## Cardiff School of Sport
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<th>Samuel Jordan Atkinson</th>
<th>Student ID:</th>
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The Effect Of A Short Term Plyometric Program On Hard Floor And Sand For The Improvement Of Vertical Jump Height In Basketball.

(Dissertation submitted under the SCRAM area)

Samuel Jordan Atkinson

ST20005730
THE EFFECT OF A SHORT TERM PLYOMETRIC PROGRAM ON HARD FLOOR AND SAND FOR THE IMPROVEMENT OF VERTICAL JUMP HEIGHT IN BASKETBALL.
Cardiff Metropolitan University
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</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><strong>CHAPTER ONE</strong></td>
<td></td>
</tr>
<tr>
<td>1.0 Introduction and Literature Review</td>
<td>1</td>
</tr>
<tr>
<td><strong>CHAPTER TWO</strong></td>
<td></td>
</tr>
<tr>
<td>2.0 Methodology</td>
<td>11</td>
</tr>
<tr>
<td>2.1 Participants</td>
<td>12</td>
</tr>
<tr>
<td>2.2 Experimental Protocol</td>
<td>13</td>
</tr>
<tr>
<td>2.2.1 Recording vertical jump data using Smartspeed Mat</td>
<td>14</td>
</tr>
<tr>
<td>2.3 Data Analysis</td>
<td>16</td>
</tr>
<tr>
<td><strong>CHAPTER THREE</strong></td>
<td></td>
</tr>
<tr>
<td>3.0 Results</td>
<td>17</td>
</tr>
<tr>
<td><strong>CHAPTER FOUR</strong></td>
<td></td>
</tr>
<tr>
<td>4.0 Discussion And Conclusion</td>
<td>21</td>
</tr>
<tr>
<td><strong>CHAPTER FIVE</strong></td>
<td></td>
</tr>
<tr>
<td>5.0 Recommendations</td>
<td>30</td>
</tr>
<tr>
<td><strong>CHAPTER SIX</strong></td>
<td></td>
</tr>
<tr>
<td>Reference List</td>
<td>33</td>
</tr>
<tr>
<td><strong>CHAPTER SEVEN</strong></td>
<td></td>
</tr>
<tr>
<td>Appendices</td>
<td>44</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1. Participant Characteristics 12

Table 2. Comparing Post Mean Jump Height Improvement and Standard Deviation (S.D) Between Both Training Conditions. 18
LIST OF FIGURES

Figure 1. Vertical Jump Test Procedure 14

Figure 2. Pre and Post Vertical Jump Means and Standard Deviation for the Control Group. 19

Figure 3. Pre and Post Vertical Jump Means and Standard Deviation for the Experimental Group. 20
APPENDICES

APPENDIX A – Participant Information Sheet A-1

APPENDIX B – Informed Consent Form B-1

APPENDIX C – PAR-Q C-1

APPENDIX D – 5 Week Plyometric Program D-1

APPENDIX E – Raw Data E-1

APPENDIX F – SPSS Outputs F-1
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Abstract

**Purpose:** The research objective was to observe and recognise the effects of plyometric training on different surfaces, specifically sand and hard floor for the improvement of vertical jump height in basketball.

**Method:** Thirteen Cardiff Metropolitan University students who played basketball \((n = 12\) male and \(n = 1\) female) with mean age of \(20.3 \pm 2.0\) (years), mass \(83.2 \pm 14.2\) (kg) and stature \(181.9 \pm 7.2\) (cm) agreed to participate in the study. All participants took part in a 5 week plyometric program and were randomly allocated to one of the two training conditions, plyometric program on hard floor \((HF: n = 7)\) or plyometric program in a sand pit \((SP: n = 6)\). Following the plyometric program and VJT test measures descriptive statistic were executed by mean and S.D to identify a measure of central tendency. Calculation of skewness and kurtosis was needed to establish if the data was normally distributed. Data was normally distributed so it was considered appropriate to use a parametric independent samples t-test.

**Results:** Data analysis of post vertical jump height illustrated a significant increase in jump height for the sand pit compared to the hard floor condition \((P = 0.002)\). The alternative hypothesis was accepted as \((P < 0.05)\) identifying that there was a significant difference between the two conditions. Using Excel 2010 mean and S.D values could be calculated for both the experimental and control condition. Statistical data showed that the control group pre testing mean vertical jump height was \(40.76 \pm 6.67\) (cm) and post testing mean vertical jump height was \(42.1 \pm 6.74\) (cm), illustrating a mean improvement of \(1.34\) (cm). For the experimental group pre testing the mean vertical jump height was \(39.45 \pm 1.93\) (cm) and post testing mean vertical jump height was \(42.25 \pm 2.2\) (cm), demonstrating a mean improvement of \(2.8\) (cm).

**Conclusion:** The experimental condition revealed to have an additional jump improvement of \(1.46\) (cm) compared to the control condition.
Chapter I
Introduction and Literature Review
1. Introduction and Literature Review

In competitive and training situations, the application of different surfaces is considered to meet sport specific needs in order to reach peak performance (Manske, 2006). Farrow et al. (2013) and Impellizzeri (2008) agree declaring that plyometric exercise on different surfaces can be related with diverse training protocols that effects the biomechanical and neuromuscular factors, which are related to the efficiency of the stretch-shortening cycle (SSC).

Plyometric training consists of exercises or drills that integrates strength and speed to produce an explosive movement and an increase in power (Chu, 1998). Maximal power output is generated by the rapid powerful movements. The utilisation of the SSC consists of an eccentric contraction trailed by a concentric contraction through the stimulation of proprioceptive properties, thus improving reactive strength (Page and Ellenbecker, 2003; Donatelli, 2007).

Athletes who want to improve power and explosiveness prefer to administer the use of plyometric training as it is a popular and efficient process (Sharkey and Gaskill 2007; Vissing 2008). However, plyometric training is deemed as a potentially damaging method due to it being extremely impacting, especially if undertaken by an inexperienced individual or overly administered (Fleck and Kramer, 2004; McNeely and Sandler, 2006).

When implementing plyometrics, it is important to execute the correct techniques. Correct biomechanical variants must be considered in order to reduce the event of excessive supination, excessive pronation and heel strike action (Radcliffe and Farentinos, 1999). Reoccurrence of the above elements could increase the risk of lower extremity injuries, increase instability and neuromuscular maladaptation (Noyes and Barber-Westin, 2013).

On the other hand, correct application of plyometric training can help improve neuromuscular properties leading to increased performance capabilities. This can also alter biomechanical risk factors, deliver proprioceptive control and reduce the risk of anterior cruciate ligament (ACL) injuries (Caraffa et al., 1996; Myer et al., 2006; Caine et al., 2013).
Saunders et al. (2006) cited in Hong (2013) illustrates a similar perception asserting that plyometrics altering biomechanical and neuromuscular abilities can lead to better efficiency in kinetic abilities. Hewitt et al. (2007) proposes a comparable view claiming that plyometric training reveals reduced incidence of lower extremity valgus in the ankle, knee and hip.

Combined studies have indicated that performing plyometric training within a periodization phase can promote vast physiological gains in: muscular power, joint awareness, isokinetic/isometric leg strength, increased proprioception and neuromuscular activation all leading to improved vertical jump capacities (Hennessy and Kilty, 2001; Miller et al., 2002; Passuke et al., 2001;).

