CARDIFF METROPOLITAN UNIVERSITY
CARDIFF SCHOOL OF SPORT

PERMISSION FOR EXTENSION OF ASSIGNMENT SUBMISSION DATE

Name: Callum Shields  
Programme: SCRAM

<table>
<thead>
<tr>
<th>Module Number</th>
<th>Module Title</th>
<th>Assessment Type (WRIT2, EXAM1 etc)</th>
<th>Initial Submission Date</th>
<th>Period of Extension</th>
<th>New Submission Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSP6050</td>
<td>Independent Project</td>
<td>WRIT1</td>
<td>March 19th 2015</td>
<td>4 weeks</td>
<td>April 16th 2015</td>
</tr>
</tbody>
</table>

Extension granted by Adeline Phillips on (date) January 30th 2015

Deputy Dean Signature

Please ensure that you attach a copy of this extension form to your submitted assignment(s) by the new submission dates quoted. Failure to do so will result in a maximum mark of 40%.
**Cardiff School of Sport**  
**DISSERTATION ASSESSMENT PROFORMA:**  
Empirical

<table>
<thead>
<tr>
<th><strong>Student name:</strong></th>
<th>CALLUM SHIELDS</th>
<th><strong>Student ID:</strong></th>
<th>St20004911</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Programme:</strong></td>
<td>SCRAM</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Dissertation title:</strong></th>
<th>THE ACUTE EFFECTS OF ASSISTED AND RESISTED PLYOMETRIC EXERCISES AS POTENTIATING EXERCISES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supervisor:</strong></td>
<td>JEREMY MOODY</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Comments</strong></th>
<th><strong>Section</strong></th>
<th><strong>Section</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Title and Abstract (5%)</strong></td>
<td><strong>Introduction and literature review (25%)</strong></td>
</tr>
<tr>
<td></td>
<td>Title to include: A concise indication of the research question/problem.</td>
<td>To include: outline of context (theoretical/conceptual/applied) for the question; analysis of findings of previous related research including gaps in the literature and relevant contributions; logical flow to, and clear presentation of the research problem/question; an indication of any research expectations, (i.e., hypotheses if applicable).</td>
</tr>
<tr>
<td></td>
<td>Abstract to include: A concise summary of the empirical study undertaken.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th><strong>Methods and Research Design (15%)</strong></th>
<th><strong>Results and Analysis (15%)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To include: details of the research design and justification for the methods applied; participant details; comprehensive replicable protocol.</td>
<td>To include: description and justification of data treatment/data analysis procedures; appropriate presentation of analysed data within text and in tables or figures; description of critical findings.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th><strong>Discussion and Conclusions (30%)</strong></th>
<th><strong>Presentation (10%)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>To include: collation of information and ideas and evaluation of those ideas relative to the extant literature/concept/theory and research question/problem; adoption of a personal position on the study by linking and combining different elements of the data reported; discussion of the real-life impact of your research findings for coaches and/or practitioners (i.e. practical implications); discussion of the limitations and a critical reflection of the approach/process adopted; and indication of potential improvements and future developments building on the study; and a conclusion which summarises the relationship between the research question and the major findings.</td>
<td>To include: academic writing style; depth, scope and accuracy of referencing in the text and final reference list; clarity in organisation, formatting and visual presentation</td>
</tr>
</tbody>
</table>

---

1 This form should be used for both quantitative and qualitative dissertations. The descriptors associated with both quantitative and qualitative dissertations should be referred to by both students and markers.

2 There is scope within qualitative dissertations for the RESULTS and DISCUSSION sections to be presented as a combined section followed by an appropriate CONCLUSION. The mark distribution and criteria across these two sections should be aggregated in those circumstances.
THE ACUTE EFFECTS OF ASSISTED AND RESISTED PLYOMETRIC EXERCISES AS POTENTIATING EXERCISES FOR VERTICAL JUMP PERFORMANCE

(Dissertation submitted under the SCRAM area)

CALLUM SHIELDS

ST20004911
THE ACUTE EFFECTS OF ASSISTED AND RESISTED PLYOMETRIC EXERCISES AS POTENTIATING EXERCISES FOR VERTICAL JUMP PERFORMANCE
Cardiff Metropolitan University
Prifysgol Fetropolitan Caerdydd

Certificate of student
By submitting this document, I certify that the whole of this work is the result of my individual effort, that all quotations from books and journals have been acknowledged, and that the word count given below is a true and accurate record of the words contained (omitting contents pages, acknowledgements, indices, tables, figures, plates, reference list and appendices). I further certify that the work was either deemed to not need ethical approval or was entirely within the ethical approval granted under the code entered below.

Ethical approval code: 13/05/342U
Word count: 11510
Name: CALLUM SHIELDS
Date: 16 APRIL

Certificate of Dissertation Supervisor responsible
I am satisfied that this work is the result of the student's own effort and was either deemed to not need ethical approval (as indicated by 'exempt' above) or was entirely within the ethical approval granted under the code entered above.
I have received dissertation verification information from this student

Name: ______________________
Date: ______________________

Notes:
The University owns the right to reprint all or part of this document.
<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>i</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>CHAPTER 1</td>
<td></td>
</tr>
<tr>
<td>1.0 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>CHAPTER 2</td>
<td></td>
</tr>
<tr>
<td>2.0 LITERATURE REVIEW</td>
<td>4</td>
</tr>
<tr>
<td>CHAPTER 3</td>
<td></td>
</tr>
<tr>
<td>3.0 METHODOLOGY</td>
<td>14</td>
</tr>
<tr>
<td>3.1 Participants</td>
<td>14</td>
</tr>
<tr>
<td>3.2 Procedure</td>
<td>15</td>
</tr>
<tr>
<td>3.2.1 Warm up</td>
<td>18</td>
</tr>
<tr>
<td>3.2.2 Body weight</td>
<td>18</td>
</tr>
<tr>
<td>3.2.3 Resisted</td>
<td>19</td>
</tr>
<tr>
<td>3.2.4 Assisted</td>
<td>20</td>
</tr>
<tr>
<td>3.2.5 Testing</td>
<td>21</td>
</tr>
<tr>
<td>3.3 Statistical analysis</td>
<td>22</td>
</tr>
<tr>
<td>CHAPTER 4</td>
<td></td>
</tr>
<tr>
<td>4.0 RESULTS</td>
<td>23</td>
</tr>
<tr>
<td>4.1 Initial Analysis</td>
<td>23</td>
</tr>
<tr>
<td>4.2 One Way Repeated Measures ANOVA</td>
<td>27</td>
</tr>
<tr>
<td>4.3 Intraclass Correlation Coefficient</td>
<td>28</td>
</tr>
</tbody>
</table>
CHAPTER 5

5.0 DISCUSSION 29
5.1 Theoretical Implications 29
5.2 Limitations 34
5.3 Practical Implications 35
5.4 Future Research 36
5.5 Conclusion 37

REFERENCES 38

APPENDICES

Participant information sheet A-1
Informed Consent Forms B-1
**LIST OF TABLES**

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1.</td>
<td>Participants force in Newton’s, length and combination of each resistance band.</td>
<td>16</td>
</tr>
<tr>
<td>Table 2.</td>
<td>Mean ± SD results for free, resisted and assisted banded CMJ.</td>
<td>23</td>
</tr>
<tr>
<td>Table 3.</td>
<td>Participants percentage change in VJH during control and assisted, and control and resisted CMJs.</td>
<td>26</td>
</tr>
<tr>
<td>Table 4.</td>
<td>Participants percentage change in RFD during control and assisted, and control and resisted CMJs.</td>
<td>26</td>
</tr>
<tr>
<td>Table 5.</td>
<td>Participants percentage change in PF during control and assisted, and control and resisted CMJs.</td>
<td>27</td>
</tr>
<tr>
<td>Table 6.</td>
<td>Intraclass Correlation Coefficient evaluating the retest reliably of each participant under all intervention conditions.</td>
<td>28</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.</td>
<td>The force velocity curve.</td>
<td>2</td>
</tr>
<tr>
<td>Figure 2.</td>
<td>Illustration of the CMJ setup for resisted trials.</td>
<td>20</td>
</tr>
<tr>
<td>Figure 3.</td>
<td>Illustration of the CMJ setup for resisted trials.</td>
<td>21</td>
</tr>
<tr>
<td>Figure 4.</td>
<td>Z scores for control, assisted and resisted VJH.</td>
<td>24</td>
</tr>
<tr>
<td>Figure 5.</td>
<td>Z scores for control, assisted and resisted RFD.</td>
<td>24</td>
</tr>
<tr>
<td>Figure 6.</td>
<td>Z scores for control, assisted and resisted PF.</td>
<td>25</td>
</tr>
<tr>
<td>Figure 7.</td>
<td>Theoretical model of the relationship between fatigue and PAP after a conditioning contraction.</td>
<td>31</td>
</tr>
<tr>
<td>Figure 8.</td>
<td>Potential factors modulating the relationship between fatigue and PAP that subsequently may influence an ensuing performance.</td>
<td>32</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

I would like to thank my supervisor Jeremy Moody, SCRAM lecturers John Radnor and Robert Meyers for all their helpful support and constructive guidance throughout the whole independent project process. I cannot thank them enough and all the support has been greatly appreciated, without which I would have severely struggled.
Abstract

**Aim:** The aim of the present study was to investigate the acute effects of assisted and resisted plyometric exercises as potentiating exercises for vertical jump performance (VJP). **Method:** 11 male university level trained basketball players (Mean Age 21 ± 2 years, Height 182.2 ± 8 cm, Weight 78.8 ± 9.9 kg) completed a standardised warm up before performing four repetitions of either a body weight control, resisted or assisted countermovement jumps (CMJ), eight minutes before re-testing. Only one intervention was carried out each day and the participants had to rest 24 hours before undertaking another intervention. The tension of each resistance band was set at 30% of the participant’s bodyweight. Rate of force development (RFD), peak force (PF) and vertical jump height (VJH) were recorded during the testing procedure and compared against the participant’s previous baseline data. **Results:** The One-Way Repeated Measures ANOVA’s identified no significant difference ($P > 0.05$) in RFD, PF or VJH between the control and assisted, control and resisted or assisted and resisted interventions. Individual analysis identified six out of 11 participants generated an increase in VJH during the resisted intervention and five experienced an increased during the assisted intervention. Seven participants produced an increase in RFD during the resisted intervention, while six improved during the assisted jump. Only four participants improved PF during resisted jumping, while only three participants experienced improvements during assisted. **Conclusion:** The present study concludes that at tensions of 30% of bodyweight, there are no potentiating effects generated from assisted or resisted banded jumping. The individualisation of post activation potentiation (PAP) is highlighted by the present studies results and supports previous current literature covering this topic. Although the present study identified no statistical significance within the group, strength and conditioning coaches are drawn to the positive individual responses to PAP that support current research and its practical applications.
CHAPTER 1

INTRODUCTION
1.0 Introduction

The proficiency of an athlete to produce high levels of explosive power from the lower extremity can be a fundamental component towards a successful athletic performance. The use of plyometrics is increasingly becoming more established as the training modality of choice in a variety of sports and age groups that necessitate jumping and sprinting to elicit the effects of the stretch shortening cycle (SSC) and enhance athletic performance (Johnson, Salzberg and Stevenson, 2011; Simenz, Dugan and Ebben, 2005; Lloyd, Meyers, and Oliver, 2011).

