination, with EXT cues permitting the performer to exert control subconsciously, allowing a degree of 'self-organisation' (Wulf, 2007). Wulf (2007) describes self-organisation as a state in which little attention to technical aspects of performance is required, with a successful outcome generated. This has proven difficult to quantify, although Lohse, Sherwood, and Healy (2011), Vance, Wulf, Tollner, McNevin, and Mercer (2004) and Wulf et al. (2010) identified that electromyographic activity of muscles decreases with provision of EXT cues, suggesting

movement becomes more economical, and self-organisation is present. Wulf (2007) proposes that there is a link between the muscular activity observed in a given movement, and the degree of self-organisation present. It is suggested that greater muscular activity indicates that an individual is exerting conscious control over specific technical components, whereas less muscular activity is associated with subconscious control. However, this theory is yet to be supported by research, and appears to be a substantial limitation of the CAH.

The cognitive theory of motor development (Fitts & Posner, 1967) assists in identifying how experience differences may impact upon performance automaticity. The model provides three stages of skill development: cognitive, associative and autonomous. This theory proposes that as learners become more skilled, they move through each stage, ultimately leading to an autonomous performance. Each stage is characterised by changes in cognitive demand and sources of input during performance, with those in earlier stages of learning faced with larger cognitive demands, exerting conscious control over movements, with experienced performers utilising subconscious control. This theory has been supported by research in a range of learning situations (Tenison & Anderson, 2015; O and Hall, 2009).

Wulf (2007) suggests that inexperienced performers in the cognitive or associative stages of learning are likely to focus internally during performance of an unfamiliar skill, whereas experienced performers will be largely autonomous and therefore afford attention to external stimuli due to this skill familiarity. It is debatable as to whether the provision of an EXT cue would have a similar impact on groups of different experience levels, given focus preferences will likely vary. Furthermore, as experienced performers are likely to be more automatic, interference with this automaticity through the use of INT cues may be of greater detriment than it would be to those where automaticity is lacking. Despite this apparent flaw in the hypothesis, there is limited research investigating this.

Weigelt et al. (2007) and Wrisberg (2007) highlighted that many actions investigated in the currently published research involved EXT targets, such as basketball shooting or putting in golf. They suggest that it is unsurprising that success is higher with the provision of EXT cues in performances that are measured by the outcome in relation to an EXT target. Its logical that if subjects focus on the performance measure during execution, the outcome will be better than when focussing on something other than this. Therefore, the selection of VJ and CoD within this study removed obvious external targets, allowing a comparison to be drawn in which EXT conditions could be created without the need to draw attention to a specific outcome. This allowed a fairer comparison between INT and EXT conditions, as whilst both cues had a different focus of attention, they focused on the same part of the performance. This has not been the case in previous work examining the CAH.

Finally, the chosen performance measures were of moderate complexity, meaning both trained and sedentary populations were capable of executing the skills. Skills that were perhaps too simple may have been insufficient in generating differences in performance automaticity between groups, and skills that were too complex would have potentially placed sedentary subjects in a situation where successful performance was not achieved, or injury risk was high.

It is hypothesised that EXT cues will generate optimal performance in both tests, in both groups. INT cues are expected to hinder performance in both groups, but to a greater extent in the trained population. The rationale for this is based on the CAH. The trained population are likely to be at an autonomous stage of development in both tests, with a focus placed on INT aspects likely to interrupt normal performance. As VJ is likely to be a more familiar skill to the sedentary population than CoD, and therefore more automatic, it is hypothesised that INT cues will be more detrimental to VJ than CoD. It is anticipated that

sedentary performers will demonstrate an INT focus preference during control (CONT) trials, with trained performers favouring an EXT focus, according to the CAH.

**Methods**

**Experimental Approach to the Problem**

This study aims to establish if the pattern of positive effect associated with EXT cues could be applied equally to experienced and sedentary populations. This will be achieved through completion of the following aims.

- Compare the impact of INT and EXT cues on VJ and CoD performance in experienced and sedentary populations.

- Establish how each population prefer to focus attention during VJ and CoD performance in the absence of verbal instruction.

- Measure the impact of cues on kinetic and kinematic features of VJ and CoD performance.

The study utilised a within-subject repeated measures quantitative design, requiring the creation of two groups: trained and sedentary. Comparing the impact of the cues on each group allowed the CAH to be tested as these groups in theory were at opposite ends of Fitts and Posner's motor development model, and as such had differing levels of automaticity.

**Subjects**

A total of fourteen subjects participated, with subjects divided into two groups, depending upon activity level and experience. Suitability for participation and subject grouping was determined through completion of physical activity readiness and exercise history questionnaires. Group one participants (n=8, age: 27 ± 5 years; height: 1.76 ± 0.03m; body mass 78.4 ± 8.0 kg) had experience in VJ and CoD performance. Participants were recruited from local teams in sports where these skills are central to performance and would be trained regularly. Five participants competed in soccer, two in netball, and one in Australian Rules football. Group one subjects had participated in their sport and associated training frequently (average of >3 times per week) for a minimum of 3 years. Subjects had to

have engaged in both agility/CoD and plyometric training for a combined period of 6 months in this 3-year period.

Group two participants (n=6, age: 27 ± 4 years; height: 1.72 ± 0.05m; body mass 74.7 ± 13.6 kg) were sedentary, and had no VJ and CoD experience. Sedentary was defined as not meeting the government physical activity guidelines of a minimum of thirty minutes of activity per day, over the past year. Additionally, subjects had no consistent participation at any time in the identified sports or any other sport that may require CoD or jumping. This group had never participated in any plyometric or CoD training. Group two subjects were recruited from the student base of FIA Fitnation, Sydney, Australia. There was no significant difference in either height or body mass between the two groups (p>0.05). Participants in both groups were injury free in the previous 6 months, and aged 18-35 years. Ethical approval was obtained from the Ethics Committee of St Mary's University, London, Twickenham prior to study commencement.

**Procedures**

Subjects were provided with an information sheet and informed consent form, outlining all procedures, pre-test requirements, data storage and rights to cease participation. On review of these documents and the provision of consent, subjects were permitted to progress to testing if all requirements were met.

Subjects attended three testing dates no less than 48 hours apart, and no more than seven days apart. Sessions were forty minutes in duration, with subjects tested in three conditions: CONT, INT and EXT. In testing session one, subjects performed in the CONT condition for both tests to minimise potential impact of prior cues. In sessions two and three, subjects performed in either INT or EXT conditions, the order of which was determined randomly, with the subject picking one of two envelopes containing the possible conditions. Subjects were unaware of the conditions prior to participation. In each condition, three VJ

tests were performed with two minutes rest between jumps, and four 5-10-5 Pro-Agility runs with three minutes rest between each performance.  The VJ tests were performed first in each of the testing sessions.  The researcher deemed that the dynamic nature of CoD testing had greater potential to produce fatigue that may negatively impact upon subsequent performances.  Whilst steps were taken to negate this effect in the rest periods provided, it was felt that placing jumps first in testing session could contribute further to test reliability.

At the beginning of testing session one, subject height was measured with a stadiometer (SECA, 2015).  The subject's dominant foot was recorded to inform analysis of CoD.  This was determined by the inclusion of a question of foot preference within the exercise history questionnaire.  Prior to each session, subjects completed a standardised warm up as shown in Table 1.

Table 1.

*Pre-Test Warm Up*

| Exercise | Sets | Reps |
|----------|------|------|
| Walking lunges | 2 | 10 |
| Walking toe touch | 2 | 10 |
| Knee lifts | 2 | 10 |
| Twisting lunges | 2 | 10 |
| Pivot and squat | 2 | 10 |
| High knees | 2 | 10 |
| Heel flicks | 2 | 10 |
| Vertical Jump | 1 | 5 |
| 10m shuttle runs | 2 | 4 |

**Instrumentation.** For each jump and CoD performed, ground reaction forces (GRF) were recorded in Newtons (N) at a rate of 1000 Hertz (Hz) through two force plates (PASCO Scientific, PASPORT PS-2141 [Force plates]. Roseville, CA. ). Plate stability was ensured through manipulation of adjustable feet. Plates were connected to a laptop with PASCO PS-2100A USB links with PASCOcapstone™ (PASCO Scientific, 2015) display and analysis software used to gather data.

**Vertical Jump.** Force plates were placed side by side on a flat and hard surface. GRF was recorded on both force plates from prior to jump performance until completion of landing. The forces gathered from each plate were summed to provide overall GRF for each jump. Data was entered into an Excel spread sheet for completion of the integration method, determining the subject's weight, mass, jump height, impulse, velocity and power, from which maximal values were obtained. The integration method is a mathematical model that makes use of the trapezium rule. The equations for this model are shown in Figure 1 below.

Figure 1. Integration Method

Force data gathered.  Subject weight (N) calculated by:
Average Force 0.001 to 1.000 seconds*
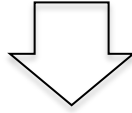
Net force (N) calculated at 0.001 second intervals by:
Total force (N) – Subject weight (N)
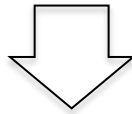
Impulse (Ns) calculated at 0.001 second intervals by:
(((Net Force Value 1+ Net Force Value 2)/2)*0.001) + Previous Impulse**
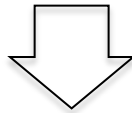
Velocity (m/s) calculated at 0.001 second intervals by:
Impulse(Ns)/Mass(kg)
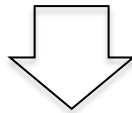
Jump height (m) calculated at 0.001 second intervals by:
(Velocity x 0.001) + Previous Displacement ***
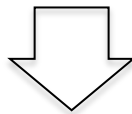
Power (W) calculated at 0.001 second intervals by:
Absolute Force (N) x Velocity (m/s)

*Note.* * = Subject was standing still during this time; ** = Initial impulse value was zero; *** = Initial displacement was zero.  N = Newtons; Ns = Newton seconds; m/s = metres per second; kg = kilograms; m = metres; W = Watts.

Subjects were instructed to step onto the plates with one foot on each device, standing as still as possible until cue delivery. The appropriate cue was provided, with subjects instructed to perform on the command 'jump' 5 seconds later. Subjects had to perform each jump with a counter swing of the arms and land with two feet on the plates, remaining in position until further instruction. If the landing did not meet this criterion, the jump was repeated. This process was replicated for each jump in all conditions.

Following each CONT VJ trial, subject were asked 'what were you focussing on as you jumped?' This was then categorised as INT, EXT or neutral, and noted for each trial.

In order to build familiarity with jumping technique, it was included within the warm up at submaximal level prior to each session, with a demonstration of technique provided. During warm up delivery, only neutral cues were communicated, minimising impact on subsequent performance. The cues provided to subjects in each VJ trial are shown in Table 2.

**Change of Direction Test.** The 5-10-5 Pro-Agility test required subjects to start at the half way mark between two points 10 metres apart. The subject stood facing forwards, in a forward lean position, with one hand positioned on the ground and feet either side of the halfway mark. Subjects ran five metres in the direction matching the grounded hand, turning 180 degrees (°), covering a further ten metres before turning 180°, sprinting back towards the start line. The test was repeated four times in each condition, with the subject starting in each direction twice. This is shown in Figure 2.

Figure 2. Pro Agility 5-10-5 Test
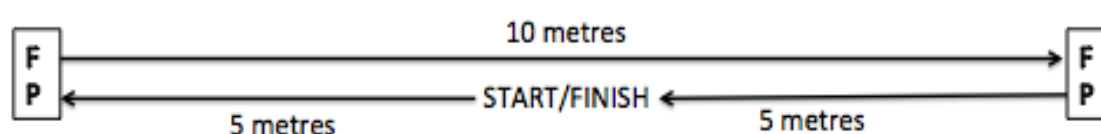


*Note.* The above figure represents a trial starting with movement to the left. FP = Force plate.

Gym floor tiles were removed, allowing force plates to be flush with the performance surface. Coloured tape was placed in the centre of the plate as a guide for the participant as to where foot contact should occur. Each plate gathered GRF during contact time with contact time determined by establishing when GRF exceeded 10N until the force value was below 10N. This is consistent with the work of Spiteri et al. (2015).

Data was further analysed in Excel, where rate of force development (RFD) – peak, RFD contact to half peak, and RFD half peak to peak were calculated in Newtons per second (N/s). Additionally, contact time (s), maximum force (N), time to maximum force (s), and relative net impulse (Ns) were established for each turn. For impulse calculations, each participant's weight was halved, as only one foot was contacting the force plate during CoD. The FreeLap Timing System (Freelap USA, Pleasanton, CA) was used to gather performance time (s) for each test. This system is an electronic timing gate system that makes use of a receiver in the form of a stopwatch that senses the magnetic field released by a set of transmitters. The stopwatch is triggered on each occasion that a subject travels in front of a transmitter.

Prior to performance, subjects were provided with a demonstration of the 5-10-5 Pro-Agility test. During delivery of the warm up, only neutrally focused cues were used to minimise impact on subsequent performance. On turning, subjects were required to make a full foot contact with the force plate. Furthermore, subjects had to make the right and left turns with the corresponding feet. If this criterion was not met, a 'no run' was recorded, with the trial repeated. The appropriate verbal cue was provided, with the subject instructed to perform on the command 'go' 5 seconds later. The cues provided to the subjects in each CoD trial are shown in Table 2. The subject activated the timing system on initial movement of the body, stopping the timer when passing through the finish line. This process was repeated for each condition. Following each CONT CoD trial, subject were asked 'what were you

focussing on when you turned?'  This was then categorised as INT, EXT or neutral, and noted

for each trial.


Table 2.

*Cues Provided in Each Trial Condition*

| Cue | VJ | CoD |
|---|---|---|
| INT | '…Focus on straightening your legs explosively…' | '…Focus on straightening your turning leg explosively out of the turn…' |
| EXT | '…Focus on pushing the ground away…' | '…Focus on pushing the ground away coming out of the turn…' |
| CONT | '…Jump as high as you can…' | '…Turn as fast as you can…' |

*Note.*  VJ = Vertical Jump; CoD = Change of direction; INT = Internal; EXT = External; CONT = Control.


**Statistical Analyses.**  SPSS Version 21 (IBM Corp, 2012) was utilised to conduct

statistical analysis of the data.  A one-factor repeated-measures design analysis of variance

(ANOVA) was utilised for both tests to firstly determine any interaction between cueing

condition and the category of subject.  This test was used to establish if differences existed

between means of each measure in each condition for both tests.  The null hypothesis would

be rejected if the *F* value exceeded the critical value at $p<0.05$.  Pairwise comparisons

revealed which means were significantly different ($p \leq 0.05$) from each other, with a

Bonferroni adjustment applied to all tests to account for multiple comparisons.  A Chi-Square

test was used to determine if there was a significant difference ($p<0.05$) in focus preferences

between the two groups for each test.  For all comparisons, the best performance by height

was selected for VJ, and the best performance by time in CoD.

## Results

**Vertical Jump.**  No interaction was established between training experience and cueing condition in relation to any performance outcomes ($F_{(10,3)} = 4.40$, $p = 0.13$).  Completion of the ANOVA established that with subject grouping removed, significant differences existed for velocity ($F_{(2,24)} = 6.22$, $p < 0.01$), impulse ($F_{(2,24)} = 5.62$, $p = 0.02$), and power ($F_{(2,24)} = 5.84$, $p < 0.01$).  There were no significant differences for height ($F_{(2,24)} = 0.89$, $p > 0.05$) or force ($F_{(1.30,15.7)} = 2.15$, $p > 0.05$).  Further post-hoc testing revealed a trend for enhanced outcomes in EXT conditions, with EXT cues producing larger peak velocity (see Figure 4), peak power (see Figure 5) and relative net impulse (see Figure 6) when compared with INT conditions.  There were no significant differences between CONT and INT or EXT conditions for any performance measure ($p > 0.05$).  Whilst insignificant, jump height was also greatest in EXT conditions (see Figure 3).  Maximum force demonstrated little variance across the three conditions, with mean values of 4006N, 3536N and 3594N for INT, EXT and CONT conditions respectively.  Focus preferences in CONT jump trials revealed a trend for INT or neutral for both groups, as shown in Table 3, with no significant difference between preferences of each group ($p = 0.19$).

Figure 3. Mean Jump Height by Condition
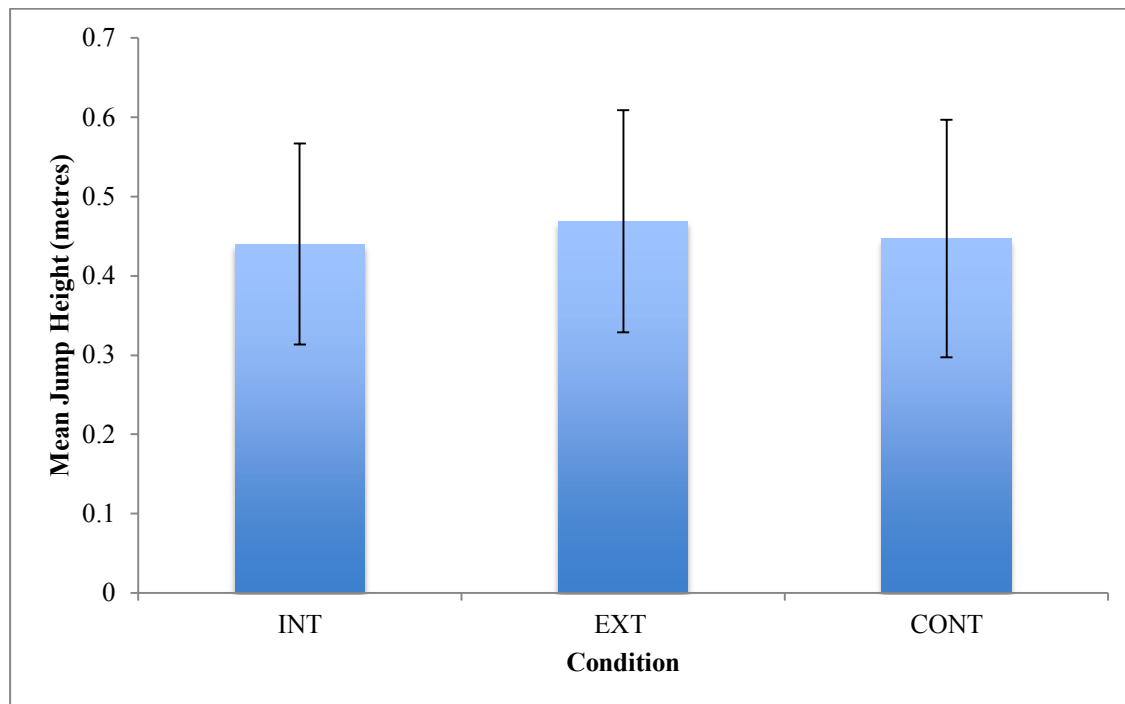


*Note.* Error bars display ± one standard deviation. There were no statistically significant differences between means. INT = Internal; EXT = External; CONT = Control.