Levange and Norkin (2011) elaborate that other physiological adaptations can be achieved by sustaining and executing an appropriate plyometric program. These adaptations include: greater achilles tendon elongation, efficient amortisation phase in the SSC, improved storage of elastic energy, recruitment of more type II fibres and improved proprioceptive abilities. A combination of the above adaptations helps improve maximal power output through involuntary contractibility of muscles (Bishop, 2012).

Stemm and Jacobson (2007) experimented applying the same plyometric program on a water based surface against an alternative experimental group to investigate any potential implications on beginner athletes. Results showed a significance ($P < 0.05$) in the two experimental conditions compared to the control group, however there was no significance recognised amongst the testing procedures. Arazi and Asadi (2011), Arazi et al. (2012) and Shiran et al. (2008), are additional studies that include similar findings.

Panda (2013) directed a study applying resistance training and plyometric training in sand for 15 male basketball athletes to examine the effects on particular bio-motor performances. Findings suggest that sand plyometrics can be applied as an effective training protocol in order to improve; acceleration speed, explosive strength, aerobic capacity and agility. Sharma and Chaubey (2013) conducted a 6 week plyometric program on sand for 30 junior volleyball players and results illustrated an improvement of power in the lower extremity and increased vertical jump height.
Research by Miller et al. (2002) illustrates a similar viewpoint insisting that training properties like water and sand provide greater resistance and viscosity for greater improvements. Shaffer (2007) expresses that greater muscle activation is required to overcome and perform same movements in these situations as it would be on land surface. It is the greater muscle activation that leads to greater physiological improvements.

Mirzaei et al. (2013) investigated the effects of countermovement jump (CMJ) and depth jump (DJ) training in sand using electromyography and vertical jump to monitor neuromuscular adaptations in the muscles. Findings showed that CMJ and DJ training on sand increases electrical activity in lower extremity muscles that leads to improving jump performance.

A study by Cressey et al. (2007) examined the effects of training on unstable surfaces (UST) to see whether it is applicable for strength and conditioning programs focusing on performance of lower extremity. Results showed that the control group on the stable surface significantly increased power output for CMJ (2.4%) and bounce drop jump (BDJ) (3.2%) respectively. Nonetheless the experimental group (UST) resulted in no significant differences.

A comparable investigation by Robinson et al. (2004) examined the effects of plyometric training in water compared to land based plyometrics on women using pain as the measurement factor. Muscle soreness feedback via an ordinal scale and palpation for sensitivity registration were the performance indicators controlled by the researchers. Results indicated that muscle soreness occurred less with the aquatic condition right from baseline testing all the way into progressed phases ($P = 0.01$). Additionally the two conditions indicated significant improvements.

Markovic and Mikulic (2010) correspond signifying short term plyometric program on soft platforms (i.e. sand or aquatic) compared to hard surfaces can produce similar or greater improvements in sprinting and jumping performances. Also resulting with considerably reduced muscular soreness.

The study by Giatsis et al. (2007) explored the effects of a sand platform (SP) and a rigid platform (RP) on the kinematic properties of vertical squat jump. Jump height was
significantly less on SP ($P < 0.001$) compared to RP, and power production and maximal force on RP was considerably larger than SP ($P < 0.05$ and $P < 0.001$). Furthermore analysis biomechanically showed there was a significant increase in angular velocity and joint motion on SP ($P<0.05$). In conclusion the SP showed lower jump height performance than RP due to the unstable properties it provides. Findings by Karver (2013) and Martin et al. (2009) concur asserting that a significant level of platform responsiveness is accredited by moderately saturated sand.

Marginson et al. (2005) conducted a study using perceived soreness on a visual analogue scale (VAS) 0-10 as one indicator. This was to examine muscle soreness in repeated bouts of plyometrics at intervals of 24, 48 and 72 hours, and counter movement jump/squat jump was selected to test muscle function. Results displayed that peak muscle soreness happened around the 24-36 hour mark.

Findings by Fatouros (2000) coincides with the study conducted by Marginson et al. (2005), acknowledging that musculotendinous junction damage and muscle fibre damage is the primary cause of decreased muscle function and increased muscular soreness following land based plyometrics. Miller et al. (2002) links these discoveries to the nature of plyometric training being highly impacting.

A study conducted using hardwood floor and a mini trampoline by Crowther et al. (2007) was to inspect the effort involved with CMJ and DJ and the effects it has on human kinetics. Results indicated a significant difference in CMJ and DJ in the experimental condition compared to the control ($P < 0.05$), showing that range of motion in the ankle, knee and hip wasn’t as severe as the hardwood floor condition.

Concurring with the above study Coburn and Malek (2011) express that there should be suitable shock absorption in surfaces when executing plyometric training. However it should not pass the threshold where an increase in eccentric transition is experienced in the SSC. Thick surfaces should also be avoided with plyometric training as it could lengthen the amortization phase which negatively affects the efficiency of the stretch reflex cycle (Andrew et al., 2004; McNeely and Sandler, 2007; Radcliffe and Farentinos, 1999).

Donoghue et al. (2011) applied plyometric exercises in water and on land and studied the kinetics of the contacts. Results showed water reduced peak force impact significantly
compared to the control condition, however the two situations were considered harmless only if correct landing technique was emphasised.

The three phases of the SSC are; the eccentric phase, the amortization phase and the concentric phase (NASM, 2010). Bandy and Saunders (2007) explain the amortization phase is the electromechanical delay in between the eccentric and concentric phases. Grimsby and Rivard (2008) elaborate that SSC performance benefits are resultant from the increased transition efficiency of the amortization phase. Research by Ashby and Heegard (2002) identified that improvement in the efficiency of amortization transition helped increase velocity in vertical jump performance.

Plyometric training utilises the energy stored during the loading of the eccentric phase, thus stimulating the SSC (Higgins, 2011). This happens by the mechanoreceptors that assists in sending a message through 1a fibres to the spinal cord, which then transmits the signal in combination with alpha motor neurons to apply tension. This results with production of maximal power in the contracting muscle during the concentric phase (Arazi et al., 2012).

McGinnis (2005) explains that the stretch reflex, also known as the myotatic reflex, is the involuntary function within the SSC. Vital components of the nervous system are the stretch reflex and the spindle apparatus which is crucial for body control. The spindle reflex is triggered when a muscle has exertion placed amongst it, where a stimulus is sent through the spinal cord to the allocated muscle/s in order to produce a powerful contraction.

Page and Ellenbecker (2003) elaborates stating that maximum force production is generated in plyometric exercises as it uses proprioceptive properties of muscles. Kubo et al. (2007) and Swanik et al. (2002) adds to the above statement expressing that plyometric training can increase muscle tendon complex and kinaesthesia which in conjunction with improved joint proprioception can improve functional stability.

Plyometric training stimulates the body’s muscle spindles to help improve recruitment efficiency of muscles (Clark et al., 2010). Hoogenboom et al. (2014) explains that this happens through the initiation of the receptors that causes antagonistic muscle activity,
which enables greater neuromuscular efficiency converting into increased explosive strength.

An 8 week plyometric program directed by Potteiger et al. (1999) was to investigate the adaptations in muscle characteristics and alterations in power output. Statistical analysis indicated type II muscle fibre percentage increased significantly which allowed for vertical jump height to improve.

Gehri et al. (1998) investigated which method of plyometric exercises has the greatest effect on improving vertical jump performance. Due to the neuromuscular specificity, findings showed that plyometric sessions implementing dynamic SSC (i.e. CMJ/DJ) had the greatest effect as concentric contractions developed.