Traditionally to manipulate the force velocity relationship, athletes with the goal of developing lower limb explosive strength utilise a combination of squats with a heavy resistance. This subsequently causes the muscles to increase isometric strength due to the working muscles contracting at a slower rate under a reasonably unremitting tension. Although the muscles are developing isometric strength in this instance, it does not prevent the execution of rapid dynamic contractions. Athletes can also approach explosive strength development by utilising reduced loads; further manipulating the force velocity relationship towards speed due to the exercises being performed at an increased velocity. This is evidenced by the current conclusive research into this field that has helped rationalise the force velocity relationship (McBride, Triplett-McBride, Davie and Newton, 2002; Peterson, Rhea, and Alvar, 2004; Cronin and Hansen, 2005) as shown in Figure 1. The force velocity relationship follows the principles that the heavier the load becomes the slower the movement can be performed. It is important to understand the force velocity relationship curve as this has a direct implication on power output. A load with a too greater resistance will start to focus on the development of the muscles strength potential; conversely a load with lighter resistance will start to focus on the muscle’s contractile velocity. Therefore it is vital for athletes, with the goal of improving explosive strength, to implement a load that combines the development of some speed characteristics and some strength characteristics of muscle tissue to enhance maximal explosive power. Some explosive movement components are not adequately enhanced by the modes of strength training outlined above, for example, a muscle’s ability to rapidly change from a state of eccentric contraction to a concentric contraction as well as the expeditious excitability of muscle.
Plyometric training (PT) can be seen as an involuntary shock stimulus that imposes maximum ballistic tension upon a muscle. This method of stimulation involves a rapid eccentric stretch precipitously ceased by a vigorous isometric and eccentric isometric contraction, followed by an immediate concentric contraction that is enhanced by the myotatic stretch reflex characteristics within skeletal muscle and other aspects of the series elastic component (SEC) during the eccentric phase; consequently producing a more powerful concentric contraction than could be produced from a position at rest (Cissik, 2012; Lloyd et al 2011; McArdle, Katch, and Katch, 2010; Verkhoshansky and Siff, 2009). The myotatic stretch reflex and SSC characteristics of muscle in the lower extremity can be exploited through the execution of explosive movement patterns which simulate that of in game situations like bounding, jumping and hopping, often from different heights. Baechle and Earle, (2008) define a plyometric exercise as one that rapidly decelerates the body, the eccentric phase, directly followed by a brief transitional phase and a rapid acceleration in the opposite direction, the concentric phase. This sequence of events as described by LaChance (1995) activates the SSC.

Although not without reservations, there is numerous positive evidence within current literature that highlights the importance of PT to a strength and conditioning (S&C) coach.
in developing neuromuscular performance, consequently perfecting a muscle’s ability to generate explosive power, enhance muscle activation strategies, running velocity and jumping performance (Bruce-Low and Smith, 2007; Sáez-Sáez de Villarreal, Requena and Newton, 2010; Markovic, 2007; Makaruk, and Sacewicz, 2010; Chimera, Swanik, Swanik, and Straub, 2004). Furthermore, the importance of utilising PT at different intensity levels within a programme, in isolation or in conjunction with other modalities, is highlighted by the high dynamic stabilisation demands required by the lower extremity during plyometrics; which is paramount in injury prevention or rehabilitation, especially during the landing phase, a common phase of high injury occurrence (Van Lieshout, Anderson, Shelburne, and Davidson, 2014; Kipp, and Palmieri-Smith, 2012; Ebben, Vanderzanden, Wurm, and Petushek, 2010).

Vertical jump (VJ) is documented to have a high prevalence and is an essential aspect of a vast and varying number of sports. Consequently, many sports coaches use VJ as a measure of power and, indirectly performance, to rank athletes accordingly, monitor development or to predict the probability of future success (Reaburn, Dascombe, and Scanlan, 2011; Sheppard, Gabbett, and Stanganelli, 2009; Platanou, 2005; Bloomfield, Polman, and O’Donoghue, 2007; McGee and Burkett, 2003). Therefore indicating to an S&C coach the potential significance in advantageously developing an athlete’s VJ to enhance athletic performance.

Post activation potentiation (PAP) describes the occurrence in which acute muscle force output is enhanced as a consequence of contractile history, with its manipulation continually being suggested as a mechanism for enhancing chronic adaptations and acute performance (Robbins, 2005). Sale (2002) supports this definition by defining PAP as the momentary increase in performance of contacting muscle tissue after previous contractile activity. Robbins (2005) and Sale (2002) both highlight much evidence for the existence of PAP, however, determining the best methods to manipulate and utilise PAP for human performance remain vague.

The purpose of this present study is to investigate the acute effects of assisted and resisted plyometric exercises as potentiating exercises for vertical jump performance (VJP). The present study will look to highlight any potential benefits for a long term training intervention, potential practical implications/applications and any potential evidence towards future research.
CHAPTER 2

LITERATURE REVIEW
2.0 Literature review

Plyometrics is a unique mode of speed strength training exercises that accentuate the development of SSC competences of an athlete through forceful and rapid contractions designed to overload a muscle (Gamble, 2013: McArdle et al, 2010.). The SSC is composed of combinations of eccentric, isometric and concentric contractions, causing the muscle to become stretched directly before contraction; the concentric contraction of the SSC is potentiated by the preceded eccentric stage to produce a powerful contraction beyond that of a contraction solely using concentric actions (Baechle and Earle, 2008; Gamble, 2013). When a muscle is provoked into contracting when the body or a limb is prevented from further movement due to contact with an external surface, there is an electromechanical delay that denotes the elapsed time from the beginning of the action potential within the motor neurons and the commencing muscle contraction. The stored kinetic energy causes the production of an extremely powerful myotatic stretch reflex; an eccentric contraction follows this accompanied by a very explosive isometric contraction. Afterwards the SEC and the concentric involuntary contraction of the muscle induced by the stretch reflex release stored elastic energy. After the completed concentric muscle contraction the elastic energy that has been released from the SEC and the kinetic energy conveyed by the concentric muscle contraction continue to aid the movement of the body or body part (Verkhoshansky and Siff, 2009).

Ground contact contraction thresholds can be used to categorise the SSC into fast SSC (FSSC) exercises, typically sprinting, with a contraction time of <250 milliseconds with anything slower than that threshold classed as slow SSC (SSSC) exercises such as a maximum VJ (Flanagan and Comyns, 2008; Lloyd et al, 2011). The greater force generated during the concentric contraction of the SSC is thought to be resultant of the myotatic stretch reflex characteristics within skeletal muscle, elastic energy stored within the elastic components of muscle tissue and within the tendon, called the SEC; Although some muscular components are incorporated, tendons are thought to represent the majority within the SEC (Makaruk and Sacewicz, 2010; Baechle and Earle, 2008). An athlete’s efficiency in utilising the SSC has been proposed to increase the metabolic proficiency of movement (Bobbert, Gerritsen, Litjens and Van Soest, 1996; Bobbert and Casius, 2005) Although these two studies only used simulations rather than actual human studies, their findings are supported by Voigt, Bojsen-Møller, Simonsen and Dyhre-
Poulsen (1995) and Verkhoshansky, (1996) that indicated as running velocity increases so does the contribution of none metabolic energy reserves; 40% of the total energy expended during sprinting economically, using the SSC efficiently, can be recovered by the metabolic process. Although these two articles could be considered to be out of date and one being limited by the number of participants, their contribution to knowledge and small evidence for practical application in this area is vital. The resultant reduction in metabolic cost suggests an athlete that is able to illicit the positive effects of the SSC efficiently, may be more competent and exceed performance than an athlete who is not as efficient. Therefore, the reduction in metabolic cost combined with the SSC being a natural procedure of muscle function in everyday movement patterns highlights the significant role the SSC could have on successful performance, as many sports are dependent on the SSC’s efficient utilisation during a specific movement skill. This emphasises to an S&C coach the importance of incorporating PT into a programme to enhance an athlete’s capability to exploit the SSC.

The present study investigates the use of PAP, the occurrence in which the amplification of muscle fibre twitch and oscillation of tetanic contractions are induced by specific conditioning movements (Sale, 2002). The experimental nature of the present study will help identify any potential mechanism for enhancing chronic adaptations and or acute performance. Byrne, Kenny and O’ Rourke (2014) investigated the PAP effects of depth jumps (DJ) on sprinting, deducing that when DJ are included in warm up they had a significant PAP effect. Byrne et al’s (2014) inclusion of the DJ was important, as this has been shown to directly affect the FSSC utilised during sprinting (Flanagan and Comyns, 2008). It would be interesting to see if the inclusion of an SSSC movement had the same PAP effects. Stevenson, Warpeha, Dietz, Giveans and Erdman (2010) investigated if a greater eccentric force contributed to enhance the concentric phase. Stevenson et al’s (2010) data supports the use of resistance bands as a method of PAP stimulus, as it was concluded eccentric peak velocity and rate of force development (RFD) significantly increased through the inclusion of resistance bands. However Stevenson et al (2010) identified that concentric mean and peak velocity were enhanced without the addition of bands. The identification of different adaptations during different contractions therefore contradicts aspects for the inclusion of elastic resistance bands in PAP exercises, a coach would need to determine which characteristics of the movement contractions they would want to train to enhance performance. During Stevenson et al’s (2010) study, they stated there was no tension from the bands at the bottom phase of the squat to normalise loading.
between conditions; however, Wallace, Winchester and McGuigan (2006) state that allowing slack in the bands whilst squatting at the lowest position has the potential to cause a force spike during the concentric upward phase. This factor could have affected Stevenson et al’s (2010) data and conclusions. At the time of this proposed study and to the best of the authors knowledge there was no known studies that investigated the potentiating effect, if any, of the SEC and SSC through resisted and assisted plyometrics on VJP.

