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Programme: SCRAM  Year: 3  Term: 2

Module Number & Title: SSP6050 Independent Project

Original Submission Date: 21 March 2014

Date extension requested: 4 March 2014

Programme Director: Robert Meyers

Date agreed by PD: 4 March 2014

New Submission Date: 17 April 2014

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# Cardiff School of Sport
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<td>Programme:</td>
<td>Sports Conditioning, Rehabilitation and Massage</td>
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<td>Dissertation title:</td>
<td>The Relationship between Strength, Power and Trampoline Jump Height</td>
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THE RELATIONSHIP BETWEEN STRENGTH, POWER AND TRAMPOLINE JUMP HEIGHT

SCRAM

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ACKNOWLEDGMENTS

I would like to thank my dissertation supervisor, Robert Meyers, for his continued help, guidance and support throughout this process.

I would also like to thank all of the participants for giving their time to take part in this study.
ABSTRACT

Aim: Therefore the aim of this investigation was to identify the relationships between jump height on a trampoline and measure of lower limb strength and power.

Method: Eight National level trampolinists were recruited for this study. Participants were required to perform three tests; ten straight jumps on a trampoline where the height and depth was recorded for each jump, three countermovement jumps (CMJ) and a one repetition maximum (1RM) leg press. The maximum depth, maximum height, average depth and average height were taken for the trampoline jumps, the best and average CMJ and the 1RM value were the variable used. Participants were also required to complete a questionnaire stating their trampoline history e.g. level of competition and years of trampoline experience, they were also required to state any strength and power training they performed within the average week. Pearson’s correlations, independent T-test and percentage difference of means were then performed to analyse the results of these testing variables.

Results: Results showed a statistically significant relationship between 1RM leg press and the maximum height jumped on the trampoline (R=0.798, p<0.05, R²=0.637). Results also showed there to be no correlation between the CMJ and trampoline jump height (p>0.05).

Conclusion: Results from this investigation would suggest that strength training should be prioritised over that of power training with regards to trampoline jump height. The contact time in the trampoline is greater than that spent generating force in the CMJ and is therefore closer to the measure of strength than the CMJ. The time for force application during a trampoline jump is more related to the strength portion of the force-velocity curve than that of the power and therefore this should be the priority.
CHAPTER ONE

INTRODUCTION
1.0 Introduction

1.1 Trampolining

Since its invention by George Nissen in 1936, the popularity of trampolining has risen tremendously. The first world championship was held in London in 1964 (P. Esposito & L. Esposito, 2009) however trampolining wasn’t an Olympic sport until the Sydney Olympic Games in 2000 this lead to a rise in the profile of the sport. There are three forms of trampolining; individual, synchronised and mini-trampoline, however only individual trampoline is present in the Olympics. Trampolining requires the gymnast to complete a series of ten skills for which they receive execution scores out of ten, a difficulty score, and a flight time of the routine, these are added together to give an overall mark. Skills can consist of anything from a single somersault to somersaults consisting of multiple rotations and twists. Trampolining requires a large amount of postural control, balance, spatial awareness, coordination, rhythm and timing (Atilgan, 2013). The ability to generate height on the trampoline is imperative to allow the gymnast sufficient time to perform both simple and complex skills. The higher the gymnast bounces, the more time is available to execute the phases of the skill and prepare for landing into the trampoline bed to set up for the next skill, maintenance of a good height, rhythm and phasing throughout the ten skills of a routine will lead to greater execution scores from the judges and a greater flight time score. With many now striving to reach national, international and world class levels and competition growing between equipment companies to develop trampolines allowing gymnasts to jump higher and perform to a greater skill level, it is interesting to note that the literature surrounding the demands that trampolinit face is still very limited. New trampolines are being developed on a regular basis however the physical demands that these place on the gymnasts are relatively unknown resulting in both coach and performer lacking a clear evidence base from which to prescribe effective training programmes. Farquharson (2012) identified strength and power to be important pre-requisites with regards to generating height and maintaining an efficient position in the trampoline bed, however no research can be found that evidences the effect of different levels of strength and power on trampoline jump height.
1.2 Overview of Strength and Power

Strength is the ability to exert force (Baechle & Earle, 2008) and power is the ability to apply force rapidly (McGuigan, Cormack & Gill, 2013) whereby power is equal to force multiplied by velocity (Baechle & Earle, 2008). Power has been identified as being a major determinant of sports performance in those that require explosive force production (Kawamori & Haff, 2004; Marques, 2010; Haff & Nimphius, 2012) and research has indicated maximum strength as being the basic quality affecting power output (Stone et al, 2003; Carlock et al, 2004).