Kovacs (2009) expresses that ballistic stretching forces the limb beyond the standard range of motion when the muscle has not relaxed enough to enter it. The method entails quick bouncing movements where at the end range of motion a double bounce is performed. An experiment by Woolstenhulme et al. (2006) observed if a variety of stretching promoted or hindered basketball performance. After a 6 week program, ballistic stretching was shown to have a minor increase on vertical jump performance.

On the other hand a recent study by Hoeger and Hoeger (2012) discovered a correlation to prove the possible negative effects of plyometrics combined with ballistic stretching, believing it to be hazardous and pointless. Conclusions by Nelson and Kokkonen (2001) correspond as results suggested ballistic stretching hinders maximum muscle strength.

Shaji and Isha (2009) conducted research to identify the effects of implementing dynamic stretching into a plyometric program on the improvement of vertical jump height in basketball performance. Subjects were randomly assigned to one of the three groups; Group-A underwent dynamic stretching, Group-B underwent plyometrics and Group-C received both plyometrics and dynamic stretching. Findings demonstrated that vertical jump height improved by 4.8 (cm) (10.2%) in Group-A, 3.6 (cm) (7.9%) in Group-B and Group-C showed most significant improvement of 7.6 (cm) (16.1%). The study by Duncan and Woodfield (2006) is in accordance as results showed vertical jump height significantly increased by 9.1% in the dynamic warm up protocol compared to the static warm up condition. Additional studies that also coincide include Bremaeker (2006) and Pire (2006).
Chandler and Brown (2008) has further discovered that combining appropriate stretching with plyometrics allows for converting explosiveness into joined practical movements that follow effectual biomechanical factors. Chu and Myer (2013) restates that incorporating efficient based movements in plyometrics improves the strength of ligaments and tendons with the ambition of increasing the speed of the transition phase to increase efficiency of vertical jump performance.

A meta-analysis by Markovic (2007) was to understand the exact effects of plyometric training on vertical jump height in healthy individuals. Meta-analysis of randomised and non-randomised controlled trials that evaluated the effect of plyometric training on four typical vertical jump tests were applied. Data showed plyometric training provides a significant improvement in vertical jump height with mean effects varying from 4.7% for squat jump (SJ) and drop jump (DJ), over 7.5% for countermovement jump with arm swing (CMJA) to 8.7% for countermovement jump (CMJ). These statistics justifies that healthy individuals free of lower extremity injuries who aim to improve vertical jump height should integrate plyometrics into training regimes.

Research on male adolescent basketball athletes by Eduardo and Manuel (2011) is in agreement with the above findings as results advocate that effectual plyometric training permits significant improvements in upper and lower body explosive strength, essential for vertical jump performance.

Recent studies identify that peak effects of plyometric training occur when the time period is between 6 to 12 weeks which allows adequate time for the production of power and vertical jump improvements (Baechle and Earle, 2008; Doral et al., 2011). A 12 week program of plyometric training by Bale and Scholes (1986) identified that improvement of jump performance accounted for 57% of significance and the remaining 43% resultant in strength gains. Witze and Snow (2000) expands that research on time frames of plyometric training should consider months instead of weeks in order to determine the significant physiological properties.

High intensity plyometric training 2-3 times per week for a period of 4-6 weeks permits optimum improvement in explosiveness (Adam et al., 1992). For basketball athletes, Chandler and Brown (2008) believe implementing plyometrics more than bi-weekly during
a season is irrational and possibly dangerous due to the sheer amount of jumps performed. Findings by Souhaiel et al. (2010) coincide as key components of athletic performance in youth players increased when plyometrics was implemented bi-weekly. Therefore is it suggested that in-season training should be utilise plyometrics as a modality of durations between 4-6 weeks. Several studies that include supporting evidence to the idea include; (Adams et al., 1992; Brown et al., 1986; Cesar and Davide, 2009; Clutch and Winton 1983; Diallo et al., 2001; McClenton et al., 2008).

Chu and Myer (2013) advise that when assessing plyometric volume, the sporting situation and individual athletic performance should be considered, proposing around 400 contacts for low intensity or contacts between 80-200 for high intensity is deemed suitable per session. Numerous studies that offer similar assumptions include; (Atkinson and Reilly, 2013; Bartlett et al., 2006; Comfort and Abrahamson, 2010). Piper and Erdmann (1998) offer a comparable viewpoint suggesting plyometric modalities should begin with 100-120 contacts per session and advance towards 160 contacts. It is also important to taper off near the end stages of the program to allow optimum improvement and recovery.

Studies by Fatouros et al. (2000) and Blakeyl and Southard (1987) employing plyometric exercises in conjunction with modern and Olympic style weightlifting workouts displayed significant improvements ($P < 0.05$) in both explosive and vertical jump performance. On the other hand Brown et al. (1986) articulates there is considerable evidence that applying plyometric training by itself has significant improvements to vertical jump ability. Panda (2013) proposes that weight training has insignificant effects on vertical jump performance, and Brown (2007) and Reilly (2005) are in agreement claiming that there is no convincing evidence to show that resistance training has a significant effect on the improvement of vertical jump performance.

During a basketball season, it is important to maintain lower extremity power as it is a prerequisite for sport specific movements such as; tip offs, lay ups, jump shots, blocks and especially rebounding (McGarry et al., 2013). With the nature of basketball being highly impacting, McKeag (2008) expresses the expansion of training modalities to develop lower extremity power is vital for players to remain competitive during games.

Fleck and Kramer (2014) point out that understanding the right execution of training methods for lower extremity performance, individuals or coaches can reduce the effects of
detraining. Other than the opportunity for extended peak performance in plyometrics, there could also be the potential to investigate injury reduction and reduced fatigue (Bahr and Engebretsen, 2011).

Addressed in this study are the research objectives below:

- To identify any relationship between plyometric training on hard floor and sand for the improvement of vertical jump performance.
- To establish which surface out of hard floor and sand is most appropriate for improving vertical jump performance in basketball.
- To increase the understanding into surface application in combination with plyometric training.

The null \( (H_0) \) hypothesis will be that no significant difference will be displayed between the sand pit and hard floor on vertical jump height.

The alternative hypothesis \( (H_1) \) will be that sand pit will demonstrate a significant improvement on vertical jump height compared to the hard floor surface.

Existing literature has recognised that training on various surfaces (i.e. sand, land and aquatic) deliver physiological gains in vast sporting performances for the improvement of vertical jump ability (Mirzaei et al., 2013; Panda, 2013; Stemm and Jacobson, 2007).

Nonetheless, the question that still remains is which training surface displays the greatest benefits. Therefore the study conducted will pursue a deeper understanding and insight to which training surface is most suitable for basketball vertical jump performance.

Partial studies have been conducted to critically establish the requirement of surface training in basketball athletes. Attaining a superior knowledge into surface effects can allow athletes to tailor training programs as well as derive analysis of reflections such as; personal inclination, physiological benefits and optimum gains.
Chapter II
Methodology
2. **Methodology**

2.1 - **Participants**

Due to the biomechanical factors, specific movement patterns and benefits of the study, students of Cardiff Metropolitan University who played basketball were asked to take part. Thirteen basketball athletes \( n = 12 \) male and \( n = 1 \) female) with mean age of 20.3 ± 2.0 (years), mass 83.2 ± 14.2 (kg) and stature 181.9 ± 7.2 (cm) agreed to participate in the study (see Table 1). Participants were randomly allocated to one of the two training conditions, plyometric program on hard floor (HF: \( n = 7 \)) or plyometric program in a sand pit (SP: \( n = 6 \)).