Figure 4. Vertical Jump Mean Peak Velocity by Condition.
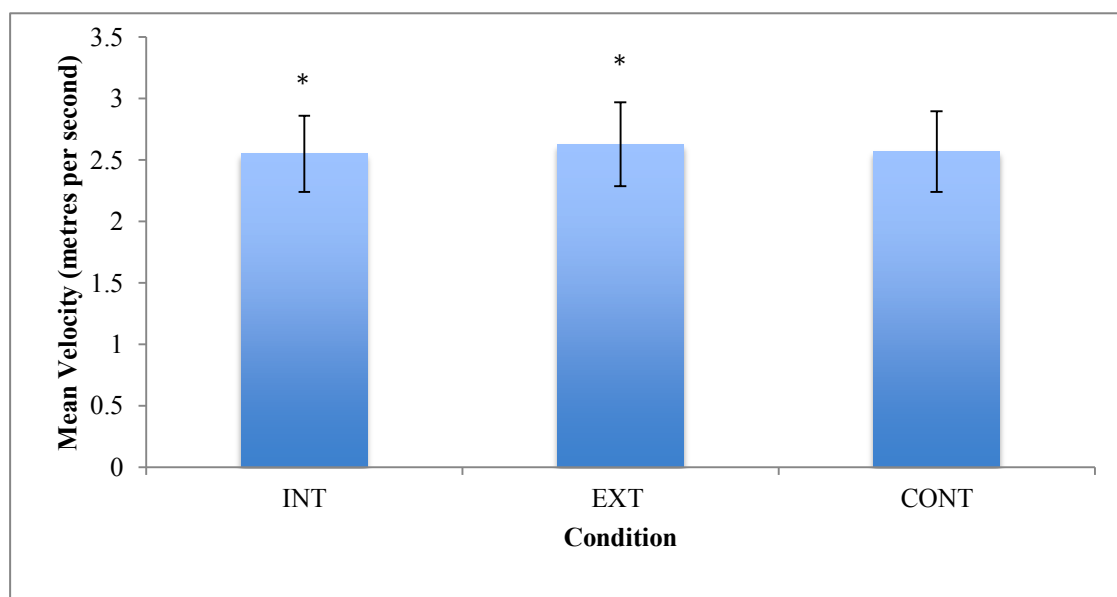


*Note.* Error bars display ± one standard deviation. * = EXT produced a significantly higher velocity than INT (p=0.04). INT = Internal; EXT = External; CONT = Control.

Figure 5. Vertical Jump Mean Peak Power Output by Condition
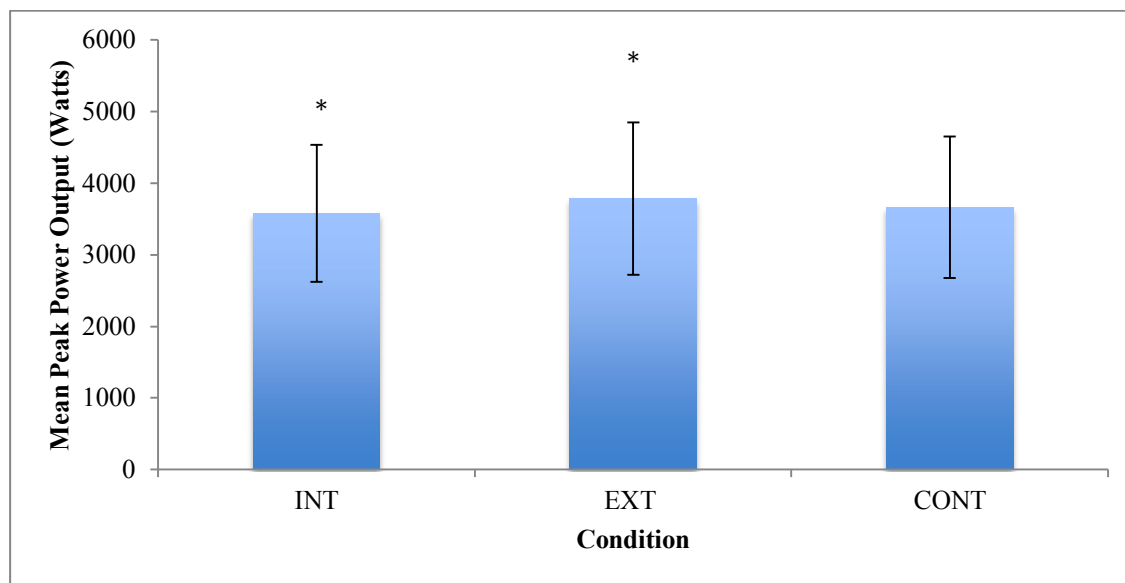


*Note.* Error bars display ± one standard deviation. * = EXT produced a significantly higher power output than INT (p=0.02). INT = Internal; EXT = External; CONT = Control.

Figure 6. Vertical Jump Relative Net Impulse by Condition
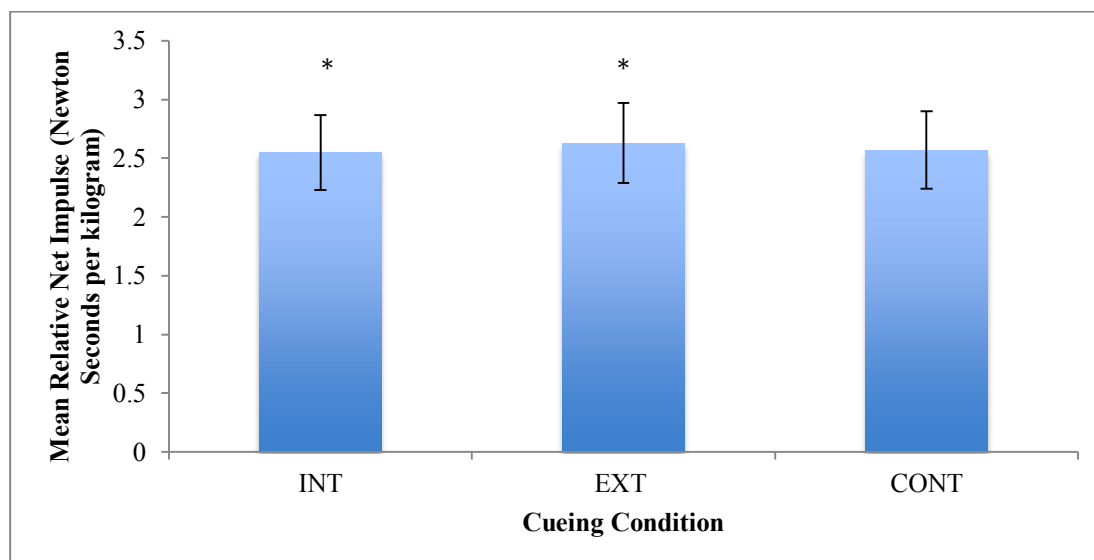


*Note.* Error bars display ± one standard deviation. * = EXT produced significantly higher impulse than INT (p=0.04). INT = Internal; EXT = External; CONT = Control.

**Change of Direction.** A significant interaction between subject category and cue was established for time to maximum force production on the left leg (F (2,24) = 4.118; p=0.02). Further analysis of 95% confidence intervals revealed a significant difference between INT trials. The interval range for INT conditions was 0.06 to 0.35, with no zero value present indicating significant difference in the impact of this form of cueing between sedentary and trained subjects. In the sedentary group, the INT condition increased time taken to reach maximum force. This pattern was absent in the trained population, creating a significantly different response. Intervals for EXT (-0.07 to 0.29) and CONT (-0.21 to 0.02) were considered insignificant due to the presence of a zero value within the intervals. There were no other interactions found.

Pairwise comparisons of all performance measures and subjects (grouping removed) revealed no apparent trend in relation to cues provided. EXT cues were favourable in relation to time when compared with CONT conditions. Although insignificant, EXT conditions also produced a quicker time trial than INT conditions (see Figure 7). INT cues produced larger impulse on right turns when compared with CONT conditions (see Figure 8), with EXT cues generating maximal force significantly quicker than INT cues on left turns (see Figure 9).

Contact time demonstrated little variance on both right and left turns in all testing conditions. On the right foot, average contact time was 0.47s, 0.46s and 0.44s for INT, EXT and CONT conditions respectively. On the left foot, contact time was 0.47s, 0.49s and 0.44s for INT, EXT and CONT conditions respectively. None of these differences were statistically significant (p>0.05).

Peak force produced on each foot in each testing condition also revealed limited, non-significant differences. On the right foot, mean values were 958N, 923N and 900N for INT, EXT and CONT conditions respectively. On the left foot, mean values were 994N, 980N and 1000N for INT, EXT and CONT conditions respectively. There were no differences in rate

of force development measurements on either right or left feet in any of the cueing conditions ($p > 0.05$).

Focus preferences in CONT CoD trials reveal a preference for INT or neutral, as shown in table 3, with no significant difference in preferences between groups ($p = 0.34$).

Figure 7. Mean 5-10-5 Pro Agility Trial Times by Condition
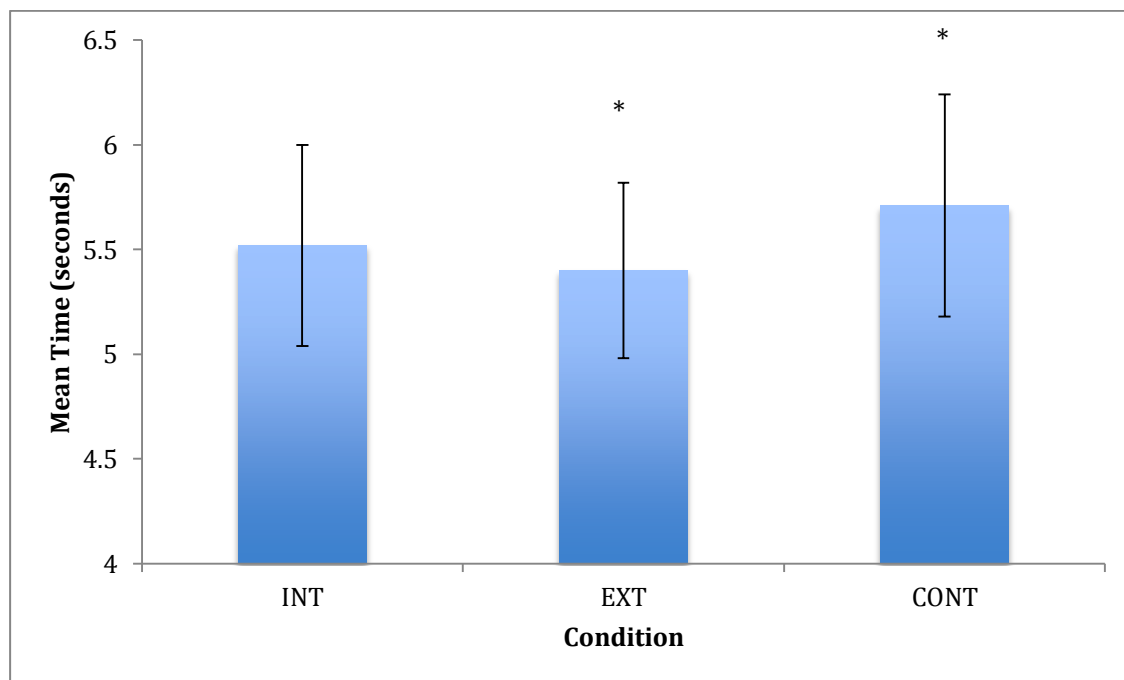


*Note.* Error bars display ± one standard deviation. * = EXT cues produced a significantly quicker time trial than CONT ($p < 0.01$). INT = Internal; EXT = External; CONT = Control.

Figure 8. Mean Relative Net Impulse on Right and Left Change of Direction by Condition
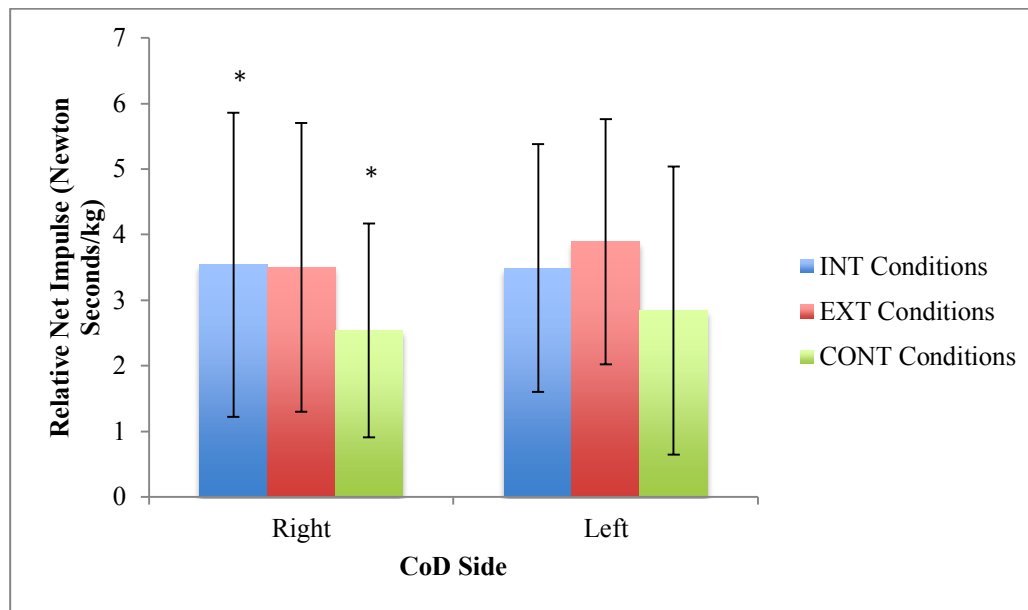


*Note.* Error bars display ± one standard deviation. * = CONT conditions produced significantly lower impulse values than INT (p=0.01) on right turns. There were no significant differences on left turns. INT = Internal; EXT = External; CONT = Control: kg = kilograms.

Figure 9.  Mean Time to Maximum Force on Right and Left Change of Direction by

Condition
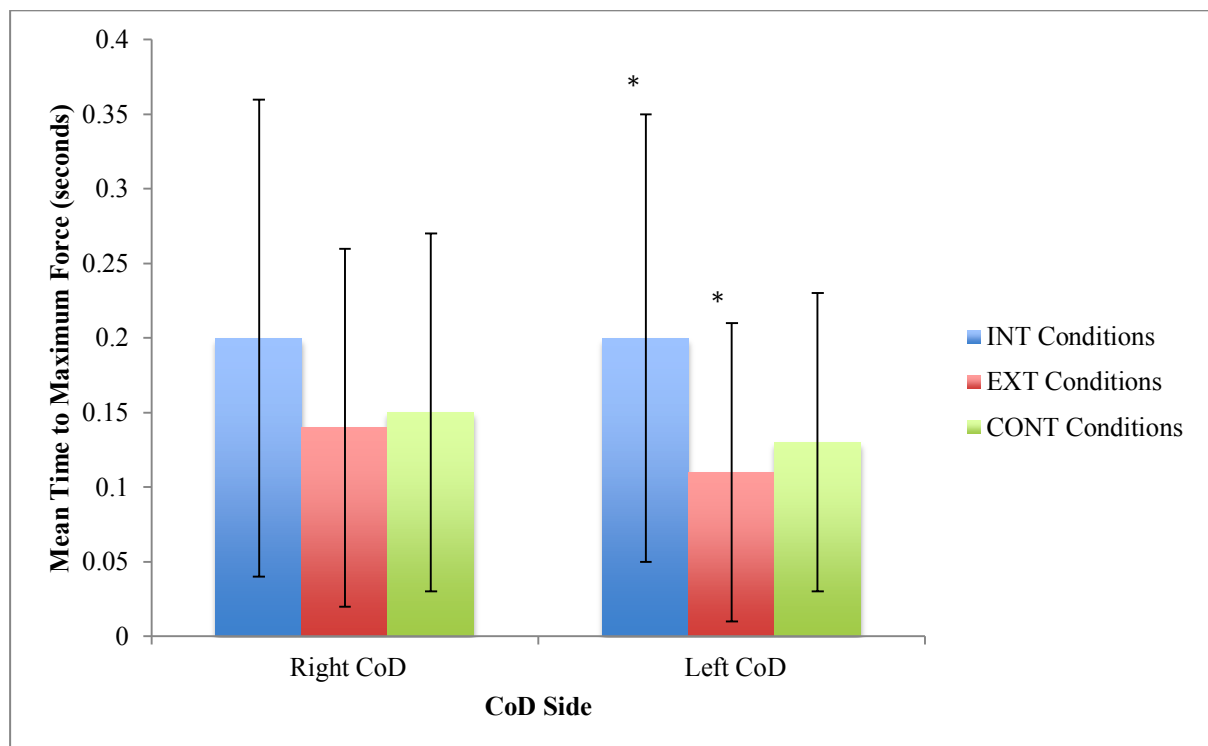


*Note.*  Error bars display ± one standard deviation.  * = Time to maximum force on left

turns was significantly faster in EXT when compared with INT (p=0.03).  There were no

significant differences on right turns.  INT = Internal; EXT = External; CONT = Control.

Table 3.

*Vertical Jump and Change of Direction Focus Preference in Control Conditions*

| | Vertical Jump | | | | Change of Direction | | | |
|---|---|---|---|---|---|---|---|---|
| | Sedentary | | Trained | | Sedentary | | Trained | |
| Focus Preference | Frequency | Percentage | Frequency | Percentage | Frequency | Percentage | Frequency | Percentage |
| INT | 13 | 72.2 | 12 | 50 | 7 | 38.9 | 6 | 33.3 |
| EXT | 1 | 5.6 | 0 | 0 | 0 | 0 | 2 | 11.1 |
| Neutral | 4 | 22.2 | 12 | 50 | 17 | 61.1 | 24 | 55.6 |

*Note.* INT = Internal; EXT = External; CONT = Control.

**Discussion**

This study indicates that experience of an individual has limited impact upon performance outcomes achieved, following provision of cues encouraging a different focus of attention, in both VJ and CoD. None of the variables measured in jump performance demonstrated an interaction between cueing condition and subject category, with only one of fifteen performance measures demonstrating an interaction in CoD trials. However, this one interaction may provide an interesting insight into the CAH.

The interaction was demonstrated in the variable time to maximum force when turning with the left foot, with INT conditions significantly increasing the time taken in the sedentary group only. The question may be raised as to why this particular measure has been influenced by subject experience, with no others close to significance.