There have been many studies investigating the use of plyometrics on varying abilities with the majority recording beneficial results, especially for strength and power. Due to plyometric trainings ability to target the neuromuscular system, an individual’s coordination and ability to increase their maximal RFD can be improved. A study by Bal, Kaur and Singh (2011) concluded that PT enhances agility, supported by Miller, Herniman, Ricard, Cheatham, and Michael (2006) who also determined that PT increased agility. An area of contention for many of the research articles included in this literature review is the trained level of participants and numbers of participants. It is common that untrained individuals are more susceptible to displaying increased adaptations especially to the neuromuscular system (i.e increased synchronisation of motor units, RFD and firing frequency) from a ballistic training intervention compared to an elite level athlete who may require an increased training stimulus due to their abilities already being finely tuned; therefore the implications for Bal et al’s (2009) and Miller et al’s (2011) conclusions for the amateur population could be considered beneficial. Reinforced by Luebbers, Potteiger, Hulver, Thyfault, Carper, and Lockwood’s (2003) investigation where complete novices demonstrated significant improvements after PT. However, the implications for elite populations combined with the small sample sizes and short intervention times may be considered to be limited. In contrast, it has been suggested that PT necessitates a high technical capacity and appropriate coordination and strength. Kutz (2003) from the National Strength and Conditioning Association states that an individual must be able to squat 1.5-2.5 times their own bodyweight before undertaking a plyometric programme. Another investigation by Cormie, McCaulley and McBride (2007) indicates that plyometrics are a more effective training modality with trained individuals; supported by Holcomb, Kleiner, and Chu (1998) who maintain untrained individuals should not undertake PT without adequate levels of strength and speed. Therefore, untrained individuals who are less technically competent may not elicit the full benefits of a PT programme and are susceptible to a greater risk of injury. Markovic (2007) refutes this as no significant
difference was observed between untrained and elite athletes, however, this could be associated with the limited number of studies conducted on elite athletes. Sáez-Sáez de Villarreal (2010) supports Markovic (2007) and suggests that Kutz (2003) and Holcomb et al’s (1998) guidelines are unjust, as they found no significant difference between experienced individuals and inexperienced individuals levels of fitness while undertaking a PT programme. This insinuates when athletes with sufficient technique preform a series of plyometric exercises, their training benefits can be interpreted as independent of their level of fitness. Bal et al (2009) failed to take into consideration other training that their participants might be undertaking as well as the training intervention, something Miller et al (2011) highlighted to their participants ensuring they withdrew and did not commence any lower leg strength training. This could mean Bal et al’s (2009) results could be biased due to other training modalities the participants could have been undertaking therefore eliciting greater beneficial effects.

From the research, the control variables for intensity of PT are still ambiguous. Bal et al (2009) and Miller et al (2011) measured intensity via the amount of foot strikes per training session; these were between 80 and 110 compared to 90 and 140 respectively. Areas for future research could be to investigate how a significant increase in foot strikes per training session would affect the potential benefits of a training intervention, and at what level fatigue would start to have an implication on any potential results. Kutz (2003) suggests high intensity for elite athletes should consist of between 200-400 foot strikes, whereas for amateurs it should be 60–150 per training session. Luebbers et al (2003) monitored intensity instead with distances; this could have implications on their results as a smaller participant could be subjected to a greater number of foot strikes and therefore a greater intensity than a taller person during the duration of the intervention. PT has been repeatedly demonstrated to have significant beneficial effects on strength performance, a key characteristic associated with VJP, with some highly convincing quantitative evidence suggested by Sáez-Sáez de Villarreal et al’s (2010) paper. These studies indicate that PT can produce desirable adaptations to the neural system and musculature to improve other fitness components that are also seen as desirable for improving VJP, thus supporting the use of plyometrics for the outlined study.
The manipulation of plyometric effects on VJP is one of the main topics raised during the present study, so it is important to understand the literature that has already investigated similar topics. Luebbers et al (2003) investigated the effects of two different durations of PT programme followed by a four week recovery period of no PT, concluding that both durations were equally effective for improving vertical jump height (VJH), vertical jump power and anaerobic power. However, Luebbers et al (2003) noted that the four-week training programme might not be as effective if the subsequent four-week recovery period was not adhered to. This could be seen as a potential limitation to Luebbers et al (2003) study, with no control groups they had no additional data to compare and further validate their findings. Luebbers et al (2003) only stated no PT could take place during the recovery period, though the participants could continue to participate in strength training, potentially creating a combination training programme, something that Cormie et al (2007) and Fatouros et al (2000) propose might further enhance the effects of a plyometric programme. Conversely, a study conducted by Makaruk and Sacewicz (2010) contradicts the results of Luebbers et al (2003) by concluding that a six-week PT programme yielded no improvements in VJH. This could be due to the types of plyometric movements employed by Makaruk and Sacewicz (2010) during their programme; they employed movements that utilised mainly the FSSC and some for the SSSC. Research has shown that SSSC movements focus more on maximal VJH (Flanagan and Comyns, 2008; Lloyd et al, 2011), therefore not including many SSSC movements could explain why Makaruk and Sacewicz (2010) observed no improvements in VJH.

It would be interesting to know if the combination of training both SSSC and FSSC movements at the same time, although unlikely, were detrimental to each other instead of solely training just one component; as they are arguably two very different aspects of the myotatic stretch reflex characteristics within skeletal muscle and use the neural system in slightly different ways. Hunter and Marshall, (2002) touched upon this area highlighting an athlete’s desired goal should determine the movements implemented for training. Hunter and Marshall (2002) observed different contradicting adaptations in leg stiffness after solely completing DJ or counter-movement jumps (CMJ). These adaptations could potentially be advantageous, immaterial or even detrimental towards the athlete’s performance. Hunter and Marshall’s (2002) observations are supported by Markovic’s (2007) meta-analysis into plyometric effects on jump height, with data implying superior positive adaptations can be expected during jumping technique utilising the SSSC rather than FSSC for jump height; potentially due to the differences in the biomechanics of the
SSSC and FSSC and variations in power production. Although Sáez-Sáez de Villarreal et al’s (2010) results indicate, in terms of strength and rapid force development, that PT yields comparable positive effects whether SSSC or FSSC movements are implemented.

Another area of contention for further analysis could be the type of stretching utilised by Makaruk and Sacewicz (2010) within the warm up and the effects they have on training. Some studies have shown that different stretching protocols can be detrimental to performance, whereas some other investigations have not, potentially causing athletes to not maximise their potential gains (Hough, Ross, and Howatson. 2009; Dalrymple, Davis, Dwyer and Moir. 2010). Nevertheless, Makaruk and Sacewicz (2010) study supports the use of PT for some aspects of VJP as they observed positive improvements regarding maximal power output, substantial reduction in rebound time during the DJ and knee flexion angles throughout the PT group. Makaruk and Sacewicz (2010) findings support the evidence that PT increases tendon stiffness and the ability of the myotatic stretch reflex characteristics within the muscle-tendon complex to hold and release more elastic energy; increasing the efficiency of the SSC and proficiency of an athlete to use it, something that would be beneficial for improving VJP. Markovic’s (2007) detailed qualitative analysis supports this theory by concluding PT, statistically, has a high probability to significantly improve VJH. Markovic’s (2007) data also indicate that the adaptations demonstrated from PT on VJH can be transferred to other determinants of athletic performance which supports the observations of Bal et al (2009), Miller et al (2011) and Sáez-Sáez de Villarreal et al’s (2010). Bruce-Low and Smith, (2007) contest the aforementioned conclusions as Bruce-Low and Smith, (2007) believe that the evidence within current research does not indicate that PT is a superior modality for developing muscle power and jumping performance over conventional heavy resistance training. Bruce-Low and Smith, (2007) also believe typical PT exercises are not directly transferable to performance and pose potential injury risks.

Ronnestad et al's (2008) observations could be resultant of an incredibly small number of participants in each training group, therefore they cannot effectively determine if the data is reflective of the true population. The use of professional football players might also influence Ronnestad et al's (2008), as training stimulus could have been insufficient to elicit further gains from elite athletes. During the training programme Ronnestad et al (2008) utilised a half squat, potentially further implicating the data because the participants would not be going through their full functional range of movement; therefore the muscles are not exposed to the full effects of the training stimulus and theoretically minimising the potential adaptations that could take place.

Numerous investigations have demonstrated that a natural progression for increasing the training stimulus is towards resisted PT, possibly further enhancing and maximising the gains associated with PT (Sáez-Sáez de Villarreal, 2010; Khlifa et al, 2010; Shepard et al, 2008; Hrysomallis, 2012). Sheppard et al (2008) investigated the use of loaded plyometrics on VJH in the eccentric phase of the CMJ only. Participants held weighted plates while performing the eccentric phase, dropping them during the concentric phase. Sheppard et al (2008) concluded the additional load improved VJH by 11%. Although this study looked at the use of added load, it was specifically only focussed on the eccentric phase. Holding weighted plates in Sheppard et al’s (2008) study could potentially distract away from the movement itself as this could be unnatural for the participants, having to focus on releasing the plates and shifting focus on balancing; therefore hypothetically limiting the functional movement and obstruct the performance gains. A similar study by Aboodarda, Yusof, Abu Osman, Thompson, and Mokhtar (2013) also investigated the effects of accentuated eccentric load during the CMJ. Aboodarda et al’s (2013) data supports the conclusions of Sheppard et al (2008) with significant increases in GRF, VJH, and power output under resistance of 30% of body weight. Self-selection of knee and hip flexion during the accentuated CMJ could expose participants to varying durations of resistance depending on how low they performed the CMJ; consequently some participants may increase motor unit recruitment and thus increase power output and RFD, in turn increasing take off velocity and jump height over other participants.