**Table 1: Participant Characteristics**

<table>
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2.2 – Experimental Protocol

Participants that volunteered were only accepted on the condition that they were not using any type of plyometric program at the time of the research and were also injury free of lower extremities. As the participants were over the age of 18 years there was no need to obtain parental consent. In order to avoid statistical discrepancies all subjects were informed not to alter current training regimes throughout the duration of the study, particularly strength and conditioning of lower extremity.

Before the study commenced participants were notified of; purposes, procedures, potential risks and the possible benefits which was given via the use of a participant information sheet as well all aspects re-emphasised verbally. Participants were then given adequate time to ask any questions or highlight any queries about the project. Participants that volunteered to take part was given a Physical Activity Readiness Questionnaire (PAR-Q) to identify any health issues and following this was the completion of an informed consent form. At this stage of filling in relevant forms, participants were reminded that they had the right to withdraw from the study at any given time. See appendices for the forms that were completed.

Anthropometric measures of each subject was recorded before baseline testing commenced. A stadiometer (Holtain Fixed Stadiometer, Crosswell, Crymych, Pembs) was used to record stature (cm) and digital scales (SECA- Model 770, Vogel & Halke, Hamburg, Germany) to record mass (kg). Participants needed to complete two vertical jump tests (VJT), one pre intervention and the other post, via the use of a jump mat (Smartspeed Jump Mat, Smartjump, Fusion Sport, Brisbane, Australia).

Before the pre intervention VJT was conducted, the researcher described the jumping protocol and allowed practise jumps to occur. This was to ensure there was
a high level of familiarisation and consistency. The VJT was applied using the same procedure as Linthorne (2001) as shown in Figure 1.

Subjects started in an upright stance, then initiated with a downwards motion by flexing at the hip, knee and ankles. When a flexion degree of 90° at the hip and knees was met, subjects immediately extended the hip, knee and ankles with an arm swing to generate upwards momentum to complete the vertical jump movement. Landing occurred with arms down by their sides with a slight knee bend to cushion the impact of the vertical jump. Subjects completed three vertical jumps on the Smartspeed Mat having thirty second rest in between each jump. After recording data of each jump an average of all three was calculated.

2.2.1 – Recording vertical jump data using Smartspeed Mat.

- Start off by connecting the Grabba Sleeve to the Smartspeed Mat.
- Using the PDA, select ‘Smartspeed’ from the start menu.
Ensure the message “Grabba Sleeve Connected” is displayed then click ‘Start a new session’.
Press ‘Scan’ to recognise units.
Ensure the correct amount of units are scanned (Sleeve and G-Mat) and press ‘Next’.
From the full drill list tab select ‘Jumping’ > ‘Jumping Test Feedback Mode’ and press ‘Next’.
Confirm that you have selected the correct drill by clicking ‘Next’ or ‘OK’ to change.
Step on then off the mat to activate. Lights will flash green on the sleeve when completed then press ‘Next’.
Select the number of participants you will collect jump data for. Click ‘Next’ to enter data collection screen.
Choose ‘Manual’ running mode from the drop down menu in the bottom left.
Select the “options” tab and select the ‘number of repetitions’ you wish to collect for each subject. Deselect “enable player’s mass adjustment”.
Return to “tracks” tab. Select the player you want to jump from the drop down menu and select ‘Ready’.
To begin data collection select ‘GO’, wait for the green light on the sleeve then ask the participant to step onto the mat to perform their jump.
Results of the last player will appear in the ‘Results’ tab.
Record and write down all subjects’ jumps into a table.

The study involved a 5 week plyometric program where the control group was administered on hard floor and the experimental group on a sand pit. The intensity and volume of the plyometric training was modelled around Miller et al. (2006) by incorporating similar exercises, contact repetitions and rest times. The plyometric sessions occurred twice a week with both sessions being supervised by the researcher. Going by Mraginson et al. (2005) recommendation a 48 hour recovery period between each session was applied in order to ensure efficient recovery. The session intensity and volume started off low in the beginning stages aiming around 45 seconds per exercise and approximately 120 contact repetitions per session whilst frequently increasing as the weeks went on. Week 4 aimed to conclude with 75 seconds per exercise and approximately 160 contact repetitions per session with a tapering effect for week 5 in order to prevent fatigue during post testing (Piper and Erdmann, 1998).
Throughout the five weeks, both training groups completed each session on the same two days at the same times. Both sessions were supervised in order to ensure participants had acceptable levels of ability to complete each plyometric exercise, and were also instructed to maintain ability throughout.

Sessions of the 5 week plyometric program occurred on Monday and Thursday evenings at 8:30pm and were approximately 45 minutes in duration. Each session consisted of a warm up, dynamic stretching, the plyometric session concluding with a cool down. Both the control group and experimental group conducted the sessions at Cardiff Metropolitan University, Cyncoed Campus in the National Indoor Athletics Centre (NIAC). The cardiovascular warm up consisted of 3 laps around the 200m track in NIAC and was followed by a series of dynamic stretches such as; high knees, lunges, sumos, floor sweeps and skipping. After the plyometric session was completed, the warm down was less vigorous which entailed a light jog around the 200m track and concluded with some static stretches. See appendices for the full session plans.

2.3 – Data Analysis.
Once all raw data was recorded and organised, mean and standard deviation was calculated to determine a measure of central tendency. The data was analysed using IBM Statistical Package for the Social Sciences (SPSS Version 20) with Microsoft Excel 2010. A skewness and kurtosis calculation was done to identify if the data fell between 2 and -2 which shows the data is normally distributed. As the data was between 2 and -2 it was deemed suitable to use an independent samples t-test to obtain a $P$ value. Following this the mean and standard deviation calculated for pre and post in each condition was presented using a standard deviation bar chart to illustrate the differences.
Chapter III
Results
3. **Results**

The independent samples t-test that was run for the post improvement data between the hard floor and sand pit resulted with a $P$ value of ($P = 0.002$). Since ($P < 0.05$), the alternative ($H_1$) hypothesis can be accepted proposing that plyometric training on sand significantly improves vertical jump height compared to hard floor. Additionally a paired samples t-test was run for each condition individually to identify whether the training surface had a significant effect on improving vertical jump height.

With the control group (hard floor), post mean jump height improvement was $1.34 \pm 0.07$ (cm) and for the experimental group (sand pit) post mean jump height improvement was $2.80 \pm 0.28$ (cm) (see Table 2). Data analysis of vertical jump height identified there was a significant difference between sand pit and hard floor, with sand pit having greater improvement ($P < 0.05$). See appendices for SPSS data outputs and raw data.

**Table 2. Comparing Post Mean Jump Height Improvement and Standard Deviation (S.D) Between Both Training Conditions.**

<table>
<thead>
<tr>
<th>Condition (surface)</th>
<th>N</th>
<th>Mean jump height improvement (cm)</th>
<th>Standard Deviation (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Pit</td>
<td>6</td>
<td>2.80</td>
<td>0.28</td>
</tr>
<tr>
<td>Hard Floor</td>
<td>7</td>
<td>1.34</td>
<td>0.07</td>
</tr>
</tbody>
</table>
The mean jump height for pre and post testing along with standard deviation are shown above (Figure 2). Pre testing the mean vertical jump height was 40.76 ± 6.67 (cm) and post testing mean vertical jump height was 42.1 ± 6.74 (cm), illustrating a mean improvement of 1.34 (cm). The paired sample t-test revealed that post-test jump height was significantly different to the pre-test ($P = 0.02$). Therefore it can be assumed that plyometric training on hard floor has a significant effect on increasing vertical jump height.
Figure 3. Pre and Post Vertical Jump Means and Standard Deviation for the Experimental Group.