1.2.1 Brief Overview of Neuromuscular and Biomechanical Factors

There are many factors that have been identified as being contributors to the manifestation of strength and power; Firstly the number of motor units recruited and the frequency at which they are fired (rate coding) during a muscular contraction are influential to the muscular force generated. Muscular force is increased when an increased size and number of motor units are recruited with rate of firing being quicker; improvements in strength and power are evidenced to be attributed to these neural adaptations (Kawamori & Haff, 2004; Baechle & Earle, 2008). Additionally the cross-sectional area of a muscle can be a predictor of a muscles force capacity and research shows a relationship between a muscles strength and its cross-sectional area whereby hypertrophy can contribute to increased strength, however only to a point as excessive hypertrophy may become detrimental to performance (Semmler & Enoka, 2000; Kawamori & Haff, 2004; Baechle & Earle, 2008). Another contributing factor to strength is the specific tension of muscle fibres. Specific tension is “the force that a muscle fibre can exert per unit of cross-sectional area” (Semmler & Enoka, 2000, p.5), the varying fibre-type proportions of each muscles result in different levels of specific tension. Lastly, coordination and specificity of training; research has identified that the types of training and exercises used should closely mimic that of the demands of the sport or the muscular contraction wanting to be developed in order to develop the strength, activation and contractibility of those muscles leading to optimisation of performance (Umberger, 1998). With the paucity of research into relationships between trampolining, strength and power it is important to review the current literature.
CHAPTER TWO

LITERATURE REVIEW
2.0 Literature review

2.1 Trampolining

Many sports such as athletics, football and basketball have had extensive research carried out into the biomechanical and physiological demands placed on the athletes resulting in training programmes based on these scientific principles (Smout & Swift, 1968). However, with the limited literature regarding the physical demands of trampolining, both coach and performer lack a clear evidence base from which to prescribe effective training programmes.

Trampolining is a high impact sport requiring gymnasts to generate height and perform complex movements whilst airborne. A German study in 1974 reported forces of six to seven times body weight when in contact with the trampoline bed (Grossman, 1974), this figure is supported by that of Vaughan (1980) who used the body mass of a gymnast and the linear acceleration on the bed in order to calculate the upward vertical force exerted by the trampoline. The results indicated that performers were subjected to five to seven time’s body weight during jumping tasks. Glitsch and Henrichs’ (1992) studied the pressure distribution under the foot during take-off, with results indicating some participants were exposed to resultant forces of nearly 3000N (7.5 times body weight). The results of a study by Kraft (2001) illustrate forces that performers were subjected to from a given height and body weight. Furthermore, Kraft (2001) reported bed contact times, illustrating that a gymnast weighing 60kg and jumping at a height of two metres will have a contact time of 338ms, but jumping three metres will have a contact time of 317ms, from the results it can be seen that those weighing more have a longer contact time than those who are lighter, however the higher the performer jumps, no matter what weight, will have a shorter contact time than if they were to jump lower. Kraft (2001) also observed that the same gymnast will experience up to 8.1 times gravity when jumping at a height of two metres. It should be noted that all of the afore mentioned studies are quite dated and that with the advancements in both equipment and technique within the sport these may not necessarily be applied to today, however being that similar resultant forces were found across two decades this data should be factored in when considering the training necessary for performers to be able to handle the demands of trampolining. In addition not all studies detailed the weight of the participant and their level of trampoline experience. With the gymnasts body experiencing multiple times their body weight when at full depression in the
trampoline bed, it is important to consider these physiological and biomechanical demands when designing programmes to prepare for trampolining performance.

Although the physiological literature is limited, a study by Smout and Swift (1968) did look at cardiovascular responses during a ten-bounce sequence finding trampolinists to be under maximum stress during this period leading to oxygen debt and a spasmodic recovery in heart rate. However, it should be noted that this data may not correspond to the demands of modern trampolining performance. Smout and Swift (1968) carried out electromyographic experiments, these showed a considerable amount of muscle activity throughout the entirety of a skill from take off to landing, with the activity being large on landing in order to maintain balance and absorb kinetic energy. The authors also noted that due to the high gravitation forces experienced there is displacement of the thoracic and abdominal regions leading to interference of breathing patterns. This study is limited by the use of only one participant and although the authors stated that the subject did not perform at a very high level they did not define the actual level or whether the participant competed. A use of a range of abilities may have indicated higher or lower levels of muscular activity during different phases of the skill.