Khlifa et al (2010) investigated the effects of weighted vest (10-11% of body mass) PT on VJP and deduced that added load from weighted vests produced significantly greater gains than un-weighted PT. The methods utilised by Khlifa et al’s (2010) ensured the resistance was a consistent load throughout the whole movement. Research conducted by
Leontijevic, Pazin, Bozic, Kukolj, Ugarkovic and Jaric (2012) determined there was an increase in ground reaction force throughout loaded jumps, however, jumping performance decreased which contradicts Khila et al's (2010) and Sheppard et al's (2008) conclusions. Leontijevic et al's (2012) verdict could be attributed to the element of inertia enforced upon participants during selected jumps. This could be of importance to the present study, as participants will experience a certain amount of sudden inertia during the assisted element of this investigation.

The aforementioned studies support this present studies methodology, to investigate the use of resistance through the application of elastic bands throughout the full range of movements, rather than just the eccentric or concentric phase, providing a variable resistance as the movement is performed (Findley, 2004). Three Studies conducted by Rhea, Peterson, Oliverson, Ayllón, and Potenziano (2008a), McClenton, Brown, Coburn, and Kersey (2008) and Rhea, Peterson, Lunt, and Ayllón (2008b) investigated the effects of a Vertimax system, to provide varying resistance throughout the whole movement, on VJP. McClenton et al (2008) noted that the use of a Vertimax training system did not significantly improve jumping performance over traditional resisted PT modalities. McClenton et al's (2008) assumptions could be related to several factors. Firstly, the jumps incorporated during the Vertimax training and DJ training had the risk of affecting the SSC in different ways as already mentioned previously. Secondly the Vertimax training group decreased training volume and increased resistance over time, whereas the DJ group increased both height of the box and volume, potentially increasing their training stimulus over the Vertimax group. The increments in the height of the DJ, up to a one-meter, may also start to move the normal FSSC movement to an SSC; it would be interesting to investigate the effects this had on ground contact time. Conversely, Rhea et al (2008a) disputes McClenton et al’s (2008) research, distinguishing Vertimax training was more successful in enhancing lower limb power when compared to traditional resistance and PT. Rhea et al's (2008a) study incorporated division one National Collegiate Athletics Association athletes who could be deemed to be elite athletes, it is known that elite athletes require a greater training stimulus than untrained athletes. The use of elastic resistance through the Vertimax could be one way in which this could be achieved. A similar study conducted by Rhea et al, (2008b) concluded comparable results with lesser-experienced athletes thus supporting Rhea et al's (2008a) data and further supports the methodology of this present study to implement elastic bands as a resistance mechanism during plyometrics than conventional resistance or PT.
There appears to be limited research into the effects of assisted jumping. Therefore, the experimental nature of this present study might provide insight into predicting possible adaptations to performance, specifically related to VJP, thus improving the prescription of precise training programmes targeting abilities associated with power. Kilgallon and Beard (2010) investigated the effects of banded assistance on the jump squat, noting that using resistance bands demonstrated a successful approach for enhancing power within the lower limbs. Kilgallon and Beard (2010) noticed as the assistance was linearly increased, movement speed and VJH also increased. The linear increase could be resultant of the assistance encouraging the participant to produce greater force at an increased velocity. A similar investigation conducted by Sheppard, Dingley, Janssen, Spratford, Chapman and Newton (2011) examined the effects of ten kilograms of assisted weight with a bungee system on the CMJ and spike jump. It was concluded the assisted technique produced gains of $2.7 \pm 0.7$ centimetres for CMJ and $4.6 \pm 2.6$ centimetres for the spike jump in comparison to unassisted jumping. However, the technique employed by Sheppard et al (2011) potentially limited the amount of load during the eccentric and concentric movements; conceivably causing a reduction in peak power due to the altered method in which the muscles become activated, as identified in McBride, McCaulley and Cormie’s (2008) paper. Sheppard et al’s (2011) implementation of an absolute assisted load of ten kilograms could mean that lightweight participants would have received greater assistance than heavier participants, whereas if a relative load to body mass was utilised then all participants would have experienced the same assistance. The aforementioned studies suggest it is beneficial for athletes who are accustomed to performing many jumping movements, to incorporate assisted jumping movements into a training programme to provide an extra training stimulus; further providing a rationale towards the present studies use of investigating the potentiating effects of assisted jumping on VJP. From Sheppard et al’s (2011) and Kilgallon and Beard’s (2010) research it could be considered assisted jumping demonstrates comparable characteristics to sprint assisted training. Paradisis and Cooke (2006), Corn and Knudson (2003) and Ebben (2008) provide evidence that assisted sprint training can enhance sprinting performance. Subsequently, it could be construed that assisted jumping has potential to permit equivalent adaptations to the neuromuscular system to occur for VJP as demonstrated with assisted sprint training and overall sprint speed.
Although these studies have investigated the effects of PT on different variables they have not investigated the effects of banded resisted or assisted PT as potential potentiating exercises to improve VJP, further supporting the purpose of this present investigation. Many of the studies in this literature review express strong evidence that PT exploits the SSC, neuromuscular system and musculature in such way to increase performance in many variables such as reduction in rebound times, RFD, synchronisation and power output. The lack of current literature and conclusive research indicates the need to investigate the possibility that increased resistance or assisted contractions from resistance bands might further help exploit the SSC through potentiation to enhance overall VJP. Conventional strength training modalities might be inadequate in developing power if an athlete already demonstrates exceptional strength levels; therefore the present study could assist in developing innovative methods for developing lower limb power once an athlete’s abilities have become highly tuned and require an increased training stimulus. Investigating the acute effects of resisted and assisted banded jumping could possibly be a beneficial method to exploit the velocity force relationship to further enhance lower limb explosive power.

It is hypothesized that resisted jumping will increase maximum peak force (PF), RFD and VJH. Assisted jumping is hypothesized to increase RFD and VJH, but decrease PF.
CHAPTER 3

METHODS
3.0 Methods

3.1 Participants

11 male university level trained basketball players (Mean Age 21 ± 2 years, Height 182.2 cm ± 8, Weight 78.8 ± 9.9 kg) volunteered and participated in the present investigation. University level basketball players were recruited because the research aforementioned within the literature review, specifically Markovic (2007) and Sáez de Villarreal (2010), indicated that there was no significant difference after a PT intervention between untrained or elite level or between male and female athletes. All participants had been actively competing, taking part in basketball training for two hours at least twice a week, were free of injury for the last six months and reported no other contraindications to physical activity before the investigation commenced. All participants had a basic understanding of resistance training and PT techniques; however, few had used resistance bands while performing jumping activities. To account for this a familiarisation session was conducted prior to testing to allow participants time to practice with the equipment and become accustomed to the techniques required. The associated risks involved with the investigation were explained to each participant (see Appendix A), who then signed an informed consent form prior to the commencement of the investigation (see Appendix B). The Cardiff Metropolitan University ethics committee sanctioned the procedure for human participation within the experimental investigation. The investigation was carried out within the strength and conditioning at the National Indoor Athletics Centre. Participants were instructed to attend on three separate days at least 24 hours apart. During each testing day participants would undertake a warm up before any testing commenced. On the first day participants conducted a series of body weight CMJ before being tested, on the second and third day participants repeated the procedure performed on day one, replacing body weight CMJ with either resisted or assisted CMJ. Although there is some evidence that a DJ could be superiorly beneficial towards enhancing some characteristics of VJP over a CMJ (Gehri, Ricard, Kleiner, and Kirkendall, 1998); more recent research carried out by Aboodarda et al (2013) and Sheppard et al (2008) indicates that utilising a CMJ can significantly increase GRF, VJH and power output. The more recent evidence, combined with Markovic’s (2007) research that demonstrated both SSSC and FSSC plyometric contractile movements produce significant improvements in VJP validate the preferred inclusion of CMJs over DJs.
All participants were instructed to abstain from any physical activity, drugs or alcohol consumption for at least 24 hours prior to testing to prevent any fatiguing effects or other detrimental effects occurring that could have invalidated the data during testing. Research conducted by Cortes, Onate and Morrison (2014) concluded that fatigue not only impaired an individual’s capacity to produce force, but also demonstrated that a subject’s ability to execute controlled movements diminished. One of the proposed mechanics behind PAP involves acute effects to muscle fibre and motor unit recruitment (Hodgson, Docherty and Robbins, 2005). If participants were already fatigued, any conceivable PAP effects for VJP could have become severely diminished, as the potential to recruit larger motor units is reduced. Ensuring participants abstained from physical activity at least 24 hours prior to testing, further assured the collected data was reliable and as accurate as possible. The resistance and assistance imposed on each participant was calculated to be equivalent to 30% of each individual’s body mass. Although research has indicated that resistance loads between 10-11% body weight generated greater gains than body weight (Khlifa et al, 2010); a relative resistance equal to 30% of body mass was preferred as previous research conducted by Aboodarda et al (2013) demonstrated a tried and tested protocol, specifically using elastic bands, that generated significantly greater gains than lesser percentages of body mass. An absolute measure of resistance was decided against to ensure all participants experienced the same intensity of resistance or assistance. Because of the insufficient evidence on assisted jumping and associated protocols, it was determined that unloading the participant’s 30% of their total body mass would be an appropriate level of assistance to allow for comparable results. Due to the master’s thesis data on band tensions and selection of bands available during testing, it was difficult to reproduce exactly 30% body mass for each participant; therefore the tensions were calculated to be as close to 30% as possible.

3.2 Procedure

A portable stadiometer (SECA 321, Vogel and Halke, Hamburg, Germany) and a set of scales (SECA 770, Vogel and Halke, Hamburg, Germany) were used to measure each participant’s height to the nearest centimetre (cm) and weight to the nearest KG respectively. Each subject’s weight was then converted into a measure of Newton force (N) to help determine the required tensions of the elastic resistance bands (Perform Better, 1.3cm, 3cm, 4.6cm width bands, Perform Better, Southam, UK). Force was calculated using the formulae:
As described by McArdle et al (2010), where \( F = \text{force}, \ m = \text{mass} \) and \( a = \text{acceleration} \) (9.81 meters per second squared \( [\text{m/s}^2] \)). Each Participant’s force in Newton’s, length and combination of each resistance band are shown in Table 1.