Figure 3 shows the mean jump height for pre and post testing along with standard deviation. Pre testing the mean vertical jump height was 39.45 ± 1.93 (cm) and post testing mean vertical jump height was 42.25 ± 2.2 (cm), demonstrating a mean improvement of 2.8 (cm). Again, the paired sample t-test run for the experimental condition exposed that post-test jump height was significantly different to the pre-test ($P = 0.00$) and it can be presumed that sand based plyometric training has a significant effect on vertical jump height.

Overall, the experimental condition revealed to have an additional jump improvement of 1.46 (cm) compared to the control condition ($P = 0.002$).
Chapter IV
Discussion and Conclusion
4. Discussion and Conclusion

The research has ascertained a significant difference between using a hard floor surface and a sand pit on vertical jump height thus confirming the alternative hypothesis of \( P = 0.002 \).

The results the study has found have identified significant improvements in vertical jump heights achieved by the participants using the sand pit. These results support the work conducted by Mirzaei et al. (2013), Sharma and Chaubrey (2013) and Panda (2013) into the effects of a sand base surface on vertical jump height as mentioned in the literature review previously. These findings challenge the consensus among other researchers into this topic.

Studies by Stemm and Jacobsen (2007) and Arazi et al. (2012) examining the effects of aquatic training showed similar characteristics as land based training however no significant difference was found between the conditions \( P > 0.05 \). The research conducted in this study contrast the findings above as results found a significant difference between both conditions. Statistical data established physiological developments occurred in conditions but the improvements observed with the experimental group were significantly higher than the gains seen in the control group.

Significant evidence was found showing physiological improvements in explosive power for basketballer players \( F > 0.05 \) in a study observing effects of sand plyometrics (Panda, 2013). This supports the results found in this paper that sand plyometrics have beneficial use for basketball development.

Agreeing with above literature, Mirzaei et al (2013) found that sand training had a significantly positive effect on vertical jump performance \( P < 0.05 \). With this in mind it can be recommended to coaches that designing plyometric programs on sand will reap significant rewards in the player’s neuromuscular competence.

Sharma and Chaubey (2013) found increases in vertical jump heights through the implementation of a six week training plan in sand which led to the significant strengthening of the relevant leg muscles. This supports the work conducted by Markovic and Mikulic (2010) and Shaffer (2007) who found that using training programmes built
around the use of sand increases the need for superior muscle activation and adaptive neuromuscular strength far more so than training programmes on hard surfaces, leading to significant physiological improvements.

There is some literature that suggests physiological developments can be explained by extenuated muscular recruitment on surfaces that have high resistance. (Miller et al., 2002). This has been backed up through research by Gatisis et al (2007) who found that using sand surfaces reduced the maximum force and saw a reduction in the propulsion ability of the ankles as sand has minimal traction which in turn leads to enhanced balance and performance. Karver (2013) assumes that superior performance can be achieved by using sand as a training modality as research supports the concept that sand sees a noticeable biomechanical and neuromuscular difference.

Martin et al. (2009) found that slightly saturated sand (7% moisture content in this case) is better than using dry sand as it is more responsive. This has been explained by the fact that the water acts as a lubricant which softens the sand particles. This proves the fact that saturation levels can be a significant factor in the responsiveness of the participant. It should be noted however that this evidence is hard to qualify due to the unpredictable saturation due to the ever changing weather (Martin et al., 2009).

Turnbrow (1994) goes against the consensus and puts forward an alternative theory. It is insisted that saturated sand as a training platform reduces muscular and biomechanical parameters. This has been afforded to the fact that many saturated sand pits offer no consistency in the amount of saturation applied.

Research by Donoghue (2011) concluded that emphasis on good landing and take-off technique is paramount for safe and significant gains and that far too much emphasis is placed on the saturation levels of sand platforms.

Cressey et al. (2007) came to the conclusion that unstable surface training (UST) is ineffective and has a potentially negative impact on athletic performance. However Cressey et al. (2007) does concede that UST is beneficial for an athlete’s rehabilitation. In contrast to the study, surface training platforms showed some evidence to back the idea that power output increased in countermovement (2.4%) and bounce drop jump (3.2%). Going by the results found in Cressey et al. (2007) study, the two conditions within the
research found considerable physiological developments, this is due to both variants being conducted on stable training platforms. O’Sullivan et al. (2013) notes that these benefits may be attributed to concise and reliable biomechanical movements which simply couldn’t be achieved using unstable surfaces.

In one investigation on the manipulation of training surfaces and how they were influenced by different training methods, it was observed that countermovement jump (CMJ) (p=0.033) and CMJ/Squat Jump (SJ) (P=0.005) was improved considerably (p<0.001) by training on grass (Impellizzeri et al., 2008). Athletes training on sand experienced less pressure on the muscles than those who trained on grass (P<0.001) however it should be noted that performance was not enhanced because of this. These results agree with previous beliefs that surface manipulation can harvest several effects for different training methods (Farrow et al., 2013).

Observations have also been made that water based platforms institute a reduction in stress injuries. This is due to the buoyancy of aquatic based platforms upon landing. However it should be noted that aquatic based platforms have little or no effect on vertical jump height improvements (Stemm and Jacobsen, 2007). These findings are in direct agreement with Donoghue et al. (2011) who states that regardless of a 33%-54% reduction in peak impacts with aquatic surfaces, little to no performance improvements can be found.

Fatouros et al. (2000) suggests that reduced muscle function could be the result of land based plyometrics potentially damaging musculotendinous junctions, therefore highlighting the possible benefits on sporting performance by implementing reduced impacting surfaces.

Even though previous projects have indicated that aquatic and non-compliant surfaces show a lack of benefits to performance, it can still be determined that sand can reduce impact and significant physiological changes are attainable. Martin et al. (2009) express this could be due to the specific assets that lie within individual surfaces.

Relating the above findings with research by Robinson et al. (2004), using ordinal pain examination for land based surface vs. aquatic based, results acknowledged that aquatic
training promoted quicker recovery and predominantly showed less muscular soreness. Results also concluded that performance improvements were similar in both conditions.

The study conducted in this paper follows an alternative correlation with the existing literature above. Results from the project identified that sand provided reduced responsiveness and impact which funded extra improvement in vertical jump performance, and Karver (2013) agrees with this conclusion.

The study by Marginson et al. (2005) in repeated bouts of plyometrics using perceived soreness after different recovery intervals showed muscle function decrements at 73-85% with mean VAS of 6.8 ± 1.7 of baseline scores. However after 48 hours rest period perceived soreness was much less with mean VAS of 2.1 ± 1.8 and 27-33% muscle function decrement of baseline scores. Additionally pain plateaued in repeated bouts at the 30 minute mark. From these findings it can be suggested that prime recovery period happens after 48 hours with the suggested theory that repeated bouts should not exceed 30 minutes in duration. The same recovery period modelled from the above literature was implemented within the project between sessions to ensure suitable recovery followed. Results by Howley and Thompson (2007) and Kolt and Snyder-Mackler (2007) correspond with the above suggestions.