A possible explanation is the difference in cognitive demand associated with turning on the left leg. Each of the sedentary participants identified their strong leg as their right. As such, it would be reasonable to suggest that making a turn on the opposing leg would not be a familiar skill, and the cognitive demand of doing so would be greater than other parts of the test. Whilst seven of the eight trained subjects indicated a preference for their right foot, the skill would be familiar as subjects in this group participated regularly in sports where turning with both legs is a fundamental skill (Sheppard & Young, 2006). It would be fair to suggest that CoD with the weak foot may be the area with potentially greatest difference in performance experience between groups. Whilst an effort was made to ensure participants in the sedentary group had limited physical activity experience, it is unlikely they would be completely unfamiliar with the action of jumping, or CoD using their strong leg.

The CAH states that INT cues negatively impact upon performance automaticity. However, this study finds that INT cues impact negatively in a situation where low automaticity is likely in the sedentary group, with no impact on the trained group where automaticity is likely to be higher. If the CAH were to be true, the opposite result would be expected. The result suggests that INT

cues may be more detrimental in instances where performance is more complex and unfamiliar, bringing with it a higher cognitive demand (Fitts and Posner, 1967). The assumption within the CAH of the presence of automaticity in performance if an individual has not previously completed that type of performance seems strange (Muller, 2007), and a substantial limitation of the CAH. In instances such as this, inexperienced performers will already have a large cognitive load when performing the unfamiliar task. The addition of further information in the form of an INT cue creates an environment in which too much information is provided. This agrees with Poolton, Maxwell, Masters, and Raab (2006), who concluded that an INT focus increases cognitive load, and therefore led to decreased performance in putting. This was attributed to the fact that the provision of EXT cues allows the subject to focus only on movement effect information, creating a more implicit learning environment in which EXT cues allow the performer to independently establish the technical components that are central to generating the performance outcome. Whilst an INT cue provides explicit information, placing a focus on proprioceptive feedback, the focus of movement effect is not entirely removed, thus increasing the cognitive demand (Poolton, Maxwell, Masters, & van der Kamp, 2007), and therefore negatively impacting upon performance. Linking this to the model of working memory (Baddeley, 2000), Poolton et al. (2007) suggest explicit information can increase the demands placed on the limited capacity of the working memory, and reduce performance. In initial development of this model, Baddeley and Hitch (1974) provided three key components to the working memory: the central executive, the visuo-spatial scratch pad and the phonological loop. The most important part of this model is the central executive, with the responsibility of deciding what an individual pays attention to. As described above, the use of INT cues can potentially provide the participant with a variety of focus options, as EXT influences are not entirely removed. This creates additional work for the central executive. This is considered to be particularly detrimental to beginner performers, as they will not have experience and information within the long-term memory to draw upon to determine what their attentional focus is best dedicated to.

Interestingly, the theory of overloading working memory suggests that whilst the most obvious impact is in the short term, it will inevitably be detrimental to long term learning, which is of great concern to the coach. Whilst experience and repeat performance will likely reduce the demands placed on the central executive, this theory would suggest that the use of EXT cues throughout coaching can help to limit initial attentional conflict, resulting in enhanced performance development, as the long-term memory is more likely to contain information that provides clarity on how attentional resources are best allocated. However, it is interesting to note that this study suggests that experienced performers, who in theory would have access to this information within their long-term memory, are also affected by increased demands placed on the working memory due to INT cueing.

The conclusion that INT cues interfere with working memory and performance in the short term may be used to support the suggestion that EXT cues are generally favourable in optimising performance with subject grouping removed. EXT conditions produced both higher VJ (0.03m higher than INT and 0.02m higher than CONT conditions), and faster time trials (0.13s faster than INT, and 0.31s faster than CONT). This is consistent with findings across a range of other activities, including golf (Wulf, Lauterbach, & Toole, 1999; Wulf & Su, 2007), standing long jump (Porter et al., 2010) and sprinting (Porter, Wu, Crossley, Knopp, & Campbell, 2015), as well as in vertical jump (Wulf & Dufek, 2009; Wulf, et al., 2010) and CoD (Porter et al., 2010). These results are in line with the CAH. However, the role of automaticity in generating these differences can be questioned based on the lack of interactions discussed previously. The author suggests that CONT conditions would most likely generate a performance that comes naturally to the individual, and with that, a degree of automaticity. The provision of coaching cues would only divert attention away from and interfere with what the subject would normally do, particularly for trained subjects. As such, if the CAH was to be considered accurate, and maintenance of automaticity to be central to performance, it would be expected that CONT conditions would produce the best performance, especially in those with experience. The results of this study indicate that this is not the case.

The opinion that further considerations beyond interference with automaticity is required to fully understand the impact of focus of attention is a common one, and is supported by the findings of this study. As this study examined two groups with assumed differences in automaticity levels, it would be expected that a greater number of interactions between subject category and cue would be seen if automaticity was integral to the CAH. It is however worth considering that no other interactions were established for other performance measures of CoD on the left leg. This coupled with the small sample size within the study may raise some queries as to how important this interaction is, and therefore how certain the conclusions drawn from this can be.

That said, there does appear to be some further support for the consideration of additional motor learning factors through the findings of other studies where cues encouraging different foci of attention were trialled on subjects of varying abilities. Firstly, Perkins-Ceccato, Passmore, and Lee (2003) examined the impact of INT and EXT cues on novice and expert golfers during pitching, concluding that EXT cues suited experienced performers, whilst INT cues suited novice performers. Wulf and Su (2007) also examined golfing performance, finding that EXT cues were beneficial to all performance levels. Given there is a lack of agreement in findings comparing performers of different levels and automaticity, its role within the CAH appears even more debatable. The results indicate the need to consider further factors within the CAH that allow a degree of individualisation of the theory.

An area worth consideration would be the learning preferences of the individual. Learning style theories have well established that verbal instructions have varying impact upon different individuals (Dunn, 2009) depending on their learning preferences, with some learners showing minimal response to this form of delivery. Furthermore, Gonzalez-Haro, Calleja-Gonzalez and Escanero (2010) established that these learning preferences vary with participant level.

It may also be beneficial to conduct research in a more holistic coaching environment. Most commonly, coaching of motor skills will involve a wide range of delivery methods, including verbal instruction, demonstration, the use of visual aids such as video, as well as many other tools

(Massey et al., 2002). Whilst perhaps verbal communication is the most frequently used tool (Gallo & De Marco, 2008), its isolation in this study and others creates an unrealistic coaching environment that may disadvantage the learner who does not respond to these methods. Hayes, Hodges, Scott, Horn, and Williams (2007) identified that a coaching environment that incorporated both verbal instructions and demonstration produced improved movement reproduction when performing previously unfamiliar skills. Consideration of this variety of learning preferences and teaching approaches within the CAH would make it a more robust theory that could be adapted and applied in a more meaningful manner to individual subjects.

Some research also suggests that participant age may impact upon how coaching cues and feedback are received. Sullivan, Kantak, and Burtner (2008) found that children and adults responded differently to coaching cues when learning a new skill. The authors suggest a range of potential causes of this, including the individual's stage of development and previous and current learning experiences.

It is worth highlighting that this is only a sample of some of the potential influencing factors that will differ from one individual to the next. There has been limited work specifically examining how these individual differences impact upon the CAH, and therefore reaching the definitive conclusion that automaticity is the integral component is questionable.

There is a suggestion that the proximity of the cue to the body, as well as the movement effect can impact upon cue effectiveness (Bund, Wiemeyer, & Angert, 2007). It is hypothesised that all cues sit on a continuum of proximity to the body and movement effect, with the use of cues directed further from the body towards the movement outcome considered preferable (Hegele & Erlacher, 2007). In some cases however, an INT cue can provide subjects with a focus closer to the movement outcome than that of an EXT cue, and would therefore be preferable. In the current study, both INT and EXT cues would be considered relatively proximal, and therefore may assist in explaining why there were relatively few significant differences between conditions.

The minimal significant findings and interactions in this study suggest skill components of higher cognitive demand that are less familiar to the inexperienced population would benefit from the use of EXT cues. That said, this would appear to be too broad of generalisation, given the range of sporting skills that are unique in their demands, both physically and psychologically. Given the variations in skills themselves, the broad spectrum of performers that a coach may encounter, and the lack of obvious patterns within this study, suggesting a blanket approach to the use of verbal cues seems unlikely to generate optimal performance universally.

It may be beneficial to consider the complexity of skill being coached and performed, alongside the level of the individual. Ehrlenspiel (2007) suggests individuals will choose to focus attention optimally based on the demands that they perceive. These individual demands would be closely related to the experience of the subject. Furthermore, Hommel (2007) suggests that past performance may influence focus, with success building confidence, permitting more EXT focus, whereas poor performance encourages the performer to examine INT factors. In addition to this, Oudejans, Koedijker, & Beek, (2007) suggest that there are instances where participants with an automated performance and ingrained technique may benefit from INT focus where detailed technical adjustment is required to improve. This may also be true of a rehabilitating athlete who requires muscle activation in a particular area (Marchant, 2007). Evidence demonstrates that INT cues are useful in increasing muscle activity (Lohse et al., 2011; Vance et al., 2004; Wulf et al., 2010). Whilst this increased muscle activity is used within the CAH to explain decreased automaticity, there has been limited explanation provided to indicate what this relationship is (Maurer & Zentgraf, 2007).

The findings of Wulf and Dufek (2009) reported higher displacement in EXT conditions, although this was attributed to higher force production. This is not consistent with the findings of this study, where EXT conditions generated lowest peak force values. Whilst differences were insignificant, peak force values were highest in INT conditions, yet did not result in greater displacement. This may indicate more efficient use of force, with decreased activity in muscles

that have minimal impact on performance outcome, produced in EXT conditions, another common benefit cited in the CAH to support EXT cue use (Wulf, 2007). The results of the CoD trial times also support aspects of the CAH, with EXT conditions producing the best performance.

It is interesting to note that cues only significantly impacted on 3 of 14 CoD variables, yet overall time was significantly different between EXT and CONT conditions. This might suggest that EXT coaching cues, even though this was not their focus, may have impacted upon the actions between CoD. This could imply that the content of the cue has a role to play, not just the focus. Kunzell (2007) highlighted that the functionality of the cue was important to consider. For example, whilst a cue may be EXT, it doesn't guarantee that it is of use to performance. A relevant INT cue may be more beneficial than an irrelevant EXT cue. The CAH does not appear to address this, assuming that the coach will consider cue functionality. For example, the EXT cue of 'push the ground away' may have been applied to movement between the CoD points, and in turn generated an improved time. Coaches may benefit from carefully considering the content of the cue, and how this can be applied in overall performance, using verbal instruction as efficiently as possible.

This study, like many others in this field, placed subjects in an artificial environment where they were aware of the scrutiny that their performance was under. This awareness, known as the Hawthorne Effect (McCarney et al., 2007), may have created an environment in which subjects did not perform as they would naturally, and as such disrupt levels of automaticity. For example, on questioning participants on their focus following the control trials in both tests, it was common to receive detailed explanations as to what they had dedicated attention to. It would appear unlikely that those with experience would perform familiar skills such as VJ and CoD with that level of cognition (Wulf, 2007). Marchant (2007) identifies the need to ensure that naturally occurring performance is measured to fully understand the CAH. Whilst difficult to implement, creating an environment in which subjects can perform without such obvious tracking may allow fairer comparisons to be drawn.

The influence of the testing environment may also assist in explaining some of the patterns seen in focus preferences during both VJ and CoD in CONT conditions. It is apparent in the results that an EXT focus was an uncommon preference for both sedentary and trained population groups, yet when provided with the EXT cue, performance improved. The CAH states that it would be expected that an experienced performer would demonstrate EXT focus preferences. However, the unfamiliarity of the nature of performance and detailed analysis discussed above may have altered the focus of participants.

Another reasonable consideration in explaining these preferences is the past exercise instruction model that the subjects had been exposed to. Kunzell, (2007) concluded that it would appear the use of internally focussed cues is a 'norm' within exercise instruction, and as such, may have influenced performers. Supporting this, Marchant (2007) suggests a possible research approach would be to examine the cueing preferences of coaches, determining how this impacts upon performance. If the CAH were to be accurate, it would be expected that coaches of successful performers would demonstrate a preference for EXT cues.

Furthermore, coaching cues provided to subjects were not specific to the individual performances observed. Again, this is not a realistic coaching environment in which cues would be individualised to suit the strengths and weaknesses. This relates closely to the issue of cue functionality raised previously. It may have been beneficial to provide cues with different foci based on the observations of the researcher.

In addition to the unrealistic experimental environment, it should be noted that the small sample size is a substantial limitation of the study, with the researcher unable to recruit the desired number of subjects to give appropriate statistical power to the findings.. Power calculations prior to the completion of the study calculated that a sample size of 32 would be required to achieve power of 0.95 for VJ tests with p=0.05, and a sample of 16 for CoD tests at the same significance level. Failure to achieve this number of participants may firstly contribute to the lack of significant difference between cue conditions in this study, when compared with others in the same field, with

a high chance of significant differences going undetected. Furthermore, it questions whether the conclusions drawn can be applied to the wider population.

Finally, it should be recognised that the process of motor learning is normally delivered over a period of months or years. This study, as well as many others in the field, has not measured the impact of coaching cues over a prolonged period. Whilst some impact has been observed across three individual sessions, determining the long-term impact on learning would be of greater benefit to the coach (Bund et al., 2007).

In conclusion, experience and activity levels have limited impact on the effect of cues upon VJ and CoD performance. Whilst the results of the study support the CAH in part, with EXT cues producing optimal performance, the role of automaticity in this should be questioned and investigated further, particularly with larger sample sizes. This study suggests that more attention should be given to the influence of cues on cognitive demand.

The researcher suggests that the CAH would benefit from greater integration of well-established theories of motor learning, as well as additional individual differences that exist between participants. Additionally, treating each performance event as unique in relation to the verbal instruction provided would appear valuable in ensuring the cues used are effective in generating the required response. A generic approach to cueing goes against many theories of motor learning, with this study concluding that a degree of individualisation is essential in the application of any motor development theory.

It appears fair to suggest that the content of a coach's verbal instructions can bear substantial influence on performance, and therefore attention should be paid to specifics of verbal communication, measuring and recording where possible, the impact cues have on individuals.

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**Appendix 1 - Participant Invitation Email**

Hi there,

Have you ever wanted to know how quick you are, how much force you can produce or how your performance compares to elite athletes? Now is your chance to find out!

My name is Ewan Birnie. I'm currently studying an MSc in Strength and Conditioning with St Mary's University, Twickenham, London, UK. As part of this study, I'm required to complete a final year research project.

I have chosen to investigate agility and jump performance as my focus of this research. In order to complete this study, I require 30 participants. You will find more specific details about the study in the attachment.

If you would like to participate, or have any further questions, please contact me on the details below. Thank you for your time.

Kind Regards,

Ewan Birnie

135268@live.stmarys.ac.uk

0488046656

**Appendix 2 - Participant Information Sheet**

St Mary's
University
Twickenham
London

**Testing the constrained action hypothesis – the impact of internal and external cues on vertical jump and change of direction performance in trained and sedentary populations.**

Information Sheet
The Research Project
The study aims to inform 'best practice' guidelines for strength and conditioning coaches in both coaching and testing of their athletes. This will be achieved through the testing of the constrained action hypothesis in vertical jump and change of direction performance. This has not been tested in this manner previously, and with therefore contribute valuable insight as to how this theory can be applied to the instruction and testing of exercise performance.

You are invited to participate in the study - Testing the constrained action hypothesis – the impact of internal and external cues on vertical jump and change of direction performance in trained and sedentary populations. Study participation will require the completion of pre-screening paperwork and attendance at three practical testing sessions, each lasting up to forty minutes. During each testing session, you will be required to perform five vertical jumps, and four 5-10-5 Pro Agility tests.

The research is being conducted by Ewan Birnie, and supervised by Dr. Daniel Cleather of St. Mary's University, Twickenham, UK. The research forms part of the final year of study of the MSc Strength and Conditioning programme.

The results of the study will be analysed and published in a dissertation project, as part of completion of the MSc Strength and Conditioning programme at St. Mary's University, Twickenham, UK. There is no funding source for completion of this project.

Should you require further information, please don't hesitate to contact Ewan Birnie on 135268@live.stmarys.ac.uk or 0488046656. The contact details for the University are St Mary's University, Waldegrave Road, Strawberry Hill, Twickenham, London, TW1 4SX. The phone number is 02082404000.

Your Participation in the Research Project
You have been invited to take part in this research project as it is believed you may meet the inclusion criteria in relation to your physical activity background. Completion of the initial participant screening will confirm this.

You are under no obligation to take part in this study, and can at any time withdraw, informing Ewan via the contact details above.

Your involvement in the study will firstly require the completion of basic paperwork to confirm your suitability for the study, whilst allowing accurate grouping. From here, you will be required to attend three separate testing sessions, each of forty minutes in duration. At the beginning of each session, you will be required to complete a ten minute warm up as instructed. Following this, you will complete five vertical jumps with two minutes rest between performances, followed by four 5-10-5 Pro Agility tests, each separated by three minutes of recovery.

Given the physical nature of participation in physical activity, there are some minor risks of injury, generally of a musculoskeletal nature. This will be managed through an appropriate warm up, detailed instruction and close supervision during all performances.

Your legal rights are not compromised by agreeing to participate in this study, should something go wrong. There are no specific pre-test requirements or pre-cautions required prior to participation in the study.

The data gathered from your performances will be published in the completed dissertation. At all time, participant details will be kept confidential through the use of a participant numbering system, as well as password protected storage of all details.

On completion of the study, you may access your own performance data on request to Ewan. This will be provided to you in a summary table that identifies basic performance measures, as well as biomechanical data on both jump and change of direction.

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

**Appendix 3 – Informed Consent and Physical Activity Readiness Questionnaire**

St Mary's University Twickenham London

**Practical activity consent form**

Name of participant:

……………………………………………………………………………………..

Title of the practical activity:

………………………………………………………………………………….

Main coordinator and contact details:

………………………………………………………………………….

Participants of the practical activity:

1. I agree to take part in the above practical activity.
2. I have had the practical activity explained to me, and understand what my role will be. All of my questions have been answered to my satisfaction.
3. I understand that I am free to withdraw from the practical activity at any time, for any reason and without prejudice.
4. I have been informed that the confidentiality of the information I provide will be safeguarded.
5. I am free to ask any questions at any time before and during the practical activity.
6. I am aware that I can obtain a copy of this form, and the relevant Confidential Medical History and/or Physical Activity Readiness Questionnaire (PAR-Q) Form.
   Data Protection: I agree to the University College processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the teaching activity as outlined to me.

Name of participant (print)……………………………..Signed…………………..….Date………………

Name of witness (print)…………………………………..Signed…………………..….Date………………

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If you wish to withdraw from the practical activity, please advise the practical activity coordinator, and complete the form below.