Table 1 – Participants force in Newton’s, length and combination of each resistance band

<table>
<thead>
<tr>
<th>BW (N)</th>
<th>30% BW (N)</th>
<th>Required Tension Each Side (N)</th>
<th>Resistance Band Distance (cm)</th>
<th>Colour Band Required</th>
<th>Assistance Band Distance (cm)</th>
<th>Colour Band Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>878.00</td>
<td>263.40</td>
<td>131.70</td>
<td>1.54</td>
<td>Orange x 2</td>
<td>1.36</td>
<td>Red + Orange</td>
</tr>
<tr>
<td>809.33</td>
<td>242.80</td>
<td>121.40</td>
<td>1.41</td>
<td>Orange x 2</td>
<td>1.51</td>
<td>Orange x 2</td>
</tr>
<tr>
<td>857.39</td>
<td>257.23</td>
<td>128.61</td>
<td>1.30</td>
<td>Red + Orange</td>
<td>1.47</td>
<td>Orange x 2</td>
</tr>
<tr>
<td>619.99</td>
<td>186.00</td>
<td>93.00</td>
<td>1.37</td>
<td>Orange x 2</td>
<td>1.68</td>
<td>Orange</td>
</tr>
<tr>
<td>761.26</td>
<td>228.38</td>
<td>114.19</td>
<td>1.34</td>
<td>Red + Orange</td>
<td>1.48</td>
<td>Orange x 2</td>
</tr>
<tr>
<td>832.87</td>
<td>249.86</td>
<td>124.93</td>
<td>1.28</td>
<td>Red + Orange</td>
<td>1.44</td>
<td>Orange x 2</td>
</tr>
<tr>
<td>810.31</td>
<td>243.09</td>
<td>121.55</td>
<td>1.40</td>
<td>Red + Orange</td>
<td>1.50</td>
<td>Orange x 2</td>
</tr>
<tr>
<td>570.94</td>
<td>171.28</td>
<td>85.64</td>
<td>1.33</td>
<td>Orange x 2</td>
<td>1.59</td>
<td>Orange</td>
</tr>
<tr>
<td>746.54</td>
<td>223.96</td>
<td>111.98</td>
<td>1.37</td>
<td>Orange x 2</td>
<td>1.53</td>
<td>Red</td>
</tr>
<tr>
<td>847.58</td>
<td>254.26</td>
<td>127.14</td>
<td>1.33</td>
<td>Red + Orange</td>
<td>1.50</td>
<td>Orange x 2</td>
</tr>
<tr>
<td>772.05</td>
<td>231.61</td>
<td>115.81</td>
<td>1.40</td>
<td>Orange x 2</td>
<td>1.44</td>
<td>Orange</td>
</tr>
</tbody>
</table>

An important consideration towards the CMJ is the participant’s ability to perform a squat. Despite each participant being involved in basketball training and exposed to resistance training few have been exposed to accurate technical coaching, therefore, their squatting technique was limited. A goniometer (30cm, Assist Creative Resources Ltd, Wrexham, UK) was used to calculate each participant’s squat depth. The knee flexion angle was measured by placing the centre of the goniometer on the fulcrum between the lateral condyle of femur and the tibial plateau, the stationary arm was placed to point down the centre of the lateral fibula towards the lateral malleolus and the free arm was positioned to point up lateral femur to the greater trochanter. Although research into CMJ magnitude and its relationship to VJP is inconclusive, from the limited research available and after assessment a knee flexion joint angle of or 70° for all CMJ trials was preferred for the present study. Research conducted by Salles, Baltzopoulos, and Rittweger (2011) indicated that greater knee flexion angles maximised VJH but limited ground reaction
forces, although was insignificant in effecting PF. 70° of knee flexion represented the middle value of Salles et al’s (2011) study, to try and elicit benefits in both VJH and GRF. Moran and Wallace (2007) support the decision of 70° knee flexion as it was concluded 70° produced greater enhancements than greater degrees of CMJ magnitude. McErlain-Naylor, King and Pain (2014) and Domire and Challis (2007) data concur with the highlighted researchers, however, both McErlain-Naylor et al (2014) and Domire and Challis (2007) highlight that during sports performance jumping utilising a deep squatting motion is rare, unpractised and not optimal to practical performance, thus supporting the preferred 70° knee flexion angle.

Before the start of the intervention each participant was instructed to hold position in the bottom of the squat position, determined previously, while the distance from the attachment point of the elastic bands on the squat cage (Hammer Strength Life Fitnes Elite Power Rack. Queen Adelaide, Ely, Cambridgeshire) and the attachment point on the sprint harness (XLR8 Power Speed Resistor, XLR8, Speed Power & Stability Systems NZ Ltd, Christchurch, New Zealand) was measured using a tape measure (SECA 201, Vogel & Halke, Hamberg, Germany) The subsequent force and distance data were then inputted into an Microsoft Excel (Microsoft Excel for Mac 2011, Microsoft Corporation) document containing unpublished masters thesis data on band tensions. The excel page calculated the required length and combination of elastic bands that produced 30% resisted and assisted tension of each individuals body weight. For the present study it was vital to ensure the concentric action occurred immediately after the eccentric phase, and the eccentric action was not protracted or required considerable motion about the specific joint, so the amassed energy was not dissipated and lost through heat (Baechle and Earle, 2008). Elastic band tension was determined at the lowest portion of the CMJ at 70 degrees of knee flexion, providing constant tension throughout the whole movement. This method also guaranteed the eccentric portion of movement was constantly loaded, an integral element highlighted by Sheppard et al (2008) for improving VJP. Having no slack in the bands at the lowest position also prevents against any potential to cause a force spike during the concentric upward phase as identified by Wallace et al (2006).
3.2.1 Warm Up

Participants completed standardised preparation movements before each conditioning stimulus on every testing day. The warm up procedure was derived from Aboodarda et al’s (2013) investigation and consisted of two sets of ten bodyweight squats, one minute between sets, performed to a minimum of 70 degrees knee flexion at a self-regulated velocity, accompanied by two sets of five maximum effort bodyweight CMJs. The warm up mimicked movements and primed muscles similar to the conditioning stimulus and testing protocol, to ensure every participant was prepared for the demands of the investigation and to minimise the risk of injury (Cissik, 2012). It was vital that the warm up was not excessively strenuous in nature to minimise the fatigue and PAP effects, if any, it might have had on the subsequent conditioning stimulus and testing procedure. Participants then rested for five minutes before performing one of the potentiating conditioning stimulus.

3.2.2 Bodyweight

The methods described henceforth are derived from similar procedures as described by Aboodarda et al (2013), Hara, Shibayama, Takeshita, Hay, and Fukashiro (2008) and Feltner, Bishop, and Perez (2004) with which they documented beneficial effects on performance. Bodyweight CMJs were undertaken with no additional external resistance or assistance. Participants were instructed to stand vertically upright, feet shoulder width apart, holding out their arms in front of them with roughly 45° shoulder flexion and slight elbow flexion to enable a relaxed starting position. Participants were then instructed to lower themselves utilising a rapid, while maintaining form, squatting motion to the predetermined 70° of knee flexion and then instantly jump for maximum vertical height. Participants were inspired to jump as high as possible with each jump, while minimising horizontal and lateral displacements. On landing participants were encouraged to stick the landing with both feet allowing for knee flexion to absorb the landing. Once the movement was complete participants reset themselves to execute the movement again. Inline with similar PAP studies aforementioned within the literature review, each jump was repeated four times to try and elicit any PAP effects and minimise fatigue. During every CMJ each participant was instructed to simultaneously swing their arms in a downward motion, timed with the downward squatting motion of the CMJ from the starting positions and then as
rapidly upwards as they could during the accent and jump phase. The inclusion of the arm swing has been shown by research to exhibit increases in VJP parameters during CMJs thus validating the inclusion for the present study (Hara et al, 2008; Feltner et al, 2004). The arm swing enabled each jump to be a familiar movement pattern to the participants, replicate performance in sport and to aim to produce maximum results, thus helping ensure the reliability of each jump.

3.2.3 Resisted

The executions of both the resisted and assisted CMJ were consistent with the aforementioned protocol for the bodyweight control measure, however this time each was performed within a squat cage. Participants wore a sprinting harness with a combination of two or more elastic bands; these were attached via each harness arm slot being placed through the loop of the elastic band so it would rest directly in the centre at the back of the harness. The bands were placed in the position described, and the straps of the harness adjusted to tightly fit the participant to minimise the risk of bands slipping as the participant jumped. The lower ends of the elastic bands were attached beneath the participant to the middle prong of the squat cage as shown in Figure 2. Care was taken to ensure each band was not twisted. The tension and combination of bands had previously been calculated for each participant to provide a vertical downward tensile force, relative to 30% of body mass in the base position of the CMJ with 70° knee flexion. During the concentric action, resistance increased for each participant through the ascent phase and take off phase of each jump. Arm swing was still encouraged here, although it became slightly modified for each participant due to the position of the bands.
3.2.4 Assisted

Every assisted jump, like resisted, was performed with the same equipment attached in the same way as the resisted trials, however, in this instance the bands were attached to the protruding squat cage prongs above the participant as shown in Figure 3. During the assisted trials the combination of elastic bands provided vertical upward tensile force that reduced each participant’s bodyweight by 30% in the standing position. To enable the equivalent imposed loading tensions during the eccentric and concentric phase of the CMJ as experienced during the resistance trials, technically required the length and combination of bands to be calculated during the highest point of the jump; however this was not practically possible so the closest alternative was deemed to be in the standing position. In this instance during the concentric action, banded assistance decreased though the ascent phase and take off phase of each jump. Arm swing was still encouraged here, although it became slightly modified for each participant due to the position of the bands.
3.2.5 Testing

A rest period of eight minutes was implemented after the conditioning movements and testing. Because of the ambiguous nature of current research towards optimum recovery duration for PAP, the present study found it difficult to determine an adequate rest period between a conditioning stimulus and subsequent testing to ameliorate performance. Meta-analysis's conducted by Gouvêa, Fernandes, César, Silva and Gomes (2013) and Wilson et al (2013) examined the manipulation of rest intervals for PAP effects on VJP and power production, concluding rest interval duration of eight to twelve minutes and seven to 10 minutes respectively, ameliorated VJP and lower limb power production. Kilduff, Owen, Bevan, Bennett, Kingsley and Cunningham (2008) investigated PAP on muscle contractile performance during the CMJ with results that support Gouvêa et al (2013) and Wilson et al (2013), further validating the present studies inclusion of an eight minute recuperation period.
Testing consisted of three maximal bodyweight CMJs employing the same technique used throughout the investigation, conducted on a calibrated portable force plate (AMTI AccuPower, AMTI, Boston, MA, USA.). A portable force plate was the preferred implement to collect data because research has shown force measurements and VJH collected using this method were more reliable and valid than that of other available methods (Walsh, Ford, Bangen, Myer and Hewett, 2006; Buckthorpe, Folland and Morris, 2012). Built in models for CMJ within Accupower (Accupower Software, Force Plate Analysis Software, Park City, Utah, USA) collected data using the force plate (1000Hz), which was zeroed and weighed the participant before data collection was initiated.