Findings by Shaji and Isha (2009) established that vertical jump height increased by 7.6 (cm) when dynamic stretching and plyometrics were incorporated together which converted into 16.1%. When used individually, dynamic stretching showed increase by 10.2% (4.8 cm) and plyometrics illustrated increase by 7.9% (3.6 cm). From these results the implementation of dynamic stretching after the warm up could have credited the vertical jump performance enhancements that were portrayed within the research.

The paper by Woolstenhulme et al. (2006) offers support towards the favourable concept of ballistic stretching ($P < 0.05$) within vertical jump performance in basketball. However Hoeger and Hoeger (2012) and Nelson and Kokkonen (2001) disagree with the idea of ballistic stretching due to the potentially damaging properties it holds, signifying that heavy muscle ballistic stretching hinders maximal strength ability which if implemented in the study would have been counterproductive to the research objectives.
The 8 week plyometric study by Potteiger et al. (1999) that used muscle biopsy for measurements coincides with previous assumptions. In post testing for the plyometric condition, type II muscle fibres increased by 7.8% and muscle power signified an increase of 2.8% measured by a countermovement jump (CMJ). Using the above statistics and existing literature, it can be assumed that a 6 week plyometric program enables positive muscle fibre adaptations that increases muscle power output. Results by Bishop (2012) and Levangie and Norkin (2011) illustrated that sand platforms exhibited superior increase in type II muscle fibre percentage leading to greater vertical jump performance compared to other surfaces.

Within the study, physiological advances can be recognised by effectual training with some adaptations involving; muscle power, isokinetic and isometric leg strength, greater achilles tendon elongation, and improved proprioceptive and neuromuscular operation all converting to a proficient SSC (Hennessy and Kilty, 2001; Kubo et al., 2007; Passuke et al., 2001; Swanik et al., 2002). These physiological adaptations are responsible for the improvement of explosiveness which was witnessed in the two environments of the investigation (Clark et al., 2010; Hoogenboom et al., 2014).

Data by Ellenbecker (2000) and Grimsby and Rivard (2008) associates with the adaptations in muscle fibres asserting that efficiency increase of the transition phase of the SSC is where benefits in sporting performance occur. Results by Ashby and Heegard (2002) identified a 71% increase in vertical jump velocity, primarily caused by the 12.7% improvement in the transition phase in the SSC.

Reviewing the work by Bale and Scholes (1986), statistics showed jump skill accounted for 57% of the improvement and strengths gains for the outstanding 43% enhancement. Efficient technical execution and enhanced neuromuscular gains, which is highlighted by the biomechanical influence and properties sand supplies, could be the result of the distinctive vertical jump height attained in the study (Caraffa et al., 1996; Myer et al., 2006; Caine et al., 2013). Hewitt (2007) and Noyes and Barber-Westin (2013) agree with the above review suggesting that effective execution of plyometrics benefit kinetic proficiencies and injury. Additionally this funds the concept that plyometric training is beneficial to the economy of kinetics resultant in efficient maximal power output (Saunders et al., 2006, cited in Hong, 2013).
When a 12 week program comparing plyometric training against regular resistance training, post-test CMJ the plyometric condition exhibited an increase of 10% in maximum CMJ height and 9% in maximal power ($P < 0.01$) (Vising et al., 2008). Data from a 6 week plyometric study for effects on lower extremity power revealed vertical jump performance increased by 10.67 (cm), resultant from a significant increase in power production of the hip and thigh ($P < 0.0001$) (Adams et al., 1992). Findings by Adam et al. (1992) coincides with the above results and it can be interpreted that plyometrics is an efficient training modality for the development of lower extremity power for aims of increasing vertical jump. Collective results from the listed authors above support the experimental procedure applied in this study. Previous studies have identified that considerable gains can be achieved by the implementation of plyometrics as a separate modality, additionally proposing that it is ineffective combining plyometrics with resistance training or other protocols (Brown, 2007).

Despite the above conclusions Blakey and Southard (1987) and Fatouros et al. (2000) together fund the concept of executing plyometrics in conjunction with different strength training modalities to stimulate vertical jump performance improvements. However Brown et al. (1986) disproves the above thoughts by emphasising that there is conclusive evidence showing that plyometric training is effective as a single exercise protocol which justifies the plyometrics applied in the study. Panda (2013) and Reilley (2005) reemphasise that different forms of resistance training in conjunction with plyometrics cannot provide notable improvements for vertical jump performance, considering it an inappropriate concept. Despite not incorporating resistance training in the study, results still signified noteworthy improvements.

Chandler and Brown (2008) acknowledged that basketball players perform a substantial frequency and volume of jumps within a standard season. Consequently basketball players are familiar with the neuromuscular and biomechanical requirements for plyometric training (Hoffman, 2014). The above notions could be the reason why participants improved vertical jump performance due to being familiar with the kinetics of plyometrics, nevertheless from a different viewpoint, there could have been the possible observation of better developments from participants that are unfamiliar with kinetics of plyometric training. Furthermore this could unveil new conclusions leading to a greater understanding theoretically.
Adams et al. (1992) believes that a plyometric program should be 4-6 weeks in duration, this is mainly due to the fact that optimal development in proprioceptive, muscular and neuromuscular properties occur without excessive fatigue being placed upon the musculoskeletal and central nervous systems. The implementation of plyometrics twice a week for a duration of 5 weeks in the study was deemed necessary for the physiological developments whilst training and the regular season occurred for basketball teams. It also proved not to be a threat to fitness or disadvantageous to basketball matches (Chandler and Brown, 2008; Souhaiel et al., 2010).

Even though the plyometric program during the regular season was a key element, the frequency and volume of training during offseason not containing plyometric kinetics needs to be addressed. In this offseason scenario it could be possible that a plyometric program 6-12 weeks in length could be applied to elicit maximal physiological alterations. (Baechle and Earle, 2008; Doral et al., 2011; Witze and Snow, 2000).

Chu and Myer (2013) and Piper and Erdmann (1998) express the number of repetition contacts per session should range between 80-400 contacts and both believe that progression should apply, starting off with low intensity and volume and progress towards greater intensity and contacts per session with a concluding tapering effect. Employing similar guidelines from above hypothetically allowed subjects to develop at a progressive and safe rate enabling efficient recovery (Piper and Ardmann, 1998). Atkinson and Reilly (2013) and Bartlett et al. (2006) suggest the above framework should be employed to compare against other training recommendations.

Coburn and Malek (2011) asserted that training surfaces should provide suitable shock absorbing properties to warrant a safe and efficient plyometric session. This is backed up by Fleck and Kramer (2004) emphasising that plyometrics can be hazardous due to its high impacting properties.

Andrew et al. (2004) and Radcliffe and Farentinos (1999) share a similar perspective as above specifying that plyometrics can pose a negative threat to the efficiency of the transition phase if conducted on extremely thick surfaces. Additionally McNeely and Sadler (2007) advise that surface thickness should not exceed 15 (cm) as it could be
counterproductive to plyometric execution and potentially reduce the proficiency of the SSC.

For the control group in the study, placement of padding or mats was not essential as the hard floor provided adequate absorption impact to prevent any injury. The same applied for the experimental condition. As a result it would seem that the findings in the project challenge the results by Andrew et al. (2004), McNeely and Sadler (2007) and Radcliffe and Farentinos (1999) as the sand pit exceeded 15 (cm) in thickness yet still illustrated the greatest physiological developments compared to the control group.