Title of Project:

I WISH TO WITHDRAW FROM THIS PRACTICAL ACTIVITY

Name: …………………………………………

Signed: ……………………………………………Date: …………………………………

**SCHOOL OF Sport, health and applied science**

**CONFIDENTIAL Medical History / Physical Activity Readiness Questionnaire (PAR-Q) FORM**

This screening form <u>must</u> be used in conjunction with an agreed Consent Form.

Full Name: [                    ]          Date of Birth: [          ]

Height (cm): [                    ]          Weight (kg): [          ]

Have you ever suffered from any of the following medical conditions? If yes please give details:

|  | Yes | No | Details |
|---|---|---|---|
| Heart Disease or attack | ☐ | ☐ | _____ |
| High or low blood pressure | ☐ | ☐ | _____ |
| Stroke | ☐ | ☐ | _____ |
| Cancer | ☐ | ☐ | _____ |
| Diabetes | ☐ | ☐ | _____ |
| Asthma | ☐ | ☐ | _____ |
| High cholesterol | ☐ | ☐ | _____ |
| Epilepsy | ☐ | ☐ | _____ |
| Allergies | ☐ | ☐ | _____ |
| Other, please give details | ☐ | ☐ | _____ |

Do you suffer from any blood borne diseases?        If yes please give details;

[                                                                      ]

Please give details of any **medication** you are currently taking or have taken regularly within the last year:

[                                                                      ]

Please give details of any **musculoskeletal injuries** you have had in the **past 6 months** which have affected your capacity to exercise or caused you to take time off work or seek medical advice:

[                                                                      ]

Other Important Information
During a typical week approximately how many hours would you spend exercising?

[                                                                      ]

If you **smoke** please indicate how many per day: [                    ]

If you drink **alcohol** please indicate how many units per week [                    ]

Are you currently taking any **supplements or medication?** Please give details:

[                                                                              ]

Is there any reason not prompted above that would prevent you from participating within the relevant activity?

[                                                                              ]

By signing this document I agree to inform the relevant individual(s) of any change(s) to my circumstances that would prevent me from participating in specific activities.

Signature (Participant): [                    ]      Date: [                    ]

Signature (Test Coordinator*): [                    ]      Date: [                    ]

*Test coordinator: The individual responsible for administering the test(s)/session and subsequent data collection

**Appendix 4 – Exercise History Questionnaire**

St Mary's University Twickenham London

**Exercise History Questionnaire**

Subject Number:          Date of Birth:__/__/__          Gender: M/F

Height (m):          Weight (kg):          Preferred Foot:  R  or  L

**Training Practices**

1.  How many minutes of physical activity do you particpate in on average in 1 week?

    Greater than 150 minutes  ☐  Less than 150 minutes  ☐

2.  Are you currently following a structured training programme?

3.  What training activities are included in your current training programme?

4.  What is the average number of training days included in your typical training week?

5.  Do you currently partake in competitive sport?  If yes, please specify the sport and competition

    level.

6.  What training activities have you participated in in the last 3 years?

7.  Have you taken part in jump/plyometric training previously?  If yes, please provide some

    specific information (e.g form of training, period of this form of training).

8.  Have you taken part in agility training previously?  If yes, please provide some specific

    information (e.g form of training, period of this form of training).

**Injury History**

1.  Are you currently injured?  If yes, please specify the injury and length of time for which you

    have been injured.

2. Has this injury impacted upon your training (i.e. caused you to miss more than 2 weeks of training?)

3. Have you suffered any injury in the past 6 months? If yes, please specify the injury and length of time that this injury was present?

4. Did this injury impact upon your training? (i.e. caused you to miss more than 2 weeks of training?

5. Please list any other injuries from which you have suffered in the past three years that have disrupted your training. Please provide rough dates of injury and rehabilitation time.

**Appendix 5 - Subject Recruitment Permission Request**

Hi (insert gym/team manager name),

My name is Ewan Birnie.  I'm currently studying an MSc in Strength and Conditioning with St Mary's University, Twickenham, London, UK.  As part of this study, I'm required to complete a final year research project.

I have chosen to investigate agility and jump performance as my focus of this research.  In order to complete this study, I require 30 participants.  I write this email to enquire about the possibility of recruiting subjects for this study through  (insert gym/team name). This recruitment would require the attached poster to be displayed within your facility.  I have also attached more information on the specifics of the study and required participant characteristics.

In return for participating in the study, subjects will be provided with all of their gathered data, which may be used to gauge performance and progress.

If you have any further questions, please don't hesitate to contact me on the details below.  Thank you for your help.

Kind Regards,

Ewan Birnie

ewanbirnie@msn.com

0488046656

**Appendix 6 – Recruitment Poster**

# Subject Recruitment Poster
# How Agile Are You?
# How High Can You Jump?
# How Do You Compare to Elite Athletes?
# How Much Force Can You Produce?

**Have you always wanted to know the answers to these questions? If you have, now is your chance to find out the answers! Join our jump and agility performance study and find out more about your performance.**

**If you are interested, please contact Ewan on 135268@live.stmarys.ac.uk or 0488046656.**

**Appendix 7 - Recruitment Presentation**

**FIA FITNATION**
FITNESS INSTITUTE AUSTRALIA

# Vertical Jump

- A popular tool used by S&C coaches.
- Used to identify athletic potential, measure programme impact and identify strengths and weaknesses.
- Simple test to perform with a wide range of data gathered.

www.fiafitnation.com.au
info@fiafitnation.com.au

**FIA FITNATION**
FITNESS INSTITUTE AUSTRALIA

# Join The Study!

- The study is investigating jump and agility performance in both novice and advanced performers.
- In order to participate, you must:
  - Free from injury in the last 6 months
  - Meet either group 1 or group 2 criteria (see attached sheet).

www.fiafitnation.com.au
info@fiafitnation.com.au

**Appendix 8 – Facility Use Permission Letter**

**IFIA FITNATION**
■FITNESS INSTITUTE AUSTRALIA

To Whom It May Concern:

I can confirm that FIA Fitnation have granted permission to Ewan Birnie to utilise the gym facilities at Level 3, 815 George Street Sydney, in support of the completion of his research as part of the Masters of Strength and Conditioning at St. Mary's University, Twickenham.

Should you have any questions or require any further information, please get in touch via the contact details listed below.

Yours sincerely,

Natalie Daniel
Head of College
FIA Fitnation
Email: Natalie.daniel@fiafitnation.com.au

www.facebook.com/FIAFitnation      www.twitter.com/FIAFitnation

**Appendix 9 – Risk Assessment**

**SECTION 1: Identify Hazard types -** Consider the activity or work area and identify if any of the hazards listed below are significant.

| Assessment Reference No. | | | |
|---|---|---|---|
| Assessment date | 9th of December 2015 | Activity assessed: | Portable force plate analysis of vertical jump and change of direction performance. |
| Persons who may be affected by the activity (i.e. are at risk) | User and Users of activity assessed | | |

| Brief description of activity/procedure | Analysis of vertical jump performance in different coaching conditions. Measurement of displacement, velocity, power, force and impulse through the use of portable force plates. | Description of work to be done: | Please tick (✓) the following which applies: | |
|---|---|---|---|---|
| | | | Work to be done in designated areas | ✓ |
| | | | Work to be done under close supervision | ✓ |
| | | | Work to be done in the presence of at least 2 other workers | |
| | | | Work to be done within normal hours | ✓ |
| | | | Work not to be left unattended | ✓ |

| 1 | Fall of objects | | 7 | Heating, ventilation and humidity | | 13 | Pressure vessels - autoclave | | 19 | Biological hazards – micro-organisms, human samples or non-lab fieldwork | | 25 | Working at heights | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Spillages, slips, Trips & Falls | ✓ | 8 | Layout , storage, space, obstructions | ✓ | 14 | Noise or Vibration | | 20 | Fire hazards, flammable materials and explosion | | 26 | Occupational stress | |
| 3 | Manual handling operations including repetitive movements | ✓ | 9 | Electrical Equipment | ✓ | 15 | Sharps – syringes, blades | | 21 | Handling food | | 27 | Violence to staff / verbal assault | |
| 4 | Display screen equipment | ✓ | 10 | Physical hazards – electrical, temperature | | 16 | Ergometers – rower, treadmill, bikes | | 22 | Vehicles and driving | | 28 | Lone working / work out of hours | |
| 5 | Work in public areas | | 11 | Contractors | | 17 | Ionising and non-ionising radiation | | 23 | Physical Activity | ✓ | 29 | Confined spaces | |

| 6 | Lighting levels | | 1 2 | Mechanical (machinery) and use of portable tools / equipment | ✓ | 1 8 | Chemical hazards – toxic, corrosive, flammables | | 2 4 | Outdoor work | | 3 0 | Other(s) - specify | |

**SECTION 2: Risk Controls** -  For each hazard identified in Section 1, complete Section 2.  Please refer to the Risk Assessment Guidance notes on simmsCAPital folder for Risk Matrix. **Please note that <u>L refers to Likelihood</u>; <u>S refers to Severity</u> and RS refers to Risk Score (L times S equals RS)**

| Hazard No. | Outcome due to Hazard description (Substance / equipment / procedure) | Initial risk Level (tick one) Refer to the risk matrix | | | Controls needed to eliminate or adequately reduce risks | Remaining Risk Level (tick one) | | |
|---|---|---|---|---|---|---|---|---|
| | | High (13-25) | Med (5-12) | Low (0-4) | | High (13-25) | Med (5-12) | Low (0-4) |
| 2 | Spillages, slips, trips & falls – wires. | | ✓ | | Ensure that all wires from force plates and laptop are taped securely to the floor. Ensure adequate space around the force plates. Pre-test check of facility. | | | ✓ |
| 3 | Manual handling operations including repetitive movements – force plates, laptop. | | ✓ | | Ensure user is familiar with setup protocol. Refer to manual handling guide. In the instance of heavy lifting, assistance will be sought from other personnel, and appropriate equipment used. | | | ✓ |
| 4 | Display screen equipment – laptop. | | | ✓ | Equipment is checked prior to each test performance. Ensure user familiarity with the equipment. Position equipment appropriately to minimise distraction for test participants. | | | ✓ |

| | | | ✓ | | | | | ✓ |
|---|---|---|---|---|---|---|---|---|
| 8 | Layout, storage, space, obstructions – all equipment, gym floor. | | ✓ | | Pre-test checks of facility to ensure all obstructions are removed and there is adequate space for equipment setup. Equipment to be stored is assigned storage areas at non-testing times. Continuous review of space through test performance. The testing space will be booked out removing the risk of external gym users. | | | ✓ |
| 9 | Electrical equipment – force plates, laptop. | | ✓ | | Users should be familiar with equipment setup. All wires and equipment should be checked prior to each use. Ensure no fluid consumption next to equipment. Switch off equipment when not in use. Ensure equipment is PAT tested as required. Do not connect numerous extension leads together. | | | ✓ |
| 12 | Mechanical (machinery) and use of portable tools/equipment – force plates, laptop. | | ✓ | | User should be familiar with and trained in the use of the equipment. | | | ✓ |

| 23 | Physical activity – warm up, vertical jump, change of direction cool down. | | ✓ | | All equipment and testing environment to be checked prior to test performance. Ensure participant is familiar with all aspects of the protocol and provided with the opportunity to ask questions. Ensure all test participants have signed an informed consent form and completed a Physical Activity Readiness Questionnaire (PAR-Q) Test subjects to be supervised at all times. Ensure the provision of clear instructions to all test participants. Test participants to be provided with instructions on how to perform the vertical jump and agility test safely, with particular reference to landing and turning. Demonstration of correct technique provided. Researcher to be suitably qualified to supervise and observe performance, ceasing activity should it be deemed unsafe to continue. Close monitoring of participant tolerance to exercise testing, with testing to be ceased if continuation deemed unsafe. Presence of a fully qualified first aider during all testing, with additional staff available to assist in the case of injury. | | | ✓ |

**SECTION 3: Action Plan in the event of an emergency**      - For each hazard identified in Section 2, complete Section 3.
- Please refer to the Risk Assessment Guidance.

| Hazard Number | Hazard Description – Substance / equipment / procedure | Action required (describe) |
|---|---|---|
| 2 | Spillages, slips, trips & falls. | Apply relevant First Aid and seek Medical Assistance <u>where appropriate</u> |
| 3 | Manual handling operations including repetitive movements. | Apply relevant First Aid and seek Medical Assistance <u>where appropriate</u> |
| 4 | Display screen equipment. | Apply relevant First Aid and seek Medical Assistance <u>where appropriate</u> |
| 8 | Layout, storage, space, obstructions | Apply relevant First Aid and seek Medical Assistance <u>where appropriate</u> |
| 9 | Electrical equipment | Apply relevant First Aid and seek Medical Assistance <u>where appropriate</u> |
| 12 | Mechanical (machinery) and use of portable tools/equipment. | Apply relevant First Aid and seek Medical Assistance <u>where appropriate</u> |
| 23 | Physical activity | Apply relevant First Aid and seek Medical Assistance <u>where appropriate</u> |

SECTION 4: Arrangement for supervision and/or monitoring effectiveness of control
- For each hazard identified in Sections 2/3, complete Section 4.
- Please refer to the Risk Assessment Guidance notes.

| Hazard No. | Hazard Description – Substance/equipment/procedure | Comments |
|---|---|---|
| 2 | Spillages, slips, trips & falls. | Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required. |
| 3 | Manual handling operations including repetitive movements. | Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required. |
| 4 | Display screen equipment. | Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required. |
| 8 | Layout, storage, space, obstructions | Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required. |
| 9 | Electrical equipment | Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required. |
| 12 | Mechanical (machinery) and use of portable tools/equipment. | Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required. |
| 23 | Physical activity | Monitoring achieved through pre and post checks, continual supervision by test coordinator and/or separately recruited individual where further supervision is required. |

**SECTION 5: Further comments** – If a more complex assessment is required, continue below:

IMPORTANT CONTACT DETAILS (including where activities are undertaken off campus):

St Mary's University College Security – 0208 240 4335 (advise in the event of calling the emergency services)
FIA Fitnation Gym Facilities – 0282047807
FIA Fitnation Office - 0292804948

GUIDELINES FOR REFFERAL (as a hard copy attachment, listed web link or other source):

(Examples of supporting information could be a Material Safety Data Sheet (MSDS) or a Qualification/Accreditation guideline).

**SECTION 6: Period of cover** – If a more complex assessment is required, continue below:

By signing this risk assessment I confirm that I have read and understood all of the risks associated with the activity specified on sheet 1, and that I will follow all of the specified controls to reduce the risks identified with the activity.

| PERIOD OF COVER FOR TASK/EVENT | | PRINT NAME OF TASK/EVENT LEADER | SIGNATURE | DATE SIGNED | HAZARDS IDENTIFIED (mark with a tick or a cross) |
|---|---|---|---|---|---|
| FROM | TO | | | | |
| 4/1/16 | 16/3/16 | Ewan Birnie | | 16/12/15 | X |
| | | | | | |
| | | | | | |
| | | | | | |
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| | | | | | |

**Appendix 10 – Dissertation Completion Timeline**

The table below outlines the proposed completion timeline for each of the key tasks within the dissertation.  The completion process is over 46 weeks (3rd August 2015 to 29th of June 2016).  Each shaded box corresponds with a time at which the associated task will be completed.  This table represents a plan that may be changed, depending on the circumstances that present during each stage of the process.

| Week Number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Background Reading | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Proposal Writing | | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Proposal Review | | | | | | | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Proposal Hand In | | | | | | | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Supervisor Assigned | | | | | | | | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Meeting with Supervisor | | | | | | | | ■ | | ■ | | ■ | | | ■ | | | ■ | | | | | | | | | | | ■ | | ■ | | | ■ | | ■ | | ■ | | | ■ | | | ■ | ■ | |
| Proposal Changes | | | | | | | | ■ | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Completion of Ethics | | | | | | | | | | | ■ | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Excel & SPSS | | | | | | | | | | | | | ■ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Data Collection | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | ■ | | | | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | | | | | | |
| Intro & Methods | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | | | | | | | | | | | | | | | | | | | | | |
| Data Analysis | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | | | | | | | | | | | | | | | | | | |
| Results | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | | | | | | | | | | | | | | | |
| Discusssion & Conclusion | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | ■ | | | | | | | | | | |
| Review | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | | | | | | | |
| Initial Submission | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | | | | | | |
| Poster Prep | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | ■ | | ■ | ■ |
| Feedback Received | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | | | | |
| Make Changes | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ | ■ | |
| Poster Presentation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ |
| Viva | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | ■ |

**Appendix 11 – Vertical Jump Raw Data**

| | Category | Gender | Mass | HeightINT | HeightEXT | HeightCONT | VelINT | VelEXT | VelCONT | PowerINT | PowerEXT | PowerCONT | ImpulseI... | ImpulseEXT | ImpulseCONT | ForceINT | ForceEXT | ForceCONT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 1 | 80.23 | .699 | .762 | .787 | 3.044 | 3.323 | 3.108 | 5086.833 | 5517.961 | 5015.471 | 3.048 | 3.278 | 3.108 | 4274.800 | 4573.350 | 2855.770 |
| 2 | 1 | 1 | 86.09 | .439 | .413 | .576 | 2.677 | 2.632 | 2.734 | 4142.773 | 4074.327 | 4238.328 | 2.678 | 2.633 | 2.729 | 6408.810 | 6471.710 | 5712.570 |
| 3 | 2 | 1 | 77.73 | .548 | .550 | .517 | 2.749 | 2.780 | 2.789 | 4221.881 | 4290.300 | 4411.396 | 2.733 | 2.766 | 2.776 | 5333.280 | 4649.490 | 4936.360 |
| 4 | 2 | 1 | 83.24 | .597 | .528 | .501 | 2.556 | 2.684 | 2.625 | 3379.678 | 4046.544 | 3642.799 | 2.556 | 2.685 | 2.622 | 3841.030 | 3564.540 | 3407.340 |
| 5 | 2 | 2 | 65.12 | .429 | .618 | .448 | 2.540 | 2.667 | 2.582 | 2909.331 | 3299.883 | 3085.135 | 2.542 | 2.664 | 2.581 | 2826.500 | 267.040 | 3100.690 |
| 6 | 2 | 1 | 67.93 | .501 | .442 | .452 | 2.783 | 2.764 | 2.765 | 3453.057 | 3449.713 | 3537.497 | 2.786 | 2.762 | 2.763 | 4248.240 | 4145.880 | 4330.160 |
| 7 | 1 | 2 | 58.34 | .386 | .423 | .387 | 2.378 | 2.499 | 2.401 | 2829.307 | 2861.131 | 2831.425 | 2.380 | 2.496 | 2.405 | 2897.570 | 3642.060 | 2994.540 |
| 8 | 1 | 2 | 86.89 | .265 | .176 | .125 | 2.100 | 2.088 | 1.973 | 3029.940 | 2977.879 | 2769.896 | 2.087 | 2.068 | 1.973 | 3200.130 | 4124.820 | 4123.410 |
| 9 | 2 | 1 | 76.27 | .498 | .602 | .532 | 2.852 | 2.966 | 2.851 | 3968.882 | 4324.177 | 4376.177 | 2.853 | 2.960 | 2.851 | 4510.390 | 4818.390 | 3413.690 |
| 10 | 1 | 2 | 64.26 | .432 | .443 | .445 | 2.503 | 2.491 | 2.507 | 2429.292 | 2468.899 | 2507.887 | 2.501 | 2.488 | 2.504 | 1760.220 | 2612.460 | 2192.620 |
| 11 | 2 | 1 | 85.99 | .505 | .500 | .517 | 2.888 | 2.892 | 2.882 | 4913.389 | 5162.955 | 5105.907 | 2.884 | 2.891 | 2.879 | 2918.200 | 2015.270 | 2246.410 |
| 12 | 1 | 1 | 91.31 | .305 | .371 | .387 | 2.306 | 2.522 | 2.373 | 4024.407 | 4506.624 | 4116.820 | 2.301 | 2.518 | 2.367 | 3243.200 | 3253.190 | 4407.640 |
| 13 | 1 | 2 | 61.25 | .264 | .366 | .283 | 1.880 | 1.912 | 1.942 | 1637.441 | 1613.107 | 1687.591 | 1.879 | 1.912 | 1.941 | 1819.030 | 1563.080 | 3047.070 |
| 14 | 2 | 1 | 90.28 | .319 | .381 | .304 | 2.474 | 2.636 | 2.428 | 4092.549 | 4391.537 | 3942.388 | 2.473 | 2.635 | 2.428 | 4098.090 | 4254.990 | 4460.210 |