3.3 Statistical Analysis

The Accupower data was transferred into Excel to calculate PF, RFD and VJH. Cormack, Newton, McGuigan and Doyle (2008) indicated that these variables are accurate measures for identifying changes in VJP. McLellan, Lovell and Gass (2011) additionally identified that RFD and PF were the predominant variables influencing VJP during a CMJ; further validating the present studies use to measure the aforementioned variables.

Standardised statistical procedures were implemented for the calculation of standard deviations, means and percentage changes for all participant's anthropometric measures and performance variables. The best measures across all three CMJ trials for each participant were measured and used for statistical analysis as identified by Aboodarda et al (2013). One-Way Repeated Measures ANOVAs and intraclass correlation coefficients were implemented for statistical analysis using SPSS software (IBM SPSS Statistics for Macintosh, Version 22.0, Armonk, NY) to identify any significant differences between interventions and reliability of each trial respectively (Aboodarda et al, 2013; Kilduff et al, 2008).
CHAPTER 4

RESULTS
4.0 Results

4.1 Initial Analysis

The mean for each dependant variables during each experimental condition are reported in Table 2. There was a maximum VJH of 48.3, 42.7 and 49.5 recorded for control, assisted and resisted conditions across all participants respectively with a minimum VJH of 22.6, 21.8 and 27.4 cm respectively. There was a maximum RFD 12.0, 12.2 and 12.7 N·s⁻¹ for control, assisted and resisted conditions across all participants respectively with a minimum of 6.5, 6.6 and 8.0 N·s⁻¹ respectively. There was a maximum PF of 2281.7, 2301.8 and 2247.8 N recorded for control, assisted and resisted conditions across all participants respectively with a minimum of 1537.5, 1432.3 and 1529.0 N respectively.

Table 2 – Mean ± SD Results for Free, Resisted and Assisted Banded CMJ

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Assisted</th>
<th>Resisted</th>
</tr>
</thead>
<tbody>
<tr>
<td>RFD (N·s⁻¹)</td>
<td>8.4 ± 3.1</td>
<td>9.1 ± 1.8</td>
<td>9.7 ± 1.6</td>
</tr>
<tr>
<td>PF (N)</td>
<td>1984.5 ± 253.7</td>
<td>1902.8 ± 235.9</td>
<td>1961.3 ± 217.0</td>
</tr>
<tr>
<td>VJH (cm)</td>
<td>33.9 ± 8.1</td>
<td>32.9 ± 6.6</td>
<td>36.0 ± 7.9</td>
</tr>
</tbody>
</table>

Figures 4, 5 and 6 show participant Z-scores for each experimental intervention condition illustrating how each participant performed within the group against the group mean.
Figure 4 – Z Scores for Control, Assisted and Resisted VJH

Figure 5 – Z Scores for Control, Assisted and Resisted RFD
Each participant’s results for all intervention methods were compared against the control data to calculate a percentage change and identify which, if any, intervention method the participants respond greatest to. Table 3, 4 and 5 illustrate the percentage change response for VJH, RFD and PF respectively for assisted and resisted banded CMJs when compared to bodyweight CMJs.
Table 3 – Participant’s percentage change in VJH during control and assisted and control and resisted.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Control and Assisted (%)</th>
<th>Control and Resisted (%)</th>
<th>Best Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14.7</td>
<td>51.2</td>
<td>Resisted</td>
</tr>
<tr>
<td>2</td>
<td>-2.7</td>
<td>-11.0</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>-9.9</td>
<td>-11.3</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>-15.8</td>
<td>2.1</td>
<td>Resisted</td>
</tr>
<tr>
<td>5</td>
<td>3.6</td>
<td>-3.6</td>
<td>Assisted</td>
</tr>
<tr>
<td>6</td>
<td>-3.4</td>
<td>41.6</td>
<td>Resisted</td>
</tr>
<tr>
<td>7</td>
<td>10.5</td>
<td>6.6</td>
<td>Assisted</td>
</tr>
<tr>
<td>8</td>
<td>-20.0</td>
<td>-10.6</td>
<td>None</td>
</tr>
<tr>
<td>9</td>
<td>5.7</td>
<td>-0.8</td>
<td>Assisted</td>
</tr>
<tr>
<td>10</td>
<td>2.0</td>
<td>14.9</td>
<td>Resisted</td>
</tr>
<tr>
<td>11</td>
<td>-6.5</td>
<td>14.1</td>
<td>Resisted</td>
</tr>
</tbody>
</table>

Table 4 – Participant’s percentage change in RFD during control and assisted and control and resisted.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Control and Assisted (%)</th>
<th>Control and Resisted (%)</th>
<th>Best Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31.7</td>
<td>-13.9</td>
<td>Assisted</td>
</tr>
<tr>
<td>2</td>
<td>-6.5</td>
<td>15.6</td>
<td>Resisted</td>
</tr>
<tr>
<td>3</td>
<td>-1.9</td>
<td>2.4</td>
<td>Resisted</td>
</tr>
<tr>
<td>4</td>
<td>0.4</td>
<td>42.0</td>
<td>Resisted</td>
</tr>
<tr>
<td>5</td>
<td>-9.6</td>
<td>-4.9</td>
<td>None</td>
</tr>
<tr>
<td>6</td>
<td>5.6</td>
<td>-9.4</td>
<td>Assisted</td>
</tr>
<tr>
<td>7</td>
<td>-31.7</td>
<td>5.4</td>
<td>Assisted</td>
</tr>
<tr>
<td>8</td>
<td>14.2</td>
<td>16.9</td>
<td>Resisted</td>
</tr>
<tr>
<td>9</td>
<td>-14.5</td>
<td>-27.6</td>
<td>None</td>
</tr>
<tr>
<td>10</td>
<td>17.2</td>
<td>11.5</td>
<td>Assisted</td>
</tr>
<tr>
<td>11</td>
<td>2.9</td>
<td>66.7</td>
<td>Resisted</td>
</tr>
</tbody>
</table>
Table 5 – Participant’s percentage change in PF during control and assisted and control and resisted.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Control and Assisted (%)</th>
<th>Control and Resisted (%)</th>
<th>Best Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.9</td>
<td>-5.4</td>
<td>Assisted</td>
</tr>
<tr>
<td>2</td>
<td>-3.7</td>
<td>3.0</td>
<td>Resisted</td>
</tr>
<tr>
<td>3</td>
<td>-5.3</td>
<td>-4.9</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>-1.8</td>
<td>5.2</td>
<td>Resisted</td>
</tr>
<tr>
<td>5</td>
<td>-0.4</td>
<td>-0.9</td>
<td>None</td>
</tr>
<tr>
<td>6</td>
<td>-2.0</td>
<td>-0.8</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>-4.3</td>
<td>-5.3</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>-6.8</td>
<td>-0.6</td>
<td>None</td>
</tr>
<tr>
<td>9</td>
<td>-5.7</td>
<td>-7.1</td>
<td>None</td>
</tr>
<tr>
<td>10</td>
<td>2.3</td>
<td>3.2</td>
<td>Resisted</td>
</tr>
<tr>
<td>11</td>
<td>1.5</td>
<td>3.8</td>
<td>Resisted</td>
</tr>
</tbody>
</table>

4.2 One-Way Repeated Measures ANOVA

The assumption of data normality (p > 0.05) was confirmed using a Shaprio-Wilk test within all the intervention data (O’Donoghue, 2012). Three, One-Way Repeated Measures ANOVA’s were calculated to provide a report of significance between the mean RFD, VJH and PF for each intervention differed significantly from the collective mean across all intervention conditions (O’Donoghue, 2012). Mauchly’s Test of Sphericity identified that Sphericity was assumed for all ANOVA’s (p > 0.05). The Pairwise Comparisons identified RFD, VJH and PF displayed no significant differences (p > 0.05) between control and assisted, control and resisted or assisted and resisted banded CMJs.

4.3 Intraclass Correlation Coefficient (ICC)
An ICC was implemented to assess the reliability of the retests performed by each participant (O’Donoghue, 2012), the ICC and lower bound 95% confidence interval scores are highlighted in Table 6. All ICC’s and lower bound values for PF indicate virtually excellent levels of agreement (r > 0.900) indicating each retest was reliable. Optimal agreements are identified where the ICC and lower bound scores are r < 0.900; there are questionable agreements where r < 0.800 (O’Donoghue, 2012). The lower bound scores indicate, apart from PF, high variance between each jump therefore there is little to no agreement with retest reliability.