In conclusion, the results of the experimental research illustrated that the sand pit had the greatest significance on vertical jump height ($P < 0.05$) compared to the hard floor surface. These findings dispute previous literature that state no evident difference in performance can be distinguished between training surfaces. Knowing that the sand pit permits greater levels in performance can be beneficial to coaches and athletes as specific training programs can be set to attain the highest levels of performance in efficient time scales. Consequently the null hypothesis ($H_0$) was rejected.
Chapter V
Recommendations
5. **Recommendations**

With regards to the projects' research objectives, the investigation has permitted for the finding that plyometric training on sand is a practical way to improve vertical jump performance in basketball athletes. The study has also enhanced knowledge on program design and exercise variables for the optimal improvements in vertical jump. Despite the study being conducted, it has resulted in the probes of various questions.

Initially, Andrew *et al.* (2004) and Radcliffe and Farentinos (1999) believe that plyometric development can be hindered if implemented on unreasonably thick surfaces. McNeely and Sadler (2007) concurred advising that surface thickness should not exceed 15 (cm). The above disputes the findings of the study and other existing literature. On the other hand Coburn and Malek (2011) feel that the high impacting properties of plyometric training should be addressed by implementing shock absorption facilities on surfaces. As a result of these contradictory concepts, in depth future investigations are required to produce specific guidelines that will permit safe training environments that maintain the opportunity to accomplish set goals.

Secondly, the study by Ashby and Heegard (2002) identified that 71% increase in vertical jump velocity was resultant from the 12.7% increase in the SSC transition phase. Nonetheless it is unidentified to which amounts of these improvements are recognised by neuromuscular or muscular components in relation to sand. Results by Bale and Scholes (1986) showed that jump skill accounted for 57% of improvement and the remaining 43% resulting in strength increase. However these results were comprehensive to using plyometrics as a training method and did not take into consideration the properties of the surface, which could possibly change these results.
Therefore similar investigations on an array of diverse platforms could potentially highlight what surface type is essential for developing specific components of fitness.

Deciding on a suitable design and sample size is important to determine the essential degree of representativeness to a target population (Sekran and Bougie, 2010). Gratton and Jones (2010) maintains that samples cannot offer applicable results to a generalised population although application of specific limitations could result in the research providing greater levels of representation.

The concept above is expanded by Oliveira (2013) declaring that the sampling method determines the level of representation and the accuracy of the population approximation obtained is determined by sample size. Kirby et al. (2000) insists that selecting samples that have importance to the area of study may need to be considered in order to relate findings to a broader field of populations for beneficial use. Only a specific population was investigated so future research could possibly involve a wider age group and both genders as the sample.

Compatibility, quality, repeatability and interoperability can be maximised by standardization (Coolican, 2013), moreover it guarantees that rigorous controls are executed in order to identify trends within research areas (Bruce et al., 2013). In the experimental design the constant use of the sand pit by other individuals and teams did not permit a constant saturation level, so with the properties of the sand pit being in a different condition every session, this could have potentially altered the data and findings.

Baechle and Earle (2008), Doral et al. (2011) an Witze and Snow (2000) established that physiological developments could be guaranteed if plyometrics was implemented for at least 12 weeks which would also favour musculoskeletal and neuromuscular adaptions. Therefore if the study implemented an extended plyometric program it could have attained greater significance in the results. Garrett and Kirkendall (2000) and Reilly (1990) correspond with the above theory proposing that increased frequency of sessions per week in a shorter period could draw conclusions that are similar or greater.

The experimental study revealed that the sand pit produced significantly greater development on vertical jump performance compared to the hard floor surface. In order to discover new theories, it is crucial to highlight significant conclusions and link it with the
study conducted. Ford (2000) claims that attaining greater research papers and viewpoints can sanction notable theoretical understandings. Therefore conducting a comparable investigation implementing various concepts from other literature may reveal data to support the study’s beneficial application.

Chapter VI
Reference List
6. References


Chapter VII
Appendices
Appendix A
Participant Information Sheet
Participant Information Sheet

The effect of short term plyometric training on hard floor and sandpit for the improvement of vertical jump height in basketball

You are being invited to take part in a research project. It is important to understand the purpose of the research and what it will involve before deciding whether to take part. Please read the following information and if you are unsure on anything or you require further information ask the researcher. Thank you for reading this.

Purpose of the Project

The purpose of the proposed study is to measure and evaluate how various training surfaces allow athletes to achieve optimal performance. This will consist of two different training variables; sandpit and hard floor and a physiological testing via a vertical jump test via a tendo unit smartspeed mat.

You have volunteered to take part as a subject in three physiological test that measure maximal jumping capabilities and have read all the relevant information and agreed to the terms.

Do I have to take part?

Taking part in the study is completely voluntary. There will be no punishment for deciding against taking part. If you decide to take part you will be given this sheet on completing all relevant paperwork of consent to outline the risk of injury and other possible health. After completing this documentation you are still free to withdraw at any time.

What will happen to me if I take part?

If you decide to take part you will be required to attend on 10 different occasions to complete both plyometric training programs on hardwood or sandpit platform as well as 2 vertical jump test. Your power will be tested firstly using the vertical jump where flight time is recorded using the tendo unit. You will have to stand on the smartspeed mat, bend knees to 90 degrees flexion, stand still for 1 second and then jump as high as possible, landing with near straight legs on the platform (slight bend to prevent injury). This will be repeated 3 times to ensure a more accurate level of performance.

What do I have to do?

You will be required to arrive in appropriate kit for the activities and it is also advised that you eat and hydrate appropriately before the testing but not too close to the tests to allow for proper digestion. Prior to the plyometric session you will complete a warm up. This will entail 3 lap jog of the NIAC track. Then a series of dynamic stretches will be implemented to ensure your body is ready for the physiological testing.
Disadvantages and risks

Due to the high impact nature of vertical jump testing a plyometric it is not advised to part if you suffer from stress injuries or are an inexperienced exerciser. There is a slight risk of impact injuries and it is advised that you do not part take if you have any underlining health queries prior to the tests. A PAR-Q form is required to be filled out before taking part in the tests. Any problems occurring during the tests should also be brought to the attention of the researcher for your own safety.

Benefits

The benefit of the research is that it will allow basketball athletes to view which type of training platform is most useful for their sport specific training. This will allow individual athletes to tailor their program more closely to their needs and could possibly help increase performance such as increased vertical jump and decrease likelihood of stress injuries.

What if something goes wrong or the study stops?

If the study stops the reasons for this will be explained to you. If something goes wrong in the experiment or you have a complaint about the researcher, the university’s registrar and secretary are the designated officials to deal with the complaint.

Will my taking part in this project be kept confidential?

All information collected about you during this study will be kept strictly confidential and if research is disseminated your details will be removed so that you cannot be recognised from it.

The results of the study will be analysed along with those of the other participants to compare different participants vertical jump performances on the two experimental variables. The research is being carried out by Cardiff Metropolitan University and the results will not be published.

If you have any queries please feel free to contact the researcher

Sam Atkinson
99 Crowthorne Road
Bracknell,
Berkshire,
RG12 7EL
Email: samako1991@gmail.com Telephone Number: 07930 612629
Appendix B
Informed Consent Form
Cardiff Met Informed Consent Form

UREC Reference No: 14/5/9U

Title of Project: The effects of plyometric training on hard floor and sandpit platforms for the improvement of vertical jump performance in basketball

Name of Researcher: Samuel Jordan Atkinson

Participant to complete this section: Please initial each box

1. I confirm that I have read and understand the information sheet dated ………. for this evaluation 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 a reason.