**Appendix 12 – Change of Direction Raw Data (Internal Cueing Conditions)**

| | Category | Gender | Mass | TimeINT | RFDPeakRINT | RFDtoHPeak RINT | RFDHPeaktoPeak RINT | NetImpulse RINT | Contact RINT | MaxForce RINT | TimeMaxForce RINT | RFDPeak LINT | RFDtoHP LINT | RFDHPeaktoPeak LINT | NetImpulse LINT | ContactL INT | MaxForce LINT | TimeMaxForce LINT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 1 | 80.320 | 5.280 | 8444.380 | 9682.336 | 6810.511 | 4.543 | .435 | 1156.88 | .137 | 3109.... | 4925.26 | 1093.53 | 3.264 | .466 | 970.050 | .312 |
| 2 | 1 | 1 | 85.965 | 5.790 | 3563.456 | 6470.738 | 563.423 | 3.356 | .425 | 1061.91 | .298 | 2579.... | 3801.10 | 1269.40 | 3.351 | .514 | 1031.84 | .400 |
| 3 | 2 | 1 | 77.363 | 4.870 | 24828.89 | 13227.778 | 35733.889 | .932 | .330 | 893.840 | .036 | 52037... | 61857.1 | 40454.3 | 1.344 | .299 | 728.520 | .014 |
| 4 | 2 | 1 | 83.291 | 5.090 | 19081.63 | 22458.776 | 15064.898 | 3.134 | .480 | 935.000 | .049 | 3586.... | 5834.38 | 647.875 | .539 | .444 | 573.760 | .160 |
| 5 | 2 | 2 | 65.167 | 5.120 | 2569.766 | 4732.536 | 290.087 | 5.001 | .488 | 881.430 | .343 | 16236... | 10341.9 | 21679.1 | 2.336 | .360 | 1039.16 | .064 |
| 6 | 2 | 1 | 67.845 | 4.930 | 2670.247 | 3495.769 | 1787.198 | 5.205 | .487 | 971.970 | .364 | 13843... | 23389.9 | 3743.06 | 6.583 | .617 | 1176.72 | .085 |
| 7 | 1 | 2 | 58.336 | 5.790 | 37132.81 | 31236.250 | 42416.875 | 6.384 | .576 | 1188.25 | .032 | 1428.... | 1926.93 | 872.024 | 5.563 | .644 | 712.700 | .499 |
| 8 | 1 | 2 | 86.887 | 5.940 | 1521.523 | 2313.775 | 530.596 | −2.179 | .387 | 229.750 | .151 | 4716.... | 7485.46 | 1612.73 | 2.307 | .408 | 890.470 | .187 |
| 9 | 2 | 1 | 76.274 | 5.280 | 1542.840 | 2720.605 | 285.412 | 6.630 | .739 | 917.990 | .595 | 86235... | 95178.3 | 76393.9 | 7.164 | .596 | 1983.42 | .023 |
| 10 | 1 | 2 | 64.263 | 5.870 | 19929.56 | 16291.556 | 22904.000 | 5.163 | .603 | 896.830 | .045 | 21830... | 20137.9 | 22974.9 | 3.794 | .443 | 851.390 | .039 |
| 11 | 2 | 1 | 85.985 | 5.650 | 4964.112 | 5717.103 | 4057.477 | 1.876 | .438 | 1062.32 | .214 | 6958.... | 9232.04 | 4557.85 | 3.372 | .455 | 1294.31 | .186 |
| 12 | 1 | 1 | 91.314 | 6.430 | 3691.505 | 6408.294 | 825.084 | 4.033 | .566 | 1103.76 | .299 | 3398.... | 6327.42 | 410.629 | 4.273 | .525 | 1080.63 | .318 |
| 13 | 1 | 2 | 61.220 | 6.100 | 8248.660 | 12153.402 | 3464.742 | 2.541 | .330 | 800.120 | .097 | 2187.... | 3984.55 | 259.422 | 2.296 | .382 | 605.840 | .277 |
| 14 | 2 | 1 | 90.283 | 5.150 | 7662.500 | 11450.465 | 3573.140 | 2.975 | .344 | 1317.95 | .172 | 3280.... | 5697.05 | 765.906 | 2.657 | .471 | 977.540 | .298 |

**Change of Direction Raw Data (External Cueing Conditions)**

| TimeEXT | RFDPeakR EXT | RFDtoHPeak REXT | RFDHPeaktoPeakR EXT | NetImpulseR EXT | Contact REXT | MaxForce REXT | TimeMaxForce REXT | RFDPeak LEXT | RFDtoHP LEXT | RFDHPeaktoPeak LEXT | NetImpulse LEXT | ContactL EXT | MexForce LEXT | TimeMaxForceL EXT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.070 | 4382.439 | 7926.179 | 692.602 | 5.212 | .480 | 1078.08 | .246 | 3407... | 5856.61 | 817.469 | 4.820 | .478 | 1103.88 | .324 |
| 5.230 | 13600.93 | 21373.72 | 5489.070 | 1.413 | .242 | 1169.68 | .086 | 33103... | 47682.1 | 17505.8 | 4.499 | .400 | 1257.93 | .038 |
| 5.220 | 22115.93 | 30842.94 | 10174.815 | 1.352 | .390 | 597.130 | .027 | 9593... | 12934.0 | 6032.90 | 2.806 | .399 | 892.150 | .093 |
| 5.070 | 2838.148 | 5344.242 | 211.987 | 2.232 | .424 | 842.930 | .297 | 21454... | 22561.9 | 16565.0 | .962 | .469 | 686.530 | .032 |
| 5.230 | 5368.636 | 8639.318 | 1894.659 | 4.934 | .476 | 944.880 | .176 | 19130... | 24441.4 | 12869.3 | 3.044 | .581 | 1109.57 | .058 |
| 4.810 | 2177.026 | 3105.132 | 1125.803 | 5.672 | .549 | 907.820 | .417 | 8565... | 11337.6 | 5383.73 | 4.240 | .482 | 101.670 | .118 |
| 5.630 | 18393.20 | 13560.00 | 22704.000 | 6.070 | .555 | 916.660 | .050 | 18809... | 16094.7 | 20928.2 | 5.211 | .567 | 921.650 | .049 |
| 5.940 | 3572.069 | 6465.747 | 412.184 | −1.386 | .293 | 310.770 | .087 | 7105... | 12951.5 | 724.839 | 1.486 | .339 | 881.080 | .124 |
| 5.220 | 36232.96 | 33044.44 | 38072.593 | 5.236 | .589 | 978.290 | .027 | 58655... | 40265.9 | 76187.4 | 6.551 | .650 | 1583.71 | .027 |
| 5.710 | 16116.03 | 13801.38 | 17865.172 | 5.337 | .635 | 934.730 | .058 | 32193... | 38595.4 | 23209.1 | 7.538 | .787 | 1126.77 | .035 |
| 5.450 | 3770.000 | 5504.387 | 1868.922 | 1.345 | .358 | 1014.13 | .269 | 4695... | 8271.72 | 1040.37 | 3.877 | .469 | 1258.45 | .268 |
| 6.030 | 24169.42 | 14748.08 | 33128.462 | 3.911 | .479 | 1256.81 | .052 | 5412... | 9266.98 | 1422.08 | 3.296 | .369 | 1147.47 | .212 |
| 6.080 | 8937.625 | 8727.250 | 8917.000 | 4.560 | .571 | 715.010 | .080 | 17888... | 15404.3 | 18547.1 | 4.564 | .490 | 751.310 | .042 |
| 4.850 | 6765.775 | 12081.50 | 1237.968 | 3.075 | .369 | 1265.20 | .187 | 3945... | 7190.22 | 612.687 | 1.628 | .387 | 895.730 | .227 |

**Change of Direction Raw Data (Control Conditions)**

| TimeCONT | RFDPeak CONTR | RFDtoHP CONTR | RFDHpeaktoPeak CONTR | NetImpulse CONTR | Contact CONTR | MaxForce CONTR | TimeMaxForce CONTR | RFDPeak CONTL | RFDtoHP CONTL | RFDHPeaktoPeak CONTL | NetImpulse CONTL | Contact CONTL | MaxForce CONTL | TimeMaxForce CONTL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.100 | 7337.... | 8387.66 | 5986.95 | 3.552 | .427 | 1034.55 | .141 | 4659.... | 6619.79 | 2516.06 | 1.745 | .356 | 922.630 | .198 |
| 5.970 | 35112... | 42981.1 | 26486.1 | 3.186 | .398 | 1264.05 | .036 | 57820... | 61620.0 | 52606.9 | 5.465 | .471 | 1676.78 | .029 |
| 5.280 | 25615... | 31417.1 | 18640.0 | .318 | .383 | 537.920 | .021 | 11848... | 109035 | 108573 | 2.055 | .315 | 947.840 | .008 |
| 5.380 | 3150.... | 5635.99 | 402.561 | 3.069 | .482 | 910.410 | .289 | 15340... | 11299.2 | 18428.2 | 1.439 | .662 | 751.690 | .049 |
| 5.690 | 5239.... | 8285.93 | 2054.88 | 3.135 | .377 | 901.250 | .172 | 7926.... | 3938.23 | 11684.8 | .990 | .461 | 627.810 | .079 |
| 4.840 | 3432.... | 5910.28 | 755.304 | 3.166 | .403 | 847.740 | .247 | 4439.... | 7816.26 | 865.911 | 3.382 | .402 | 901.150 | .203 |
| 6.470 | 1213.... | 1904.58 | 170.444 | 3.198 | .568 | 546.230 | .450 | 2031.... | 3666.19 | 283.220 | 1.131 | .354 | 479.360 | .236 |
| 6.280 | 5157.... | 4038.79 | 5950.00 | −1.248 | .289 | 341.030 | .066 | 20899... | 13777.3 | 25413.3 | 1.716 | .367 | 940.490 | .045 |
| 5.570 | 43667... | 60106.3 | 24447.5 | 5.666 | .838 | 1397.35 | .032 | 98990... | 108369 | 87997.0 | 8.944 | .757 | 1979.80 | .020 |
| 5.850 | 20250... | 12847.5 | 25223.0 | 3.101 | .453 | 810.020 | .040 | 2470.... | 3625.05 | 1070.16 | 4.373 | .485 | 793.140 | .321 |
| 5.750 | 4146.... | 6427.52 | 1742.76 | 1.357 | .396 | 870.720 | .210 | 7998.... | 9695.54 | 5937.71 | 2.919 | .380 | 1327.82 | .166 |
| 6.250 | 5142.... | 9684.30 | 401.402 | 2.862 | .459 | 1100.41 | .214 | 4191.... | 7400.00 | 895.630 | 2.495 | .468 | 997.670 | .238 |
| 6.460 | 16787... | 14826.4 | 16926.0 | 1.793 | .276 | 889.720 | .053 | 21411... | 26522.6 | 15672.8 | 2.261 | .327 | 835.030 | .039 |
| 5.100 | 6023.... | 9676.13 | 2218.74 | 2.445 | .353 | 1150.45 | .191 | 3752.... | 5756.79 | 1611.28 | .787 | .370 | 818.070 | .218 |

**Appendix 13 SPSS – Vertical Jump Output**
**Descriptive Statistics**

| | Category | Mean | Std. Deviation | N |
|---|---|---|---|---|
| HeightINT | Sedentary | .34850 | .080714 | 6 |
| | Trained | .51200 | .112119 | 8 |
| | Total | .44193 | .127768 | 14 |
| HeightEXT | Sedentary | .36533 | .097478 | 6 |
| | Trained | .54788 | .116769 | 8 |
| | Total | .46964 | .140658 | 14 |
| HeightCONT | Sedentary | .36717 | .152437 | 6 |
| | Trained | .50725 | .134682 | 8 |
| | Total | .44721 | .154532 | 14 |
| VelINT | Sedentary | 2.30733 | .284793 | 6 |
| | Trained | 2.73575 | .197579 | 8 |
| | Total | 2.55214 | .317209 | 14 |
| VelEXT | Sedentary | 2.35733 | .286829 | 6 |
| | Trained | 2.83900 | .225869 | 8 |
| | Total | 2.63257 | .346844 | 14 |
| VelCONT | Sedentary | 2.32167 | .309519 | 6 |
| | Trained | 2.75375 | .208722 | 8 |
| | Total | 2.56857 | .330974 | 14 |
| PowerINT | Sedentary | 3015.52667 | 955.635968 | 6 |
| | Trained | 4003.20000 | 750.968255 | 8 |
| | Total | 3579.91143 | 955.085193 | 14 |
| PowerEXT | Sedentary | 3083.66117 | 1059.000816 | 6 |
| | Trained | 4310.38375 | 758.172364 | 8 |
| | Total | 3784.64550 | 1066.650792 | 14 |
| PowerCONT | Sedentary | 3025.32450 | 982.125566 | 6 |
| | Trained | 4139.59625 | 716.227142 | 8 |
| | Total | 3662.05121 | 987.251114 | 14 |
| ImpulseINT | Sedentary | 2.30429 | .287023 | 6 |
| | Trained | 2.73428 | .198021 | 8 |
| | Total | 2.55000 | .318690 | 14 |
| ImpulseEXT | Sedentary | 2.35258 | .290099 | 6 |
| | Trained | 2.83013 | .212854 | 8 |
| | Total | 2.62547 | .341922 | 14 |
| ImpulseCONT | Sedentary | 2.31979 | .308301 | 6 |
| | Trained | 2.75111 | .208417 | 8 |
| | Total | 2.56626 | .330170 | 14 |
| ForceINT | Sedentary | 3221.49333 | 1695.114426 | 6 |
| | Trained | 4006.31625 | 824.381941 | 8 |
| | Total | 3669.96357 | 1278.103222 | 14 |
| ForceEXT | Sedentary | 3611.22000 | 1659.380823 | 6 |
| | Trained | 3536.11875 | 1596.823319 | 8 |

|  |  |  |  |  |
|---|---|---|---|---|
|  | Total | 3568.30500 | 1559.979645 | 14 |
|  | Sedentary | 3746.30833 | 1258.076905 | 6 |
| ForceCONT | Trained | 3593.82875 | 907.577009 | 8 |
|  | Total | 3659.17714 | 1028.792199 | 14 |

**Vertical Jump Repeated Measures ANOVA - Univariate Tests**

| Source | Measure | | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | |
|---|---|---|---|---|---|---|---|---|---|
| Condition | Height | Sphericity Assumed | .005 | 2 | .003 | .886 | .426 | .069 | 1.771 |
| | | Greenhouse-Geisser | .005 | 1.984 | .003 | .886 | .425 | .069 | 1.757 |
| | | Huynh-Feldt | .005 | 2.000 | .003 | .886 | .426 | .069 | 1.771 |
| | | Lower-bound | .005 | 1.000 | .005 | .886 | .365 | .069 | .886 |
| | Velocity | Sphericity Assumed | .045 | 2 | .022 | 6.223 | .007 | .342 | 12.447 |
| | | Greenhouse-Geisser | .045 | 1.534 | .029 | 6.223 | .013 | .342 | 9.546 |
| | | Huynh-Feldt | .045 | 1.861 | .024 | 6.223 | .008 | .342 | 11.580 |
| | | Lower-bound | .045 | 1.000 | .045 | 6.223 | .028 | .342 | 6.223 |
| | Power | Sphericity Assumed | 245410.723 | 2 | 122705.361 | 5.842 | .009 | .327 | 11.683 |
| | | Greenhouse-Geisser | 245410.723 | 1.721 | 142608.180 | 5.842 | .012 | .327 | 10.053 |
| | | Huynh-Feldt | 245410.723 | 2.000 | 122705.361 | 5.842 | .009 | .327 | 11.683 |
| | | Lower-bound | 245410.723 | 1.000 | 245410.723 | 5.842 | .032 | .327 | 5.842 |
| | Impulse | Sphericity Assumed | .039 | 2 | .020 | 6.304 | .006 | .344 | 12.607 |
| | | Greenhouse-Geisser | .039 | 1.544 | .025 | 6.304 | .012 | .344 | 9.733 |
| | | Huynh-Feldt | .039 | 1.876 | .021 | 6.304 | .008 | .344 | 11.827 |
| | | Lower-bound | .039 | 1.000 | .039 | 6.304 | .027 | .344 | 6.304 |
| | Force | Sphericity Assumed | 64301.965 | 2 | 32150.983 | .075 | .928 | .006 | .149 |
| | | Greenhouse-Geisser | 64301.965 | 1.309 | 49114.296 | .075 | .851 | .006 | .098 |
| | | Huynh-Feldt | 64301.965 | 1.527 | 42098.568 | .075 | .883 | .006 | .114 |
| | | Lower-bound | 64301.965 | 1.000 | 64301.965 | .075 | .789 | .006 | .075 |
| Condition * Category | Height | Sphericity Assumed | .003 | 2 | .002 | .537 | .591 | .043 | 1.074 |
| | | Greenhouse-Geisser | .003 | 1.984 | .002 | .537 | .590 | .043 | 1.065 |
| | | Huynh-Feldt | .003 | 2.000 | .002 | .537 | .591 | .043 | 1.074 |
| | | Lower-bound | .003 | 1.000 | .003 | .537 | .478 | .043 | .537 |