Table 6 - ICC evaluating the retest reliability of each participant under all intervention conditions

<table>
<thead>
<tr>
<th></th>
<th>Control 95% ICC</th>
<th>Lower Bound</th>
<th>Assisted 95% ICC</th>
<th>Lower Bound</th>
<th>Resisted 95% ICC</th>
<th>Lower Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>VJH</td>
<td>0.841</td>
<td>0.565</td>
<td>0.908</td>
<td>0.752</td>
<td>0.746</td>
<td>0.317</td>
</tr>
<tr>
<td>RFD</td>
<td>0.804</td>
<td>0.456</td>
<td>0.775</td>
<td>0.372</td>
<td>0.806</td>
<td>0.471</td>
</tr>
<tr>
<td>PF</td>
<td>0.979</td>
<td>0.919</td>
<td>0.987</td>
<td>0.966</td>
<td>0.977</td>
<td>0.938</td>
</tr>
</tbody>
</table>
5.0 Discussion

5.1 Theoretical Implications

The purpose of the present study was to investigate the acute effects of assisted and resisted banded plyometric exercises as potentiating exercises for VJP. The One-Way Repeated Measures ANOVA identified no significant difference between control and assisted, control and resisted or assisted and resisted banded interventions as all results were above 0.05 of significance ($P > 0.05$). Thus disproving the hypothesis that resisted jumping will increase maximum PF, RFD and VJH, with assisted jumping hypothesized to increase RFD, but decrease VJH and PF. From the results of the present study, it can be determined that there are no significant acute potentiating effects of resisted or assisted plyometric exercises for VJP, using resistance bands equal to 30% of bodyweight. The Z scores highlighted in Figures 4, 5 and 6 demonstrate how each participant performed against the mean of the group. In most cases participants who performed above the mean of the group continued to have greater performance and those who performed below the mean continued to perform at this level. Although the Z scores are only representative of the participating group, if the group performed significantly greater or poorer then the Z scores would reflect this. In some instances, for example, participant nine's PF, participant one, two, seven, nine and eleven's RFD, participants one, two, three and nine's VJH performance fluctuated above or below the group mean throughout the interventions. This could be equated to the difficulty the participants had recreating the desired technique for each jump, which is highlighted by the poor retest reliability agreement with the ICC scores.

The participant's percentage change results for each dependent variable, after both interventions, are documented in Tables 3, 4 and 5 with the best intervention highlighted. Although the ANOVA identified no significant difference between any intervention and the control data, it can be seen from Tables 3, 4 and 5 that some individuals appeared to prove some aspects of the hypothesis correct. During the assisted banded CMJs, PF decreased for eight participants, and during the resisted banded CMJs RFD increased for seven participants. This could be equated to the small sample size used during the study. It is known that the greater number of participants the more reliable and representative the data can become (O'Donoghue, 2012; Hopkins 2000). Therefore there are some indications for future research to examine similar acute potentiating effects of resisted and
assisted banded plyometrics with a much larger sample size. The decrease in PF and VJH observed during the assisted intervention could be related to a decreased force contribution from the SSC. The imposed stretch on the myotatic stretch reflex characteristics of the muscle tendon complex, could have been significantly reduced due to the reduction in bodyweight and consequently rate of force unloading; therefore, the decreased contribution from the SSC would have caused a significant reduction in tendon recoil and force production (Kubo, Kanehisa, Takeshita, Kawakami, Fukashiro and Fukunaga, 2000). The participants in the present study who were able to increase their PF and VJH scores during the assisted intervention may have been more dependent upon producing greater levels of concentric force (Kubo et al, 2000). During the resisted intervention, participants who increased RFD, PF and thus VJH could have achieved this because of the increased resistance and reduced velocity during the CMJ movement associated with the force velocity relationship. The force velocity relationship determines that force production is increased during decreased velocities muscle contraction (McBride et al, 2002; Peterson et al 2004; Cronin and Hansen, 2005). Because of the force velocity relationship characteristics, the observed increases for RFD, PF and VJH could have been generated due to the enhanced SSC function and augmentation of the tendon recoil action; facilitated by the increased resistance and resultant increase in force unloading, generated by the resistance band (Kubo et al, 2000).

The data obtained from the present study supports the conclusions of McClenton et al's (2008) research that resisted PT did not significantly improve jumping performance over traditional resisted PT modalities. This is possibly associated with the prescribed level of tension. Though some participants improved in some areas, the prescribed tension of 30% of bodyweight may not have been great enough to elicit any PAP effects from the conditioning action. Research has indicated that loads of 80% – 90% 1RM have demonstrated significant PAP responses and subsequent improvements in jumping performance; therefore suggesting that the required band tension of 30% bodyweight was not significant enough to demonstrate a reliable PAP response (Weber, Brown, Coburn, and Zinder, 2008; Mangus, Takahashi, Mercer, Holcomb, Mcwhorter and Sanchez, 2006). Weber et al (2008) and Mangus et al (2006) conclusions could be related to a reduction in the transmission time of strength due to increased levels of muscle tendon stiffness, brought about by the increased loads (Till and Cooke, 2009). Potentially explaining why at 30% bodyweight the present study demonstrated no significant PAP responses because tendon stiffness was not optimised.
Similarly, the effects of sets, repetitions and balance between muscle fatigue may have played a part in why the statistical analysis demonstrated no significant difference between interventions. It is accepted that the greater the volume and intensity of an exercise, the more fatigued a muscle becomes. Tillin and Bishop, (2009) discuss the possibility of a relationship between fatigue and PAP, suggesting a balance is needed to maximise a PAP response. Figure 7 shows the theoretical relationship between PAP and fatigue.

Figure 7 - Theoretical model of the relationship between fatigue and PAP after a conditioning contraction (Tillin and Bishop, 2009)

Unfortunately there is no consensus between researchers as to what the optimal rest periods should be. The results of the present study support Mangus et al (2006) and Chiu, Fry, Weiss, Schilling, Brown, and Smith (2003) who observed no significant improvements in power output after rest periods of five to seven minutes. However, French, Kraemer and Cooke (2003) and Gourgoulis, Aggeloussis, Kasimatis, Mavromatis and Garas (2003) observed significant improvements in VJP immediately following a preconditioning contraction with no rest period. Conversely, Gouvêa et al (2013) and Wilson et al (2013) concluded rest intervals between eight to 12 minutes, ameliorated VJP performance.
From PAP research, it has been proposed that following a conditioning contraction there is need for an optimum recovery period to diminish the effects of fatigue and maximize a PAP response. However, the contradicting natures of these findings propose that the relationship between fatigue, PAP and subsequent performance are extremely complex and inconsistent. Tillin and Bishop (2009) suggest that the fatigue-PAP relationship can be influenced by an amalgamation of variables highlighted in Figure 8.

Figure 8 - Potential factors modulating the relationship between fatigue and PAP that subsequently may influence an ensuing performance

Figure 7 and the aforementioned research evidences a PAP response can be evident directly following a conditioning stimulus, however, at the same time fatigue is similarly present potentially decreasing subsequent performance. The complex nature of factors modulating PAP and the fatigue relationship as well as the two suggested windows for PAP to occur, insinuates that the participants of the present study may have fallen between the first and second window of a potential PAP response. In this instance, although unlikely as the conditioning stimulus may not have been great enough, fatigue may not have diminished sufficiently for a PAP response to occur for all participants. A more likely explanation is that both the fatiguing and PAP effects had already diminished due to the increased rest interval before testing. Due to the conflicting nature of rest intervals within the aforementioned research and the use of submaximal load within the present study, it could be suggested that the prescribed rest interval was too long for any PAP response to still be evident. Tillin and Bishop (2009) support this theory, as they insinuate that a PAP response could develop faster than fatigue at low load conditioning contractions.
A possible reason why the present study was unable to demonstrate any significant PAP effects following the interventions could be because of the two main mechanisms suggested to cause PAP. Firstly, as previously mentioned, the tensions of the elastic bands set at 30% bodyweight may not have been great enough to increase the recruitment of high order motor units. Secondly, the tensions may not have significantly affected the phosphorylation of myosin regulatory light chains, or the eight minutes recovery caused any stimulated effect to be reversed. Therefore not potentiating ensuing muscle contractions, as the sensitivity to myoplasmic calcium might not have increased during the interaction between actin and myosin cross-bridges, the myosin head structure may not have been altered or moved apart from its filament backbone (Hodgson et al, 2005; Szczesna, Zhao, Jones, Zhi, Stull and Potter, 2002).

Rixon, Lamont and Bemben (2007) highlighted gender, muscle fibre type and training age as dominant variables related to individualisation affecting PAP. Therefore, individuality within a participant’s musculature could explain why some participants exhibited no PAP response, highlighted in Tables 3, 4 and 5. Research has shown evidence for PAP effects to be greater in athletes possessing an increased percentage of fast twitch muscle fibres over athletes who possess less (Rixon et al, 2007). Rixon et al, (2007) identified males with a limited training age generated greater force outputs than experienced female, insinuating the mechanisms behind the difference could be associated with males possessing greater quantities of fat free mass, consequently displaying larger volumes of type two muscles fibres. Rixon et al’s (2007) conclusions can be related to the present investigation because participant’s percentage of body fat was not calculated. Consequently, some participants within the present study may have possessed greater quantities of muscle mass than others, and were thus able to benefit more from PAP. Similarly, the training age of a participant could have influenced their ability to exhibit a PAP response. Chiu et al (2003) observed PAP to be a feasible method for augmenting performance with athletes but not recreational individuals. Chiu et al (2003) proposed individuals with an increased training age might be more resilient to fatigue due to the adaptations brought about by past resistance training. In addition, PT could be further influenced by training age, thus further affecting any PAP response. Cormie et al (2007) and Kutz (2003) both suggested that PT should only be undertaken by experienced, trained individuals, however Sáez de Villarreal (2010) and Markovic (2007) both concluded that plyometric performance was unaffected by training age. The present study recruited a mixture of university students with varying ages (Age 21 ± 2 years) insinuating participants
could have been exposed to varying levels of resistance training and PT. The discrepancies in the individual results shown in Tables 3, 4 and 5 could suggest that participants who performed better and demonstrated a PAP response might have an increased training age over others who demonstrated no PAP response; consequently possessing an increased number of type two muscle fibres and additional auspicious training adaptions to stimulate a greater PAP response.