3. I understand the potential benefits and risks of the study

4. All information which has been given prior to participating in the study is true and accurate to the best of my knowledge

5. I am fully aware that any personal information will be kept confidential and will not be forwarded to any third parties without permission

Subject’s name: _____________________________________

Subject’s signature: ________________________________ Date: ___________

Researcher’s name: __________________________________

Researcher’s signature ________________________________ Date: ___________
Appendix C
PAR-Q
Physical Activity Readiness Questionnaire (PAR-Q)
If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you significantly change your physical activity patterns. If you are over 69 years of age and are not used to being very active, check with your doctor. Common sense is your best guide when answering these questions. Please read carefully and answer each one honestly: circle YES or NO.

1. Has your doctor ever said you have a heart condition and that you should only do physical activity recommended by a doctor? Yes / No

2. Do you feel pain in your chest when you do physical activity? Yes / No

3. In the past month, have you had a chest pain when you were not doing physical activity? Yes / No

4. Do you lose your balance because of dizziness or do you ever lose consciousness? Yes / No

5. Do you have a bone or joint problem (for example, back, knee, or hip) that could be made worse by a change in your physical activity? Yes / No

6. Is your doctor currently prescribing medication for your blood pressure or heart condition? Yes / No

7. Do you know of any other reason why you should not do physical activity? Yes / No

If yes, please comment below:

NO.

YES to one or more questions: You should consult with your doctor to clarify that it is safe for you to become physically active at this current time and in your current state of health.

NO to all questions:
It is reasonably safe for you to participate in physical activity, gradually building up from your current ability level. A fitness appraisal can help determine your ability levels.

I have read, understood and accurately completed this questionnaire. I confirm that I am voluntarily engaging in an acceptable level of exercise, and my participation involves a risk of injury.

Signature

Print name

Date

Having answered YES to one of the above, I have sought medical advice and my GP has agreed that I may exercise.

Signature

Date

Name:                      D O B:

Address:                   Postcode:

Email:                     Mobile:
Appendix D

5 Week Plyometric Program
**Plyometric Program**

**Week 1**

**Warm up**
- Cardio (3 laps of NIAC track)
- Dynamic Stretching
  - High Knees
  - Heel Flicks
  - Lunges
  - Sumos
  - Floor Sweeps
  - Skipping
  - Carioca

Sets | Reps | Type
--- | --- | ---
2 | 12 | low

Side to side ankle hops
Standing jump and reach 2 | 12 | low
Front cone hops 5 | 4 | low
Standing long jump 5 | 4 | low
Single leg hops 6 | 4 | medium

(45 to 60 seconds rest period between each set and exercise)

**Week 2**

**Warm up**
- Cardio (3 laps of NIAC track)
- Dynamic Stretching
  - High Knees
  - Heel Flicks
  - Lunges
  - Sumos
  - Floor Sweeps
  - Skipping
  - Carioca

Sets | Reps | Type
--- | --- | ---
2 | 12 | low

Side to side ankle hops 2 | 12 | low
Standing jump and reach 4 | 6 | low
Double Leg Hops 3 | 8 | medium
Lateral Cone Hops 2 | 8 | medium
Tuck jump with knees up 2 | 12 | medium

(45 to 60 seconds rest period between each set and exercise)
### Week 3

**Warm up**
- Cardio (3 laps of NIAC track)
- Dynamic Stretching
  - High Knees
  - Heel Flicks
  - Lunges
  - Sumos
  - Floor Sweeps
  - Skipping
  - Carioca

<table>
<thead>
<tr>
<th>Activity</th>
<th>Sets</th>
<th>Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagonal Cone Hops</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Tuck jump with heel flick</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Single Leg bounds with vertical jump at end</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Squat Depth Jump</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

### Plyometric Program

### Week 4 and 5

**Warm up**
- Cardio (3 laps of NIAC track)
- Dynamic Stretching
  - High Knees
  - Heel Flicks
  - Lunges
  - Sumos
  - Floor Sweeps
  - Skipping
  - Carioca

<table>
<thead>
<tr>
<th>Activity</th>
<th>Sets</th>
<th>Reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single leg vertical jumps (2 sets per leg)</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>30 second box drill</td>
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<td></td>
</tr>
<tr>
<td>Depth jump to standing long jump</td>
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<td>10</td>
</tr>
<tr>
<td>Box to box squat jumps (3 boxes)</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Pyramiding box jumps</td>
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<td>6</td>
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Appendix E
Raw Data
### Pre Vertical Jump Test

<table>
<thead>
<tr>
<th>Subject</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
<th>Jump 1 (cm)</th>
<th>Jump 2 (cm)</th>
<th>Jump 3 (cm)</th>
<th>Avg. (cm)</th>
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<tbody>
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<td>188.7</td>
<td>94.6</td>
<td>40.83</td>
<td>40.12</td>
<td>43.56</td>
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<tr>
<td>2</td>
<td>184.4</td>
<td>87.1</td>
<td>39.98</td>
<td>40.68</td>
<td>39.28</td>
<td><strong>39.98</strong></td>
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<tr>
<td>3</td>
<td>185.0</td>
<td>74.1</td>
<td>39.42</td>
<td>38.32</td>
<td>39.98</td>
<td><strong>39.24</strong></td>
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<tr>
<td>4</td>
<td>182.9</td>
<td>120.0</td>
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<td>6</td>
<td>178.4</td>
<td>76.4</td>
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### Post Vertical Jump Test

<table>
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<th>Subject</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
<th>Jump 1 (cm)</th>
<th>Jump 2 (cm)</th>
<th>Jump 3 (cm)</th>
<th>Avg. (cm)</th>
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## Pre Vertical Jump Test

### Hard floor Subjects

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<td>13</td>
<td>174.5</td>
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## Post Vertical Jump Test

### Hard floor Subjects

<table>
<thead>
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<th>Subject</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
<th>Vertical Jump</th>
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<td></td>
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<td>Jump 1 (cm)</td>
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Appendix F
SPSS Outputs
Paired samples t-test for the control group.

Paired Samples Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
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</thead>
<tbody>
<tr>
<td>Pair 1</td>
<td></td>
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<tr>
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<td>PostControlJump</td>
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Paired Samples Correlations

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<td>.000</td>
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Paired Samples Test

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<th>95% Confidence Interval of the Difference</th>
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<th>Sig. (2-tailed)</th>
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Paired samples t-test for the experimental group.

Paired Samples Statistics

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Paired Samples Correlations

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</thead>
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<tr>
<td>Pair 1</td>
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<td></td>
</tr>
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<td>PreControlJump &amp; PostControlJump</td>
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<td>.001</td>
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### Paired Samples Test

<table>
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<th>Sig. (2-tailed)</th>
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</thead>
<tbody>
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<td>Std. Error Mean</td>
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### Independent samples t-test for post improvements with both conditions.

#### Group Statistics

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<th>Std. Deviation</th>
<th>Std. Error Mean</th>
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<td>PostProtocolJump</td>
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#### Independent Samples Test

<table>
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<th>Sig.</th>
<th>t</th>
<th>df</th>
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<th>Mean Difference</th>
<th>Std. Error Difference</th>
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