| | | | | df | | F | Sig. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Velocity | Sphericity Assumed | .006 | 2 | .003 | .844 | .442 | .066 | 1.687 |
| | | Greenhouse-Geisser | .006 | 1.534 | .004 | .844 | .418 | .066 | 1.294 |
| | | Huynh-Feldt | .006 | 1.861 | .003 | .844 | .436 | .066 | 1.570 |
| | | Lower-bound | .006 | 1.000 | .006 | .844 | .376 | .066 | .844 |
| | Power | Sphericity Assumed | 98076.449 | 2 | 49038.225 | 2.335 | .118 | .163 | 4.669 |
| | | Greenhouse-Geisser | 98076.449 | 1.721 | 56992.228 | 2.335 | .128 | .163 | 4.017 |
| | | Huynh-Feldt | 98076.449 | 2.000 | 49038.225 | 2.335 | .118 | .163 | 4.669 |
| | | Lower-bound | 98076.449 | 1.000 | 98076.449 | 2.335 | .152 | .163 | 2.335 |
| | Impulse | Sphericity Assumed | .005 | 2 | .003 | .808 | .457 | .063 | 1.616 |
| | | Greenhouse-Geisser | .005 | 1.544 | .003 | .808 | .431 | .063 | 1.248 |
| | | Huynh-Feldt | .005 | 1.876 | .003 | .808 | .451 | .063 | 1.516 |
| | | Lower-bound | .005 | 1.000 | .005 | .808 | .386 | .063 | .808 |
| | Force | Sphericity Assumed | 1855991.949 | 2 | 927995.975 | 2.154 | .138 | .152 | 4.307 |
| | | Greenhouse-Geisser | 1855991.949 | 1.309 | 1417619.774 | 2.154 | .159 | .152 | 2.820 |
| | | Huynh-Feldt | 1855991.949 | 1.527 | 1215119.987 | 2.154 | .153 | .152 | 3.289 |
| | | Lower-bound | 1855991.949 | 1.000 | 1855991.949 | 2.154 | .168 | .152 | 2.154 |
| | Height | Sphericity Assumed | .069 | 24 | .003 | | | | |
| | | Greenhouse-Geisser | .069 | 23.810 | .003 | | | | |
| | | Huynh-Feldt | .069 | 24.000 | .003 | | | | |
| | | Lower-bound | .069 | 12.000 | .006 | | | | |
| Error(Condition) | Velocity | Sphericity Assumed | .086 | 24 | .004 | | | | |
| | | Greenhouse-Geisser | .086 | 18.406 | .005 | | | | |
| | | Huynh-Feldt | .086 | 22.328 | .004 | | | | |
| | | Lower-bound | .086 | 12.000 | .007 | | | | |
| | Power | Sphericity Assumed | 504134.357 | 24 | 21005.598 | | | | |
| | | Greenhouse-Geisser | 504134.357 | 20.650 | 24412.708 | | | | |
| | | Huynh-Feldt | 504134.357 | 24.000 | 21005.598 | | | | |
| | | Lower-bound | 504134.357 | 12.000 | 42011.196 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Impulse | Sphericity Assumed | .075 | 24 | .003 | | | |
| | Greenhouse-Geisser | .075 | 18.529 | .004 | | | |
| | Huynh-Feldt | .075 | 22.515 | .003 | | | |
| | Lower-bound | .075 | 12.000 | .006 | | | |
| Force | Sphericity Assumed | 10341539.009 | 24 | 430897.459 | | | |
| | Greenhouse-Geisser | 10341539.009 | 15.711 | 658245.052 | | | |
| | Huynh-Feldt | 10341539.009 | 18.329 | 564218.088 | | | |
| | Lower-bound | 10341539.009 | 12.000 | 861794.917 | | | |

a. Computed using alpha =

**Vertical Jump Repeated Measures ANOVA Pairwise Comparisons**

| Measure | (I) Condition | (J) Condition | Mean Difference (I-J) | Std. Error | Sig.[b] | 95% Confidence Interval for Difference[b] | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Height | 1 | 2 | -.026 | .021 | .726 | -.086 | .033 |
| | | 3 | -.007 | .020 | 1.000 | -.062 | .049 |
| | 2 | 1 | .026 | .021 | .726 | -.033 | .086 |
| | | 3 | .019 | .020 | 1.000 | -.037 | .075 |
| | 3 | 1 | .007 | .020 | 1.000 | -.049 | .062 |
| | | 2 | -.019 | .020 | 1.000 | -.075 | .037 |
| Velocity | 1 | 2 | -.077* | .026 | .040 | -.150 | -.003 |
| | | 3 | -.016 | .015 | .945 | -.059 | .027 |
| | 2 | 1 | .077* | .026 | .040 | .003 | .150 |
| | | 3 | .060 | .025 | .101 | -.010 | .130 |
| | 3 | 1 | .016 | .015 | .945 | -.027 | .059 |
| | | 2 | -.060 | .025 | .101 | -.130 | .010 |
| Power | 1 | 2 | -187.659* | 56.539 | .018 | -344.806 | -30.512 |
| | | 3 | -73.097 | 43.983 | .367 | -195.346 | 49.152 |

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| | | | Mean Difference (I-J) | Std. Error | Sig. | Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| Impulse | 2 | 1 | 187.659* | 56.539 | .018 | 30.512 | 344.806 |
| | | 3 | 114.562 | 63.709 | .292 | -62.516 | 291.640 |
| | 3 | 1 | 73.097 | 43.983 | .367 | -49.152 | 195.346 |
| | | 2 | -114.562 | 63.709 | .292 | -291.640 | 62.516 |
| | 1 | 2 | -.072* | .025 | .039 | -.141 | -.003 |
| | | 3 | -.016 | .015 | .862 | -.057 | .024 |
| | 2 | 1 | .072* | .025 | .039 | .003 | .141 |
| | | 3 | .056 | .023 | .099 | -.009 | .120 |
| | 3 | 1 | .016 | .015 | .862 | -.024 | .057 |
| | | 2 | -.056 | .023 | .099 | -.120 | .009 |
| Force | 1 | 2 | 40.235 | 215.665 | 1.000 | -559.198 | 639.669 |
| | | 3 | -56.164 | 184.634 | 1.000 | -569.348 | 457.021 |
| | 2 | 1 | -40.235 | 215.665 | 1.000 | -639.669 | 559.198 |
| | | 3 | -96.399 | 328.507 | 1.000 | -1009.476 | 816.677 |
| | 3 | 1 | 56.164 | 184.634 | 1.000 | -457.021 | 569.348 |
| | | 2 | 96.399 | 328.507 | 1.000 | -816.677 | 1009.476 |

Based on estimated marginal means

*. The mean difference is significant at the

b. Adjustment for multiple comparisons: Bonferroni.

**Appendix 14 – Change of Direction SPSS Output**
**Descriptive Statistics**

|  | Category | Mean | Std. Deviation | N |
|---|---|---|---|---|
| TimeINT | Sedentary | 5.98667 | .245981 | 6 |
|  | Trained | 5.17125 | .242454 | 8 |
|  | Total | 5.52071 | .479879 | 14 |
| TimeEXT | Sedentary | 5.77000 | .318559 | 6 |
|  | Trained | 5.11500 | .212065 | 8 |
|  | Total | 5.39571 | .419995 | 14 |
| TimeCONT | Sedentary | 6.21333 | .254454 | 6 |
|  | Trained | 5.33875 | .319349 | 8 |
|  | Total | 5.71357 | .530611 | 14 |
| RFDPeakRINT | Sedentary | 12347.91850 | 13841.150196 | 6 |
|  | Trained | 8970.54550 | 8515.489914 | 8 |
|  | Total | 10417.99107 | 10758.147831 | 14 |
| RFDPeakREXT | Sedentary | 14131.54688 | 7233.530080 | 6 |
|  | Trained | 10456.36413 | 12236.179064 | 8 |
|  | Total | 12031.44245 | 10213.105982 | 14 |
| RFDPeakCONTR | Sedentary | 13943.87297 | 12749.121215 | 6 |
|  | Trained | 12326.42773 | 14657.534019 | 8 |
|  | Total | 13019.61855 | 13374.985748 | 14 |
| RFDtoHPeakRINT | Sedentary | 12479.00250 | 10418.833982 | 6 |
|  | Trained | 9185.67100 | 6589.204936 | 8 |
|  | Total | 10597.09879 | 8245.606085 | 14 |
| RFDHPeaktoPeakREXT | Sedentary | 14752.64800 | 12133.424225 | 6 |
|  | Trained | 6909.91863 | 12991.649132 | 8 |
|  | Total | 10271.08836 | 12795.631779 | 14 |
| RFDtoHPCONTR | Sedentary | 14380.44850 | 14867.399365 | 6 |
|  | Trained | 16980.86275 | 19396.782886 | 8 |
|  | Total | 15866.39950 | 17011.373237 | 14 |
| RFDHPeaktoPeakRINT | Sedentary | 11784.12000 | 17342.870432 | 6 |
|  | Trained | 8450.32650 | 12021.237323 | 8 |
|  | Total | 9879.09514 | 14015.245980 | 14 |
| RFDtoHPeakREXT | Sedentary | 13112.69567 | 5196.295562 | 6 |
|  | Trained | 13311.01688 | 11818.160122 | 8 |
|  | Total | 13226.02207 | 9252.129272 | 14 |
| RFDHpeaktoPeakCONTR | Sedentary | 12526.16583 | 11986.394446 | 6 |
|  | Trained | 7031.08800 | 9245.840505 | 8 |
|  | Total | 9386.12136 | 10452.441593 | 14 |
| NetImpulseRINT | Sedentary | 110.60133 | 108.191481 | 6 |
|  | Trained | 144.53988 | 66.209677 | 8 |
|  | Total | 129.99479 | 84.654113 | 14 |
| NetImpulseREXT | Sedentary | 111.19850 | 95.127914 | 6 |
|  | Trained | 138.00263 | 63.443139 | 8 |

| | | | | |
|---|---|---|---|---|
| | Total | 126.51514 | 76.402335 | 14 |
| | Sedentary | 76.87067 | 70.647925 | 6 |
| NetImpulseCONTR | Trained | 109.63875 | 59.661805 | 8 |
| | Total | 95.59529 | 64.183500 | 14 |
| | Sedentary | .48117 | .114810 | 6 |
| ContactRINT | Trained | .46763 | .125785 | 8 |
| | Total | .47343 | .116780 | 14 |
| | Sedentary | .46250 | .159817 | 6 |
| ContactREXT | Trained | .45438 | .084385 | 8 |
| | Total | .45786 | .116942 | 14 |
| | Sedentary | .40717 | .111272 | 6 |
| ContactCONTR | Trained | .45738 | .158571 | 8 |
| | Total | .43586 | .137719 | 14 |
| | Sedentary | 880.10333 | 348.616382 | 6 |
| MaxForceRINT | Trained | 1017.17250 | 153.200743 | 8 |
| | Total | 958.42857 | 253.646640 | 14 |
| | Sedentary | 883.94333 | 340.995836 | 6 |
| MaxForceREXT | Trained | 953.55750 | 192.113750 | 8 |
| | Total | 923.72286 | 256.659002 | 14 |
| | Sedentary | 825.24333 | 342.043263 | 6 |
| MaxForceCONTR | Trained | 956.29875 | 250.037088 | 8 |
| | Total | 900.13214 | 288.428806 | 14 |
| | Sedentary | .15367 | .119819 | 6 |
| TimeMaxForceRINT | Trained | .23875 | .187466 | 8 |
| | Total | .20229 | .162340 | 14 |
| | Sedentary | .06883 | .017348 | 6 |
| TimeMaxForceREXT | Trained | .20575 | .132941 | 8 |
| | Total | .14707 | .120732 | 14 |
| | Sedentary | .14317 | .164546 | 6 |
| TimeMaxForceCONTR | Trained | .16288 | .095480 | 8 |
| | Total | .15443 | .124197 | 14 |
| | Sedentary | 6023.43233 | 7825.028847 | 6 |
| RFDPeakLINT | Trained | 23160.94513 | 30213.555189 | 8 |
| | Total | 15816.29679 | 24342.302276 | 14 |
| | Sedentary | 19085.40740 | 11834.682974 | 6 |
| RFDPeakLEXT | Trained | 16180.90117 | 18465.457272 | 8 |
| | Total | 17425.68956 | 15482.084823 | 14 |
| | Sedentary | 18137.45341 | 21412.074018 | 6 |
| RFDPeakCONTL | Trained | 32698.50175 | 47359.792542 | 8 |
| | Total | 26458.05246 | 37947.305657 | 14 |
| | Sedentary | 7277.23467 | 6601.431409 | 6 |
| RFDtoHPLINT | Trained | 27056.98525 | 33506.054676 | 8 |
| | Total | 18579.94929 | 26915.642634 | 14 |
| | Sedentary | 23332.49117 | 15790.551989 | 6 |
| RFDtoHPLEXT | Trained | 16607.41575 | 11781.122240 | 8 |

| | | | | |
|---|---|---|---|---|
| | Total | 19489.59093 | 13511.631208 | 14 |
| | Sedentary | 19435.18833 | 22384.228010 | 6 |
| RFDtoHPCONTL | Trained | 32816.22350 | 46892.698190 | 8 |
| | Total | 27081.49414 | 37735.554796 | 14 |
| | Sedentary | 4566.51233 | 9032.553799 | 6 |
| RFDHPeaktoPeakLINT | Trained | 18666.93463 | 27234.201231 | 8 |
| | Total | 12623.89650 | 21981.674664 | 14 |
| | Sedentary | 13722.85867 | 9997.480446 | 6 |
| RFDHPeaktoPeakLEXT | Trained | 14938.60975 | 25429.873697 | 8 |
| | Total | 14417.57357 | 19673.420203 | 14 |
| | Sedentary | 15990.34283 | 20624.459465 | 6 |
| RFDHPeaktoPeakCONTL | Trained | 29701.68000 | 43086.302755 | 8 |
| | Total | 23825.39264 | 34825.302577 | 14 |
| | Sedentary | 132.30167 | 44.638911 | 6 |
| NetImpulseLINT | Trained | 130.39125 | 84.591237 | 8 |
| | Total | 131.21000 | 67.973647 | 14 |
| | Sedentary | 157.05400 | 59.142296 | 6 |
| NetImpulseLEXT | Trained | 134.39925 | 68.114542 | 8 |
| | Total | 144.10843 | 63.078622 | 14 |
| | Sedentary | 111.00967 | 71.270172 | 6 |
| NetImpulseCONTL | Trained | 107.32850 | 100.168539 | 8 |
| | Total | 108.90614 | 85.790353 | 14 |
| | Sedentary | .48600 | .095935 | 6 |
| ContactLINT | Trained | .46350 | .106507 | 8 |
| | Total | .47314 | .098902 | 14 |
| | Sedentary | .49200 | .167126 | 6 |
| ContactLEXT | Trained | .48938 | .087715 | 8 |
| | Total | .49050 | .122014 | 14 |
| | Sedentary | .41200 | .070086 | 6 |
| ContactCONTL | Trained | .46288 | .159756 | 8 |
| | Total | .44107 | .127728 | 14 |
| | Sedentary | 862.14500 | 181.920931 | 6 |
| MaxForceLINT | Trained | 1092.93500 | 426.645521 | 8 |
| | Total | 994.02500 | 353.257418 | 14 |
| | Sedentary | 1014.36833 | 192.475780 | 6 |
| MexForceLEXT | Trained | 953.96125 | 437.707985 | 8 |
| | Total | 979.85000 | 344.055396 | 14 |
| | Sedentary | 953.74500 | 397.445105 | 6 |
| MaxForceCONTL | Trained | 1034.60125 | 432.543293 | 8 |
| | Total | 999.94857 | 404.007240 | 14 |
| | Sedentary | .28667 | .161417 | 6 |
| TimeMaxForceLINT | Trained | .14275 | .116723 | 8 |
| | Total | .20443 | .151063 | 14 |
| | Sedentary | .08333 | .071397 | 6 |
| TimeMaxForceLEXT | Trained | .14338 | .114373 | 8 |

| | | | | |
|---|---|---|---|---|
| | Total | .11764 | .099775 | 14 |
| | Sedentary | .15133 | .128341 | 6 |
| TimeMaxForceCONTL | Trained | .11763 | .087761 | 8 |
| | Total | .13207 | .103837 | 14 |