A recent review of literature (Farquharson, 2012) looked at the demands of gymnastic trampolining from touch down to take off. Farquharson (2012, p.15) states that the trampoline bed places “relatively unknown physical demands on the body” but that both musculoskeletal and central nervous system demands are at maximum. All skills in trampolining are a modification of the straight jump and therefore height and control are imperative. In order for a trampolinist to gain height during a jump they must repeat powerful triple extensions (hip, knee and ankle) with maintenance of optimal body tension to depress the bed, harness the recoil and facilitate accurate directional transmission of resultant energy (Farquharson, 2012). The success of a jump and ability to perform complex skills largely relies on the postural stiffness of the performer from the moment they touch the bed (first contact), throughout the downward phase to full depression and back to the moment they leave (last contact). Farquharson (2012) identified that both power and strength are important factors with regards to gaining height and maintaining an efficient position in order to utilise the resultant energy from the trampoline bed.
2.2 Strength and Power

From the aforementioned literature it is evident that both strength and power are two of the key factors influencing trampoline performance and therefore it is essential to identify what is meant by both these terms, and explore the literature related to these concepts.

2.2.1 Definition of Strength

Strength in the most basic sense is the ability to exert force (Baechle & Earle, 2008) and is defined as the maximal force producing capacity of a muscle during eccentric, concentric or isometric contractions during a specific movement (Newton & Kraemer, 1994; McGuigan et al., 2013).

2.2.2 Definition of Power

Power is the ability to apply force rapidly (McGuigan et al., 2013), or, the rate of doing work (Kawamori & Haff, 2004; Haff & Nimphius, 2012) whereby work is equal to the force exerted, multiplied by the distance covered in the direction for which the force is applied (Baechle & Earle, 2008). Simply, power is equal to force multiplied by velocity (Carlock et al., 2004; Baechle & Earle, 2008).

2.3 Force-Velocity Curve

Power has been identified as being a major determinant of sports performance in those requiring explosive force production (Kawamori & Haff, 2004; Marques, 2010; Haff & Nimphius, 2012). As aforementioned power is the product of force and velocity however these components are not independent of each other during muscular contraction (Marques, 2010); this relationship is most commonly illustrated by the force-velocity relationship curve (Figure 1) whereby the force that a muscle can produce decreases during concentric muscle actions when the velocity of the movement increases (Newton & Kraemer, 1994; Haff & Nimphius, 2012). As a result maximal power output is achieved at compromised levels of maximal force and velocity (Kawamori & Haff, 2004; Haff & Nimphius, 2012). In order to develop the high-force portion of the curve, heavy load, and low velocity exercises should be performed, conversely in order to develop high-velocity light load exercises performed quickly are required (Marques, Van Der, Vescovi, & González-Badillo, 2008).
8

Figure 1. Force-velocity, force-power, velocity-power, and optimal load relationship (Haff and Nimphius, 2012).

2.4 Rate of Force Development

During movements such as jumping, whereby the time for a muscle to exert large amounts of force is short (between 50 and 300ms) (Marques, 2010), Rate of Force Development (RFD) is an important factor in relation to high-power production (Newton & Kraemer, 1994; Kawamori & Haff, 2004). RFD is calculated from the slope of the force-time curve (Mirkov, Nedeljkovic, Milanovic & Jaric, 2004; Haff & Nimphius, 2012; McGuigan et al, 2013; Oliveira, Oliveira, Rizatto & Denadai, 2013) and it is of significant importance in fast, forceful muscular contractions (Haff & Nimphius, 2012) and can also be used to evaluate the capacity to rapidly generate muscular force (Oliveira et al, 2013). During movements such as jumping, the time for which force can be exerted is less than 250 milliseconds (Kawamori & Haff, 2004; Haff & Nimphius, 2012). This short window makes it difficult to generate maximal force as this can take upwards of 300 milliseconds (Haff & Nimphius, 2012). Augmentation of the early portion of the force-time curve (RFD) allows for an increase in maximal force and velocity to be achieved during rapid movement activities (Oliveira et al, 2013). Marques (2010) identified that the CMJ height was significantly related to maximum RFD, time to reach the maximum RFD and the RFD at peak force.
2.5 Relationship between Strength, Power and the Vertical Jump

Research has indicated maximum strength as being the basic quality affecting power output (Stone et al, 2003; Carlock et al, 2004), therefore when looking at a training program to maximise power development capacity the maximisation of muscular strength is a key foundational component (Haff & Nimphius, 2012). Haff and Nimphius (2012) stated that high levels of strength and the ability to produce high power outputs are influential factors on an athlete’s ability to generate high rates of force development. These components have been identified as being imperative characteristics for sports performance in those that rely on jumping (e.g. trampolining).

Darmiento, Galpin and Brown (2012) stated that in order to increase power production, velocity and/or maximal force must be improved as these are the two key components influencing power. The authors carried out a review of literature concluding that velocity is improved through performance of low-intensity, high-speed movements, for example plyometrics, and force production is improved by high-intensity, low-speed movements as in heavy strength training, for example squats. Darmiento et al (2012) concluded that weight lifting movements are a preferable and effective method of improving leg power, providing simultaneous gains in force and velocity.