The results of the present study do not support past research conducted by Kilgallon and Beard (2010) and Sheppard et al (2011) who identified assisted jumping increased VJH. The present studies results do not follow the premise that assisted jumping has potential to permit equivalent adaptations to the neuromuscular system to occur for VJP, as identified with assisted sprint training by Paradisis and Cooke (2006), Corn and Knudson (2003) and Ebben (2008). It must be noted that the present study was investigating the acute potentiating effects of banded PT on VJP rather than the effects of banded PT programme. The limited research that already exists on the effects of assisted banded jumping on performance have demonstrated that the propulsive upward vertical force, imposed on an individual, enabled them to produce greater force over a decreased period of time; theoretically related to improved neural stimulation from preforming at a supra maximal velocity (Sheppard et al, 2011; Ebben, 2008; Paradisis and Cooke, 2006). Alternatively, the poor PAP response could be explained by participants potentially relying on being pulled up by the vertical tension provided by the assisted intervention instead of contracting supra maximally. The present study highlights that many of the induced effects on performance thought to be provided by assisted jumping appear to be lost while waiting between the potentiating conditioning action and retest as previously mentioned.

5.2 Limitations

The small sample size of the present study (n = 11) has a high possibility to weaken the statistical reliability of the results and therefore may not be representative of the current population (O’Donoghue, P, 2012).

Due to the experimental nature of the present study there are some limitations that should be taken into account, which may be reflected within the data. Although the predetermined level of resistance and assistance was chosen to be 30% of bodyweight relative to each participants mass, the practicality of achieving the exact required tension with the current
employed method and equipment was considerably difficult. The required tension equal to exactly 30% of bodyweight was only achieved in two cases, all the other cases were as close to 30% as possible. Therefore each participant was experiencing a different relative resisted or assisted tension, possibly affecting the conditioning action and therefore retest data. A way to overcome this limitation could be to have a greater selection and number of bands. Anchoring the bands at different potions on the squat cage could enable different lengths and greater combinations of bands to be utilised and achieve the exact required tension.

Although every effort was made to ensure each jump was performed exactly the same by each participant, especially during testing, some variances in technique prevented this from happening and could not be controlled. Participants found it difficult to time the arm swing correctly with the concentric and eccentric phases of the CMJ, the elastic bands hampered the arm swing in some instances and participants may have swung their arms harder and higher than others which may have all affected the force output data. Some participants found it difficult recreating the exact same depth for the CMJ for all conditioning movements and subsequent testing. Eliminating the arm swing from the CMJ would remove the described limitation in technique and may produce a more reliable and specific data related to the SSC of the lower limbs, as it has been shown that an arm swing can significantly improve performance (Feltner et al, 2004). The inability to recreate the desired knee and hip flexion angles during the accentuated CMJ could have exposed participants to varying degrees of resistance depending on how low they performed the CMJ. Consequently some participants may have increased motor unit recruitment and thus increase power output and vertical jump height over other participants, evidenced by Tables 3, 4 and 5. Moir, Sanders, Button and Glaister (2005) used an adjustable bar to ensure the required CMJ depth and knee flexion angle was achieved each time, utilising a similar method may also remove the observed limitations with technique.

5.3 Practical Implications

The present study concluded there were no actuate potentiating effects on VJP from resisted or assisted banded plyometric exercises, therefore its practical applications are significantly limited using the exact same methodology. However, previous research has indicated beneficial adaptations can be gained from implementing a resisted or assisted banded PT programme for athletes with existing high strength levels, but are deficient in
producing high levels of explosive power (Rhea et al, 2008a, Rhea et al 2008b). Research has also demonstrated that the phenomenon of PAP exists, and can be manipulated to elicit chronic and acute enchantments in performance (Byrne et al, 2014; Stevenson et al, 2010). As mentioned previously, there is still conflicting and vague understanding of the underlying mechanisms behind PAP. Therefore the control and manipulation of the vast amount of variables would make it difficult to implement PAP as a training modality or warm up into a practical environment. Due to the limited time periods S&C coaches have with athletes to allow the appropriate training content to be covered within a session, it would be impractical to use a recovery time of ten minutes, a proven rest time identified by Gouvêa et al (2013), to wait for a PAP response as this would consume too much time. Shorter rest periods for the present study could potentially be utilised within a warm up, however further research is need to confirm this.

5.4 Future Research

Future research may look to investigate the use of a shorter rest period within the present study to evaluate if there was in fact a greater PAP response present earlier on after the conditioning contraction. There is much need for future research into the multifaceted variables effecting PAP such as rest periods, optimal loads and training age to identify a definitive method for producing a maximum PAP response.

The present study utilised a dynamic contraction consisting of both concentric and eccentric movements. Future research may also look to investigate the types of conditioning contraction utilised to try and provoke a PAP response to identify if a concentric, eccentric or isometric movements produce greater responses. There is also a need to investigate different conditioning contraction movements and subsequent activity to see if a PAP response could be more prevalent in different sporting movements.

Future research may look to build upon the principles of the present study and investigate the differing kinetic effects of assisted and resisted banded jumps, and how they influence the variables of VJP identified by Cormack et al (2008) and McLellan et al (2011). Researchers interested in this area could then investigate the use of an assisted or resisted banded PT programme intervention and its associated effects on VJP.
5.5 Conclusion

After analysis of the results from the present study it can be concluded that utilising resisted and assisted tensions of 30% bodyweight during the CMJ, through the use of elastic bands, provided no significant potentiating effects for improving vertical jump performance when comparing RFD, PF and VJH. However, some participants did demonstrate PAP responses after one or both assisted and resisted interventions, this is thought to be because of the significant role the individualisation characteristics of PAP have on performance.

The factors modulating PAP are vast and multifaceted with many researchers offering conflicting views on the manipulation of PAP to achieve the greatest improvements. This could further indicate why the present study had difficulty in demonstrating a significant PAP response for both interventions. Many of the variables highlighted previously, such as rest periods, intensity and training age need much further research to be able to definitively establish an effective protocol.
References


Verkhoshansky, Y. & Siff, M.C. (2009), Supertraining, Verkhoshansky SSTM, Rome


APPENDICES
APPENDIX A

PARTICIPANT INFORMATION SHEET
Participant Information Sheet

UREC reference number:

Title of Project: The Acute Effects of Assisted and Resisted Plyometric Exercises as Potentiating Exercises for Vertical Jump Performance

Participant Information Sheet Feb 2015

Background

This research study is an attempt to understand the acute effects of assisted and resisted plyometric exercises as potentiating exercises for vertical jump performance. It is being conducted by Callum Shields as part of his third year dissertation project for his sports conditioning rehabilitation and massage BSc Hons degree within Cardiff Metropolitan University School of sport.

Plyometrics have been identified as an effective way of improving vertical jump performance; elastic bands have been identified as an effective method for generating significant improvements in performance by adding greater resistance. The research study has been designed and implemented to investigate if resisted and or assisted plyometrics can elicit any potentiating effects on vertical jump performance to support their use as a potential training modality.

Put simply the study will examine:

(i) If resisted plyometrics, with the use of elastic bands, have potentiating effects on vertical jump performance

(ii) If assisted plyometrics, with the use of elastic bands, have potentiating effects on vertical jump performance

The study will be presented as a report to Cardiff Metropolitan University School of Sport.
Your participation in the research project

Why you have been asked
You have been invited to take part in the research study as you fulfil all the required criteria need to be a participant. It may also help you gain an insight into potential training methods to improve your performance.

What would happen if you agree to take part?

If you agree to partake in the study, you will be required to attend three session on three separate days.

1. The first day you attend you will have height, and weight measurements taken as well as your age recorded. You will then preform a warm up followed by a vertical jump. You will then perform one of the potentiating exercises, followed by a rest and then another vertical jump.

2. The second day you attend you will then preform the warm up and vertical jump as in day one but then preform a potentiating exercises resisted or assisted, or control exercises that you did not perform on day one. You will then rest for a short period again and perform another vertical jump.

3. On the third day you will perform the same warm up procedure as in days one and two followed by the vertical jump. You will then perform the last method of potentiating exercises or control that you did not perform on days one or two, followed by a rest and another vertical jump.

During all potentiating exercises, apart form the control, you will have elastic bands attached to you, either to resist or assist your movements

Are there any risks?

A risk assessment has been carried out and there are no serious risks to you from taking part in this research study. As with any exercise there is always the risk of potential injuries but the protocol has been designed in such a way to minimise these risks. If you are feeling unwell for any reason, it is advised that you do not take part.
Your rights

Agreeing to take part in this study does not mean that you give up any legal rights. In the very unlikely event of something going wrong during the investigation, Cardiff Metropolitan University fully indemnifies its staff, and participants are covered by its insurance.

What happens to the results of the study?

The measurements that are taken at the start of the study and three more times throughout the three days will be stored securely. They will be coded so that names and any identifying details will be removed, however a record of the codes will be kept to allow measurements to be compared. The information will be presented in a reported document to Cardiff Metropolitan University. Results will not be discussed with each individual but if you wish to ask any questions then they will be answered to be the best of the conducting individuals ability.

Are there any benefits from taking part?

Yes, you will learn about plyometrics as a training modality to potentially improve your performance.

What happens next?

With this letter you will find a participation consent form to complete to state you have read all the information provided are you are willing to participate voluntary. These forms should be completed before your attend on the first day.

How we protect your privacy:

Everyone working on the study will respect your rights of privacy. Measures have been put in place to ensure that you will not be identified from any information that is collected about you.
All the information about you will be stored securely away from the consent and assent forms. At the end of the research study, all the information about you will be destroyed. Consent forms with your name and address will be kept for ten years, as Cardiff Metropolitan University requires this.

**Further information**

If you have any questions about the research or how we intend to conduct the study, please contact us.

Callum Shields

- 07523061658
- st20004911@outlook.cardiffmet.ac.uk
APPENDIX B

INFORMED CONSENT FORMS
Cardiff Metropolitan CONSENT FORM

UREC Reference No:
Title of Project: The Acute Effects of Assisted and Resisted Plyometric Exercises as Potentiating Exercises for Vertical Jump Performance
Name of Researcher: Callum Shields

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet dated Feb 2015 for this research study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2. I understand that my participation is voluntary and that it is possible to stop taking part at any time, without giving an explanation.

3. I also understand that if this happens, my relationship with Cardiff Metropolitan University or my legal rights will not be affected.

4. I understand that information from the study may be used for reporting purposes, but any personal information or my identity will not be revealed.

5. I agree to take part in this research study.

Name of Participant

___________________________________________________________
Signature of Participant Date

Name of person taking consent Date

___________________________________________________________
Signature of person taking consent