**Change of Direction Repeated Measures ANOVA – Univariate Tests**

| Source | Measure | | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|---|---|
| Condition | Time | Sphericity Assumed | .771 | 2 | .386 | 13.290 | .000 | .526 |
| | | Greenhouse-Geisser | .771 | 1.757 | .439 | 13.290 | .000 | .526 |
| | | Huynh-Feldt | .771 | 2.000 | .386 | 13.290 | .000 | .526 |
| | | Lower-bound | .771 | 1.000 | .771 | 13.290 | .003 | .526 |
| | RDFPeakR | Sphericity Assumed | 43474749.132 | 2 | 21737374.566 | .198 | .822 | .016 |
| | | Greenhouse-Geisser | 43474749.132 | 1.371 | 31719782.053 | .198 | .739 | .016 |
| | | Huynh-Feldt | 43474749.132 | 1.617 | 26885317.037 | .198 | .776 | .016 |
| | | Lower-bound | 43474749.132 | 1.000 | 43474749.132 | .198 | .664 | .016 |
| | RFDtoHPR | Sphericity Assumed | 214960497.594 | 2 | 107480248.797 | .692 | .510 | .055 |
| | | Greenhouse-Geisser | 214960497.594 | 1.579 | 136146477.565 | .692 | .480 | .055 |
| | | Huynh-Feldt | 214960497.594 | 1.929 | 111424259.645 | .692 | .506 | .055 |
| | | Lower-bound | 214960497.594 | 1.000 | 214960497.594 | .692 | .422 | .055 |
| | RFDHPtoPR | Sphericity Assumed | 98187267.698 | 2 | 49093633.849 | .491 | .618 | .039 |
| | | Greenhouse-Geisser | 98187267.698 | 1.283 | 76558534.584 | .491 | .540 | .039 |
| | | Huynh-Feldt | 98187267.698 | 1.489 | 65954835.729 | .491 | .566 | .039 |
| | | Lower-bound | 98187267.698 | 1.000 | 98187267.698 | .491 | .497 | .039 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ImpulseR | Sphericity Assumed | 9915.266 | 2 | 4957.633 | 5.459 | .011 | .313 |
| | Greenhouse-Geisser | 9915.266 | 1.573 | 6301.572 | 5.459 | .019 | .313 |
| | Huynh-Feldt | 9915.266 | 1.921 | 5161.759 | 5.459 | .012 | .313 |
| | Lower-bound | 9915.266 | 1.000 | 9915.266 | 5.459 | .038 | .313 |
| ContactR | Sphericity Assumed | .012 | 2 | .006 | 1.055 | .364 | .081 |
| | Greenhouse-Geisser | .012 | 1.294 | .010 | 1.055 | .341 | .081 |
| | Huynh-Feldt | .012 | 1.505 | .008 | 1.055 | .349 | .081 |
| | Lower-bound | .012 | 1.000 | .012 | 1.055 | .325 | .081 |
| MaxForceR | Sphericity Assumed | 22969.981 | 2 | 11484.990 | .544 | .587 | .043 |
| | Greenhouse-Geisser | 22969.981 | 1.235 | 18606.340 | .544 | .508 | .043 |
| | Huynh-Feldt | 22969.981 | 1.420 | 16179.888 | .544 | .531 | .043 |
| | Lower-bound | 22969.981 | 1.000 | 22969.981 | .544 | .475 | .043 |
| TimeMaxForceR | Sphericity Assumed | .026 | 2 | .013 | .704 | .505 | .055 |
| | Greenhouse-Geisser | .026 | 1.467 | .017 | .704 | .466 | .055 |
| | Huynh-Feldt | .026 | 1.759 | .015 | .704 | .489 | .055 |
| | Lower-bound | .026 | 1.000 | .026 | .704 | .418 | .055 |
| RFDPeakL | Sphericity Assumed | 855079540.129 | 2 | 427539770.064 | 1.288 | .294 | .097 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Greenhouse-Geisser | 855079540.129 | 1.274 | 671272544.249 | 1.288 | .286 | .097 |
| | Huynh-Feldt | 855079540.129 | 1.476 | 579262956.885 | 1.288 | .290 | .097 |
| | Lower-bound | 855079540.129 | 1.000 | 855079540.129 | 1.288 | .279 | .097 |
| | Sphericity Assumed | 576025881.410 | 2 | 288012940.705 | .800 | .461 | .062 |
| RFDtpHPL | Greenhouse-Geisser | 576025881.410 | 1.452 | 396734018.355 | .800 | .428 | .062 |
| | Huynh-Feldt | 576025881.410 | 1.737 | 331533211.017 | .800 | .447 | .062 |
| | Lower-bound | 576025881.410 | 1.000 | 576025881.410 | .800 | .389 | .062 |
| | Sphericity Assumed | 941589521.171 | 2 | 470794760.585 | 1.615 | .220 | .119 |
| RFDHPtoPL | Greenhouse-Geisser | 941589521.171 | 1.209 | 778915096.485 | 1.615 | .228 | .119 |
| | Huynh-Feldt | 941589521.171 | 1.383 | 680844857.073 | 1.615 | .227 | .119 |
| | Lower-bound | 941589521.171 | 1.000 | 941589521.171 | 1.615 | .228 | .119 |
| | Sphericity Assumed | 9303.218 | 2 | 4651.609 | 2.336 | .118 | .163 |
| ImpulseL | Greenhouse-Geisser | 9303.218 | 1.904 | 4886.666 | 2.336 | .121 | .163 |
| | Huynh-Feldt | 9303.218 | 2.000 | 4651.609 | 2.336 | .118 | .163 |
| | Lower-bound | 9303.218 | 1.000 | 9303.218 | 2.336 | .152 | .163 |
| | Sphericity Assumed | .020 | 2 | .010 | 1.031 | .372 | .079 |
| ContactL | Greenhouse-Geisser | .020 | 1.981 | .010 | 1.031 | .372 | .079 |
| | Huynh-Feldt | .020 | 2.000 | .010 | 1.031 | .372 | .079 |

| | | | | df | | F | Sig. | |
|---|---|---|---|---|---|---|---|---|
| | | Lower-bound | .020 | 1.000 | .020 | 1.031 | .330 | .079 |
| | MaxForceL | Sphericity Assumed | 1923.271 | 2 | 961.635 | .019 | .981 | .002 |
| | | Greenhouse-Geisser | 1923.271 | 1.787 | 1076.518 | .019 | .973 | .002 |
| | | Huynh-Feldt | 1923.271 | 2.000 | 961.635 | .019 | .981 | .002 |
| | | Lower-bound | 1923.271 | 1.000 | 1923.271 | .019 | .892 | .002 |
| | TimeMaxForceL | Sphericity Assumed | .078 | 2 | .039 | 4.519 | .022 | .274 |
| | | Greenhouse-Geisser | .078 | 1.633 | .048 | 4.519 | .030 | .274 |
| | | Huynh-Feldt | .078 | 2.000 | .039 | 4.519 | .022 | .274 |
| | | Lower-bound | .078 | 1.000 | .078 | 4.519 | .055 | .274 |
| | Time | Sphericity Assumed | .089 | 2 | .044 | 1.525 | .238 | .113 |
| | | Greenhouse-Geisser | .089 | 1.757 | .050 | 1.525 | .240 | .113 |
| Condition * Category | | Huynh-Feldt | .089 | 2.000 | .044 | 1.525 | .238 | .113 |
| | | Lower-bound | .089 | 1.000 | .089 | 1.525 | .240 | .113 |
| | RDFPeakR | Sphericity Assumed | 8480365.831 | 2 | 4240182.915 | .039 | .962 | .003 |
| | | Greenhouse-Geisser | 8480365.831 | 1.371 | 6187392.941 | .039 | .911 | .003 |
| | | Huynh-Feldt | 8480365.831 | 1.617 | 5244362.038 | .039 | .937 | .003 |
| | | Lower-bound | 8480365.831 | 1.000 | 8480365.831 | .039 | .848 | .003 |
| | RFDtoHPR | Sphericity Assumed | 187991438.586 | 2 | 93995719.293 | .605 | .554 | .048 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Greenhouse-Geisser | 187991438.586 | 1.579 | 119065467.667 | .605 | .519 | .048 |
| | Huynh-Feldt | 187991438.586 | 1.929 | 97444912.431 | .605 | .549 | .048 |
| | Lower-bound | 187991438.586 | 1.000 | 187991438.586 | .605 | .452 | .048 |
| | Sphericity Assumed | 56642030.777 | 2 | 28321015.389 | .283 | .756 | .023 |
| RFDHPtoPR | Greenhouse-Geisser | 56642030.777 | 1.283 | 44164900.133 | .283 | .659 | .023 |
| | Huynh-Feldt | 56642030.777 | 1.489 | 38047864.279 | .283 | .692 | .023 |
| | Lower-bound | 56642030.777 | 1.000 | 56642030.777 | .283 | .604 | .023 |
| | Sphericity Assumed | 100.387 | 2 | 50.194 | .055 | .946 | .005 |
| ImpulseR | Greenhouse-Geisser | 100.387 | 1.573 | 63.800 | .055 | .911 | .005 |
| | Huynh-Feldt | 100.387 | 1.921 | 52.260 | .055 | .941 | .005 |
| | Lower-bound | 100.387 | 1.000 | 100.387 | .055 | .818 | .005 |
| | Sphericity Assumed | .009 | 2 | .004 | .729 | .493 | .057 |
| ContactR | Greenhouse-Geisser | .009 | 1.294 | .007 | .729 | .441 | .057 |
| | Huynh-Feldt | .009 | 1.505 | .006 | .729 | .459 | .057 |
| | Lower-bound | .009 | 1.000 | .009 | .729 | .410 | .057 |
| | Sphericity Assumed | 9555.851 | 2 | 4777.925 | .227 | .799 | .019 |
| MaxForceR | Greenhouse-Geisser | 9555.851 | 1.235 | 7740.512 | .227 | .692 | .019 |
| | Huynh-Feldt | 9555.851 | 1.420 | 6731.072 | .227 | .724 | .019 |
| | Lower-bound | 9555.851 | 1.000 | 9555.851 | .227 | .643 | .019 |
| TimeMaxForceR | Sphericity Assumed | .024 | 2 | .012 | .652 | .530 | .052 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Greenhouse-Geisser | .024 | 1.467 | .016 | .652 | .487 | .052 |
| | Huynh-Feldt | .024 | 1.759 | .013 | .652 | .512 | .052 |
| | Lower-bound | .024 | 1.000 | .024 | .652 | .435 | .052 |
| | Sphericity Assumed | 815275761.940 | 2 | 407637880.970 | 1.228 | .311 | .093 |
| RFDPeakL | Greenhouse-Geisser | 815275761.940 | 1.274 | 640024944.228 | 1.228 | .299 | .093 |
| | Huynh-Feldt | 815275761.940 | 1.476 | 552298384.390 | 1.228 | .304 | .093 |
| | Lower-bound | 815275761.940 | 1.000 | 815275761.940 | 1.228 | .290 | .093 |
| | Sphericity Assumed | 1311662906.358 | 2 | 655831453.179 | 1.821 | .183 | .132 |
| RFDtpHPL | Greenhouse-Geisser | 1311662906.358 | 1.452 | 903399156.811 | 1.821 | .195 | .132 |
| | Huynh-Feldt | 1311662906.358 | 1.737 | 754931035.481 | 1.821 | .189 | .132 |
| | Lower-bound | 1311662906.358 | 1.000 | 1311662906.358 | 1.821 | .202 | .132 |
| | Sphericity Assumed | 368349498.226 | 2 | 184174749.113 | .632 | .540 | .050 |
| RFDHPtoPL | Greenhouse-Geisser | 368349498.226 | 1.209 | 304711318.998 | .632 | .469 | .050 |
| | Huynh-Feldt | 368349498.226 | 1.383 | 266346274.925 | .632 | .488 | .050 |
| | Lower-bound | 368349498.226 | 1.000 | 368349498.226 | .632 | .442 | .050 |
| | Sphericity Assumed | 906.811 | 2 | 453.406 | .228 | .798 | .019 |
| ImpulseL | Greenhouse-Geisser | 906.811 | 1.904 | 476.317 | .228 | .788 | .019 |
| | Huynh-Feldt | 906.811 | 2.000 | 453.406 | .228 | .798 | .019 |
| | Lower-bound | 906.811 | 1.000 | 906.811 | .228 | .642 | .019 |

| | | | | df | | F | Sig. | |
|---|---|---|---|---|---|---|---|---|
| | ContactL | Sphericity Assumed | .010 | 2 | .005 | .497 | .615 | .040 |
| | | Greenhouse-Geisser | .010 | 1.981 | .005 | .497 | .613 | .040 |
| | | Huynh-Feldt | .010 | 2.000 | .005 | .497 | .615 | .040 |
| | | Lower-bound | .010 | 1.000 | .010 | .497 | .494 | .040 |
| | MaxForceL | Sphericity Assumed | 145407.086 | 2 | 72703.543 | 1.446 | .255 | .108 |
| | | Greenhouse-Geisser | 145407.086 | 1.787 | 81389.123 | 1.446 | .257 | .108 |
| | | Huynh-Feldt | 145407.086 | 2.000 | 72703.543 | 1.446 | .255 | .108 |
| | | Lower-bound | 145407.086 | 1.000 | 145407.086 | 1.446 | .252 | .108 |
| | TimeMaxForceL | Sphericity Assumed | .071 | 2 | .036 | 4.118 | .029 | .255 |
| | | Greenhouse-Geisser | .071 | 1.633 | .044 | 4.118 | .039 | .255 |
| | | Huynh-Feldt | .071 | 2.000 | .036 | 4.118 | .029 | .255 |
| | | Lower-bound | .071 | 1.000 | .071 | 4.118 | .065 | .255 |
| Error(Condition) | Time | Sphericity Assumed | .696 | 24 | .029 | | | |
| | | Greenhouse-Geisser | .696 | 21.080 | .033 | | | |
| | | Huynh-Feldt | .696 | 24.000 | .029 | | | |
| | | Lower-bound | .696 | 12.000 | .058 | | | |
| | RDFPeakR | Sphericity Assumed | 2638795920.933 | 24 | 109949830.039 | | | |
| | | Greenhouse-Geisser | 2638795920.933 | 16.447 | 160441852.580 | | | |
| | | Huynh-Feldt | 2638795920.933 | 19.405 | 135988641.577 | | | |

| | | | | |
|---|---|---|---|---|
| | Lower-bound | 2638795920.933 | 12.000 | 219899660.078 |
| RFDtoHPR | Sphericity Assumed | 3726151341.652 | 24 | 155256305.902 |
| | Greenhouse-Geisser | 3726151341.652 | 18.947 | 196664963.144 |
| | Huynh-Feldt | 3726151341.652 | 23.150 | 160953469.442 |
| | Lower-bound | 3726151341.652 | 12.000 | 310512611.804 |
| RFDHPtoPR | Sphericity Assumed | 2401327109.164 | 24 | 100055296.215 |
| | Greenhouse-Geisser | 2401327109.164 | 15.390 | 156030145.970 |
| | Huynh-Feldt | 2401327109.164 | 17.864 | 134419274.116 |
| | Lower-bound | 2401327109.164 | 12.000 | 200110592.430 |
| ImpulseR | Sphericity Assumed | 21794.108 | 24 | 908.088 |
| | Greenhouse-Geisser | 21794.108 | 18.882 | 1154.257 |
| | Huynh-Feldt | 21794.108 | 23.051 | 945.478 |
| | Lower-bound | 21794.108 | 12.000 | 1816.176 |
| ContactR | Sphericity Assumed | .141 | 24 | .006 |
| | Greenhouse-Geisser | .141 | 15.523 | .009 |
| | Huynh-Feldt | .141 | 18.057 | .008 |
| | Lower-bound | .141 | 12.000 | .012 |
| MaxForceR | Sphericity Assumed | 506258.195 | 24 | 21094.091 |

| | | | | |
|---|---|---|---|---|
| | Greenhouse-Geisser | 506258.195 | 14.814 | 34173.632 |
| | Huynh-Feldt | 506258.195 | 17.036 | 29717.051 |
| | Lower-bound | 506258.195 | 12.000 | 42188.183 |
| | Sphericity Assumed | .435 | 24 | .018 |
| TimeMaxForceR | Greenhouse-Geisser | .435 | 17.598 | .025 |
| | Huynh-Feldt | .435 | 21.111 | .021 |
| | Lower-bound | .435 | 12.000 | .036 |
| | Sphericity Assumed | 7967395259.928 | 24 | 331974802.497 |
| RFDPeakL | Greenhouse-Geisser | 7967395259.928 | 15.286 | 521227698.338 |
| | Huynh-Feldt | 7967395259.928 | 17.714 | 449784369.011 |
| | Lower-bound | 7967395259.928 | 12.000 | 663949604.994 |
| | Sphericity Assumed | 8642693435.532 | 24 | 360112226.481 |
| RFDtpHPL | Greenhouse-Geisser | 8642693435.532 | 17.423 | 496049831.375 |
| | Huynh-Feldt | 8642693435.532 | 20.850 | 414527078.121 |
| | Lower-bound | 8642693435.532 | 12.000 | 720224452.961 |
| | Sphericity Assumed | 6994830592.255 | 24 | 291451274.677 |
| RFDHPtoPL | Greenhouse-Geisser | 6994830592.255 | 14.506 | 482196950.225 |
| | Huynh-Feldt | 6994830592.255 | 16.596 | 421485364.885 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Lower-bound | 6994830592.255 | 12.000 | 582902549.355 | |
| ImpulseL | | Sphericity Assumed | 47786.042 | 24 | 1991.085 | |
| | | Greenhouse-Geisser | 47786.042 | 22.846 | 2091.699 | |
| | | Huynh-Feldt | 47786.042 | 24.000 | 1991.085 | |
| | | Lower-bound | 47786.042 | 12.000 | 3982.170 | |
| ContactL | | Sphericity Assumed | .239 | 24 | .010 | |
| | | Greenhouse-Geisser | .239 | 23.774 | .010 | |
| | | Huynh-Feldt | .239 | 24.000 | .010 | |
| | | Lower-bound | .239 | 12.000 | .020 | |
| MaxForceL | | Sphericity Assumed | 1206981.433 | 24 | 50290.893 | |
| | | Greenhouse-Geisser | 1206981.433 | 21.439 | 56298.930 | |
| | | Huynh-Feldt | 1206981.433 | 24.000 | 50290.893 | |
| | | Lower-bound | 1206981.433 | 12.000 | 100581.786 | |
| TimeMaxForceL | | Sphericity Assumed | .208 | 24 | .009 | |
| | | Greenhouse-Geisser | .208 | 19.594 | .011 | |
| | | Huynh-Feldt | .208 | 24.000 | .009 | |
| | | Lower-bound | .208 | 12.000 | .017 | |

**Change of Direction Repeated Measures ANOVA Pairwise Comparisons**

| Measure | (I) Condition | (J) Condition | Mean Difference (I-J) | Std. Error | Sig.[b] | 95% Confidence Interval for Difference[b] | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Time | 1 | 2 | .136 | .058 | .106 | -.024 | .296 |
| | | 3 | -.197 | .076 | .071 | -.409 | .015 |
| | 2 | 1 | -.136 | .058 | .106 | -.296 | .024 |
| | | 3 | -.334* | .060 | .000 | -.500 | -.167 |
| | 3 | 1 | .197 | .076 | .071 | -.015 | .409 |
| | | 2 | .334* | .060 | .000 | .167 | .500 |
| RDFPeakR | 1 | 2 | -1634.724 | 3782.974 | 1.000 | -12149.398 | 8879.951 |
| | | 3 | -2475.918 | 5117.333 | 1.000 | -16699.408 | 11747.571 |
| | 2 | 1 | 1634.724 | 3782.974 | 1.000 | -8879.951 | 12149.398 |
| | | 3 | -841.195 | 2757.728 | 1.000 | -8506.224 | 6823.835 |
| | 3 | 1 | 2475.918 | 5117.333 | 1.000 | -11747.571 | 16699.408 |
| | | 2 | 841.195 | 2757.728 | 1.000 | -6823.835 | 8506.224 |
| RFDtoHPR | 1 | 2 | 1.053 | 4050.043 | 1.000 | -11255.932 | 11258.039 |
| | | 3 | -4848.319 | 5858.805 | 1.000 | -21132.710 | 11436.073 |
| | 2 | 1 | -1.053 | 4050.043 | 1.000 | -11258.039 | 11255.932 |
| | | 3 | -4849.372 | 4146.829 | .795 | -16375.371 | 6676.626 |
| | 3 | 1 | 4848.319 | 5858.805 | 1.000 | -11436.073 | 21132.710 |
| | | 2 | 4849.372 | 4146.829 | .795 | -6676.626 | 16375.371 |
| RFDHPtoPR | 1 | 2 | -3094.633 | 4083.748 | 1.000 | -14445.302 | 8256.036 |
| | | 3 | 338.596 | 4777.654 | 1.000 | -12940.765 | 13617.958 |
| | 2 | 1 | 3094.633 | 4083.748 | 1.000 | -8256.036 | 14445.302 |
| | | 3 | 3433.229 | 2066.691 | .368 | -2311.082 | 9177.541 |
| | 3 | 1 | -338.596 | 4777.654 | 1.000 | -13617.958 | 12940.765 |
| | | 2 | -3433.229 | 2066.691 | .368 | -9177.541 | 2311.082 |
| ImpulseR | 1 | 2 | 2.970 | 10.402 | 1.000 | -25.942 | 31.882 |

| | | | Mean Difference | Std. Error | Sig. | Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| | | 3 | 34.316[*] | 9.415 | .010 | 8.148 | 60.484 |
| | 2 | 1 | -2.970 | 10.402 | 1.000 | -31.882 | 25.942 |
| | | 3 | 31.346 | 14.158 | .141 | -8.006 | 70.698 |
| | 3 | 1 | -34.316[*] | 9.415 | .010 | -60.484 | -8.148 |
| | | 2 | -31.346 | 14.158 | .141 | -70.698 | 8.006 |
| | 1 | 2 | .016 | .030 | 1.000 | -.067 | .099 |
| | | 3 | .042 | .017 | .087 | -.005 | .089 |
| ContactR | 2 | 1 | -.016 | .030 | 1.000 | -.099 | .067 |
| | | 3 | .026 | .037 | 1.000 | -.077 | .130 |
| | 3 | 1 | -.042 | .017 | .087 | -.089 | .005 |
| | | 2 | -.026 | .037 | 1.000 | -.130 | .077 |
| | 1 | 2 | 29.888 | 35.822 | 1.000 | -69.680 | 129.455 |
| | | 3 | 57.867 | 73.371 | 1.000 | -146.065 | 261.799 |
| MaxForceR | 2 | 1 | -29.888 | 35.822 | 1.000 | -129.455 | 69.680 |
| | | 3 | 27.979 | 50.618 | 1.000 | -112.711 | 168.670 |
| | 3 | 1 | -57.867 | 73.371 | 1.000 | -261.799 | 146.065 |
| | | 2 | -27.979 | 50.618 | 1.000 | -168.670 | 112.711 |
| | 1 | 2 | .059 | .055 | .903 | -.093 | .210 |
| | | 3 | .043 | .062 | 1.000 | -.129 | .215 |
| TimeMaxForce R | 2 | 1 | -.059 | .055 | .903 | -.210 | .093 |
| | | 3 | -.016 | .034 | 1.000 | -.109 | .078 |
| | 3 | 1 | -.043 | .062 | 1.000 | -.215 | .129 |
| | | 2 | .016 | .034 | 1.000 | -.078 | .109 |
| | 1 | 2 | -3040.966 | 4345.264 | 1.000 | -15118.511 | 9036.580 |
| | | 3 | -10825.789 | 6672.562 | .392 | -29371.995 | 7720.418 |
| RFDPeakL | 2 | 1 | 3040.966 | 4345.264 | 1.000 | -9036.580 | 15118.511 |
| | | 3 | -7784.823 | 9046.246 | 1.000 | -32928.621 | 17358.975 |
| | 3 | 1 | 10825.789 | 6672.562 | .392 | -7720.418 | 29371.995 |
| | | 2 | 7784.823 | 9046.246 | 1.000 | -17358.975 | 32928.621 |
| RFDtpHPL | 1 | 2 | -2802.844 | 6163.777 | 1.000 | -19934.895 | 14329.208 |

| | (I) | (J) | Mean Difference | Std. Error | Sig. | Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| | | 3 | -8958.596 | 5901.387 | .465 | -25361.342 | 7444.150 |
| | 2 | 1 | 2802.844 | 6163.777 | 1.000 | -14329.208 | 19934.895 |
| | | 3 | -6155.752 | 9204.922 | 1.000 | -31740.585 | 19429.080 |
| | 3 | 1 | 8958.596 | 5901.387 | .465 | -7444.150 | 25361.342 |
| | | 2 | 6155.752 | 9204.922 | 1.000 | -19429.080 | 31740.585 |
| RFDHPtoPL | 1 | 2 | -2714.011 | 3414.712 | 1.000 | -12205.112 | 6777.090 |
| | | 3 | -11229.288 | 6690.419 | .357 | -29825.127 | 7366.551 |
| | 2 | 1 | 2714.011 | 3414.712 | 1.000 | -6777.090 | 12205.112 |
| | | 3 | -8515.277 | 8431.368 | .997 | -31950.038 | 14919.484 |
| | 3 | 1 | 11229.288 | 6690.419 | .357 | -7366.551 | 29825.127 |
| | | 2 | 8515.277 | 8431.368 | .997 | -14919.484 | 31950.038 |
| ImpulseL | 1 | 2 | -14.380 | 15.339 | 1.000 | -57.014 | 28.253 |
| | | 3 | 22.177 | 18.661 | .773 | -29.690 | 74.045 |
| | 2 | 1 | 14.380 | 15.339 | 1.000 | -28.253 | 57.014 |
| | | 3 | 36.558 | 16.959 | .156 | -10.578 | 83.693 |
| | 3 | 1 | -22.177 | 18.661 | .773 | -74.045 | 29.690 |
| | | 2 | -36.558 | 16.959 | .156 | -83.693 | 10.578 |
| ContactL | 1 | 2 | -.016 | .040 | 1.000 | -.127 | .095 |
| | | 3 | .037 | .037 | .986 | -.065 | .139 |
| | 2 | 1 | .016 | .040 | 1.000 | -.095 | .127 |
| | | 3 | .053 | .038 | .551 | -.052 | .158 |
| | 3 | 1 | -.037 | .037 | .986 | -.139 | .065 |
| | | 2 | -.053 | .038 | .551 | -.158 | .052 |
| MaxForceL | 1 | 2 | -6.625 | 88.488 | 1.000 | -252.576 | 239.326 |
| | | 3 | -16.633 | 70.236 | 1.000 | -211.854 | 178.587 |
| | 2 | 1 | 6.625 | 88.488 | 1.000 | -239.326 | 252.576 |
| | | 3 | -10.008 | 96.119 | 1.000 | -277.169 | 257.152 |
| | 3 | 1 | 16.633 | 70.236 | 1.000 | -178.587 | 211.854 |
| | | 2 | 10.008 | 96.119 | 1.000 | -257.152 | 277.169 |

90

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| TimeMaxForceL | 1 | 2 | .101[*] | .034 | .035 | .007 | .196 |
| | | 3 | .080 | .043 | .255 | -.039 | .199 |
| | 2 | 1 | -.101[*] | .034 | .035 | -.196 | -.007 |
| | | 3 | -.021 | .028 | 1.000 | -.100 | .058 |
| | 3 | 1 | -.080 | .043 | .255 | -.199 | .039 |
| | | 2 | .021 | .028 | 1.000 | -.058 | .100 |

Based on estimated marginal means

*. The mean difference is significant at the

b. Adjustment for multiple comparisons: Bonferroni.

**Change of Direction Repeated Measures ANOVA – Confidence Intervals Category * Condition**

| Measure | Category | Condition | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Time | Sedentary | 1 | 5.987 | .100 | 5.770 | 6.204 |
| | | 2 | 5.770 | .107 | 5.537 | 6.003 |
| | | 3 | 6.213 | .120 | 5.952 | 6.475 |
| | Trained | 1 | 5.171 | .086 | 4.983 | 5.359 |
| | | 2 | 5.115 | .093 | 4.913 | 5.317 |
| | | 3 | 5.339 | .104 | 5.112 | 5.565 |
| RDFPeakR | Sedentary | 1 | 12347.919 | 4511.532 | 2518.135 | 22177.702 |
| | | 2 | 14131.547 | 4264.987 | 4838.938 | 23424.156 |
| | | 3 | 13943.873 | 5672.306 | 1584.981 | 26302.765 |
| | Trained | 1 | 8970.546 | 3907.101 | 457.703 | 17483.388 |
| | | 2 | 10456.364 | 3693.587 | 2408.729 | 18503.999 |
| | | 3 | 12326.428 | 4912.361 | 1623.313 | 23029.542 |
| RFDtoHPR | Sedentary | 1 | 12479.002 | 3429.212 | 5007.390 | 19950.615 |
| | | 2 | 14752.648 | 5160.723 | 3508.398 | 25996.898 |
| | | 3 | 14380.448 | 7206.136 | -1320.372 | 30081.269 |
| | Trained | 1 | 9185.671 | 2969.785 | 2715.065 | 15656.277 |
| | | 2 | 6909.919 | 4469.317 | -2827.887 | 16647.725 |
| | | 3 | 16980.863 | 6240.697 | 3383.553 | 30578.172 |
| RFDHPtoPR | Sedentary | 1 | 11784.120 | 5910.733 | -1094.260 | 24662.500 |
| | | 2 | 13112.696 | 3931.161 | 4547.432 | 21677.959 |
| | | 3 | 12526.166 | 4276.498 | 3208.477 | 21843.854 |
| | Trained | 1 | 8450.327 | 5118.845 | -2702.678 | 19603.331 |
| | | 2 | 13311.017 | 3404.485 | 5893.281 | 20728.753 |
| | | 3 | 7031.088 | 3703.556 | -1038.267 | 15100.443 |
| ImpulseR | Sedentary | 1 | 110.601 | 35.200 | 33.906 | 187.296 |
| | | 2 | 111.199 | 31.933 | 41.621 | 180.776 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 3 | 76.871 | 26.319 | 19.527 | 134.214 |
| | | 1 | 144.540 | 30.484 | 78.120 | 210.960 |
| | Trained | 2 | 138.003 | 27.655 | 77.747 | 198.258 |
| | | 3 | 109.639 | 22.793 | 59.978 | 159.300 |
| | | 1 | .481 | .050 | .373 | .589 |
| | Sedentary | 2 | .463 | .050 | .354 | .571 |
| ContactR | | 3 | .407 | .057 | .282 | .532 |
| | | 1 | .468 | .043 | .374 | .561 |
| | Trained | 2 | .454 | .043 | .361 | .548 |
| | | 3 | .457 | .050 | .349 | .566 |
| | | 1 | 880.103 | 103.545 | 654.497 | 1105.710 |
| | Sedentary | 2 | 883.943 | 107.996 | 648.640 | 1119.246 |
| MaxForceR | | 3 | 825.243 | 119.175 | 565.583 | 1084.904 |
| | | 1 | 1017.173 | 89.673 | 821.792 | 1212.553 |
| | Trained | 2 | 953.557 | 93.527 | 749.779 | 1157.336 |
| | | 3 | 956.299 | 103.209 | 731.426 | 1181.171 |
| | | 1 | .154 | .066 | .009 | .298 |
| | Sedentary | 2 | .069 | .042 | -.022 | .160 |
| TimeMaxForceR | | 3 | .143 | .053 | .029 | .258 |
| | | 1 | .239 | .058 | .113 | .364 |
| | Trained | 2 | .206 | .036 | .127 | .284 |
| | | 3 | .163 | .046 | .064 | .262 |
| | | 1 | 6023.432 | 9643.772 | -14988.541 | 27035.406 |
| | Sedentary | 2 | 19085.407 | 6548.018 | 4818.503 | 33352.312 |
| RFDPeakL | | 3 | 18137.453 | 15808.329 | -16305.936 | 52580.843 |
| | | 1 | 23160.945 | 8351.751 | 4964.042 | 41357.848 |
| | Trained | 2 | 16180.901 | 5670.750 | 3825.399 | 28536.403 |
| | | 3 | 32698.502 | 13690.414 | 2869.652 | 62527.352 |
| RFDtpHPL | Sedentary | 1 | 7277.235 | 10591.194 | -15798.995 | 30353.464 |
| | | 2 | 23332.491 | 5550.615 | 11238.740 | 35426.242 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 3 | 19435.188 | 15766.413 | -14916.875 | 53787.251 |
| | | 1 | 27056.985 | 9172.243 | 7072.384 | 47041.586 |
| | Trained | 2 | 16607.416 | 4806.974 | 6133.920 | 27080.912 |
| | | 3 | 32816.224 | 13654.114 | 3066.464 | 62565.983 |
| | | 1 | 4566.512 | 8819.051 | -14648.548 | 23781.573 |
| | Sedentary | 2 | 13722.859 | 8355.385 | -4481.962 | 31927.679 |
| RFDHPtoPL | | 3 | 15990.343 | 14492.262 | -15585.584 | 47566.270 |
| | | 1 | 18666.935 | 7637.522 | 2026.204 | 35307.665 |
| | Trained | 2 | 14938.610 | 7235.976 | -827.227 | 30704.447 |
| | | 3 | 29701.680 | 12550.667 | 2356.125 | 57047.235 |
| | | 1 | 132.302 | 28.880 | 69.377 | 195.226 |
| | Sedentary | 2 | 157.054 | 26.343 | 99.657 | 214.451 |
| | | 3 | 111.010 | 36.445 | 31.603 | 190.417 |
| ImpulseL | | 1 | 130.391 | 25.011 | 75.897 | 184.886 |
| | Trained | 2 | 134.399 | 22.814 | 84.692 | 184.107 |
| | | 3 | 107.329 | 31.562 | 38.560 | 176.097 |
| | | 1 | .486 | .042 | .395 | .577 |
| | Sedentary | 2 | .492 | .052 | .379 | .605 |
| | | 3 | .412 | .053 | .296 | .528 |
| ContactL | | 1 | .464 | .036 | .385 | .542 |
| | Trained | 2 | .489 | .045 | .392 | .587 |
| | | 3 | .463 | .046 | .363 | .563 |
| | | 1 | 862.145 | 141.405 | 554.051 | 1170.239 |
| | Sedentary | 2 | 1014.368 | 145.600 | 697.133 | 1331.603 |
| | | 3 | 953.745 | 170.761 | 581.689 | 1325.801 |
| MaxForceL | | 1 | 1092.935 | 122.460 | 826.117 | 1359.753 |
| | Trained | 2 | 953.961 | 126.093 | 679.228 | 1228.695 |
| | | 3 | 1034.601 | 147.883 | 712.391 | 1356.811 |
| TimeMaxForceL | Sedentary | 1 | .287 | .056 | .165 | .409 |

|  |  |  |  |  |  |
|---|---|---|---|---|---|
|  | 2 | .083 | .040 | -.005 | .171 |
|  | 3 | .151 | .044 | .057 | .246 |
|  | 1 | .143 | .048 | .037 | .248 |
| Trained | 2 | .143 | .035 | .067 | .219 |
|  | 3 | .118 | .038 | .036 | .200 |

**Appendix 15 SPSS Output – Chi Square Test – Focus Preferences Vertical Jump**

**Case Processing Summary**

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| Category * VJFocus | 42 | 75.0% | 14 | 25.0% | 56 | 100.0% |

**Category * VJFocus Crosstabulation**

| | | | VJFocus | | | Total |
|---|---|---|---|---|---|---|
| | | | INT | EXT | NEUTRAL | |
| Category | SEDENTARY | Count | 13 | 1 | 4 | 18 |
| | | Expected Count | 10.7 | .4 | 6.9 | 18.0 |
| | TRAINED | Count | 12 | 0 | 12 | 24 |
| | | Expected Count | 14.3 | .6 | 9.1 | 24.0 |
| Total | | Count | 25 | 1 | 16 | 42 |
| | | Expected Count | 25.0 | 1.0 | 16.0 | 42.0 |

**Chi-Square Tests**

| | Value | df | Asymp. Sig. (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 4.270[a] | 2 | .118 |
| Likelihood Ratio | 4.752 | 2 | .093 |
| Linear-by-Linear Association | 2.698 | 1 | .100 |
| N of Valid Cases | 42 | | |

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is .43.

**Symmetric Measures**

| | | Value | Approx. Sig. |
|---|---|---|---|
| Nominal by Nominal | Phi | .319 | .118 |
| | Cramer's V | .319 | .118 |
| N of Valid Cases | | 42 | |

**Appendix 16 - Chi Square Test – Focus Preferences Change of Direction**

Case Processing Summary

| | Cases | | | | | |
|---|---|---|---|---|---|---|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| Category * CoDFocus | 56 | 100.0% | 0 | 0.0% | 56 | 100.0% |

Category * CoDFocus Crosstabulation

| | | | CoDFocus | | | Total |
|---|---|---|---|---|---|---|
| | | | INT | EXT | NEUTRAL | |
| Category | SEDENTARY | Count | 7 | 0 | 17 | 24 |
| | | Expected Count | 5.6 | .9 | 17.6 | 24.0 |
| | TRAINED | Count | 6 | 2 | 24 | 32 |
| | | Expected Count | 7.4 | 1.1 | 23.4 | 32.0 |
| Total | | Count | 13 | 2 | 41 | 56 |
| | | Expected Count | 13.0 | 2.0 | 41.0 | 56.0 |

Chi-Square Tests

| | Value | df | Asymp. Sig. (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 2.174[a] | 2 | .337 |
| Likelihood Ratio | 2.904 | 2 | .234 |
| Linear-by-Linear Association | .401 | 1 | .527 |
| N of Valid Cases | 56 | | |

a. 2 cells (33.3%) have expected count less than 5. The minimum expected count is .86.

Symmetric Measures

| | | Value | Approx. Sig. |
|---|---|---|---|
| Nominal by Nominal | Phi | .197 | .337 |
| | Cramer's V | .197 | .337 |
| N of Valid Cases | | 56 | |

**Appendix 17 – Signed Ethics Application**


St Mary's University Twickenham London

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 re-submitted 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 | Yes | | |
| 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 | Yes | | |
| 10.DBS included | | N/A | |
| 11.Other Research Ethics Committee application (e.g. NHS REC form) | | N/A | |

I can confirm that all relevant documents are included in order of the list and in one PDF document entitled with you: *Full Name, School, Supervisor.*

Signature of Applicant:

Signature of Supervisor:

# Research Ethics Application Comments Form

**Level:** 2

**Type:** Postgraduate

**Proposer:** Ewan Birnie

**Supervisor:** Daniel Cleather

**School:** SHAS

**Programme:** Strength and Conditioning MSc

**Title:** Testing the constrained action hypothesis – the impact of internal and external cues on vertical   jump and change of direction performance in trained and sedentary populations.

**Date:** 27/01/16

**Review No.:** 1

**Comments (number corresponds to relevant section on Ethics Application Form)**
No amendments required

**Impression/Decision**
Approved, proceed with research.

Dr Jessica Hill
Ethics Representative.
School of Sport, Health and Applied Science.
St Mary's University.

# St Mary's University
# Twickenham
# London

Approval Sheet

| |
|---|
| Name of applicant:  Ewan Birnie |
| Name of supervisor:  Dr Dan Cleather |
| Programme of study:  MSc Strength and Conditioning |
| Title of project:  Testing the constrained action hypothesis – the impact of internal and external cues on vertical jump and change of direction and performance in trained and sedentary populations. |
| |
| |

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: 22/1/16 |
| **SECTION 2** |
| Refer to School Ethics Representative for consideration at Level 2 or Level 3 |
| Signature of supervisor................................................................................................................. |