Baker (1996) looked at improving vertical jump (VJ) height through three types of strength training; (1) general strength- exercises aiming to develop maximum strength and contractile capabilities of muscle. (2) Special strength- exercises aiming to develop power whereby the use of elastic energy and stretch reflex is utilised more efficiently. (3) Specific strength exercises mimicking that of the VJ combining both stretch-shortening cycle and contractile mechanisms. Baker (1996) identified that the strength gained through general strength training did not appear to correlate with that of the VJ. This is supported by Baker (1994) whereby a 12 week program was carried out on strength and power experienced male athletes, results showed a significant increase in VJ performance however the changes in VJ were not significantly correlated to that of the maximum strength of the squat. In addition Häkkinen, Komi, Alén and Kauhanen (1987) also found there to be no significant correlation between maximum strength and jumping ability. Improvements in strength may not significantly correlate with improvements in VJ however developments in strength have been seen to bring about an increase in VJ height. Wilson, Newton, Murphy and Humphries (1993) compared the three types of strength training and found that all three resulted in improvements in the countermovement jump (CMJ) with special strength
training bringing about a 17.6% increase. This offers support to the statement that the
types of training and exercises used should closely mimic that of the demands of the sport
or the muscular contraction wanting to be developed in order to develop the strength,
activation and contractibility of those muscles leading to optimisation of performance
(Umberger, 1998; Crowther, Spinks, Leicht & Spinks, 2007).

Marques et al (2008) carried out a 12-week resistance and plyometric training programme
with elite female volleyball players. Bench press, parallel squat, overhead medicine ball
throw and loaded and unloaded CMJ were tested. Results showed an improvement in
bench press, parallel squat and overhead medicine ball throw of 15%, 11.5% and 11.8%
respectively. Unloaded and loaded CMJ height increased between 3.8% and 11.2%.
Marques et al (2008) reported the significant improvements in squat strength to be
showing no association with that of any of the CMJ jump tasks. It was identified that
although biomechanically similar, the tests assess independent motor qualities. It can
however be noted from this study that resistance training can positively enhance maximum
dynamic strength, jumping and throwing ability in elite female volleyball players. In addition
these findings support that of the previously mentioned literature (Häkkinen et al, 1987;
Baker, 1994; Baker, 1996) whereby CMJ does not appear to correlate with those
increases in strength. This study is limited by the lack of a control group during this 12-
week period.

Cornie, McCaully and McBride (2007, p.996) researched the effects of a power versus a
strength-power jump squat training program. During the jump squat peak power relative to
body mass, jump height, peak force relative to body mass and peak velocity were all
measured across loads of body mass, 20,40,60 and 80kg. Results showed that peak
power significantly improved at body mass and 20kg for the power training group; however
the strength training group elicited significant improvements for all loads. Similarly, jump
height improved significantly for the power group at the lighter loads, whereas the
strength-power group showed significant improvements at all loads. This research
demonstrated larger all-around improvements in the load-power relationship with strength-
power training than that of power training alone. This shows that a combination of the two
provided significant improvements for maximum jump height and maximum power output
for the jump squat. This would imply that in order to bring about improvements in these
lower- body activities the combination of both strength and power would be greatly
beneficial for an athlete’s all-around development.
Adam, O’Shea, O’Shea and Climstein (1992) investigated the effect of three training programs; squat (S), plyometric (P) and squat-plyometric (SP) on the vertical jump. 48 male participants were split into four groups (S, P, SP groups plus a control group (C)), and carried out the programme twice a week for seven weeks. The S and P groups both showed an increase in vertical jump, on average 3.30 centimetres and 3.81 centimetres respectively, however the SP group showed an average increase of 10.67 centimetres. This study shows that both strength and power training improve vertical jump height however a combination of the two has a significantly greater effect. This study is limited by the use non-athletes and therefore it cannot be assumed that the same results would be evident when using trained athletes. However the results do exemplify a relationship between neuromuscular efficiency and dynamic strength performance.

Although it has been identified that improvements in maximal strength may not be directly related to those improvements seen in the VJ (Baker, 1994, 1996) it is evident from the vast amount of literature that improvements in VJ ability are brought about by the use of strength and power programs. In addition it is apparent that strength influences power. Carlock et al (2004) derived the peak power (PP) from the VJ; findings showed that these factors correlated strongly with weightlifting performance. A strong relationship was seen between the 1RM squat and the power-orientated movements of the clean and jerk and snatch. The research concluded that maximum strength influences power due to the strong relationship between that of the relative measures of both strength and power.

From research it can be seen that the development of maximal strength alone does not bring about remarkable improvements in power and VJ ability in elite athletes; however, when strength activities (e.g. resistance training) are combined with power activities (e.g. plyometrics) the jumping performance is greatly improved (Adams et al, 1992; Baker, 1996; Marques et al, 2008).

Newton and Kraemer (1994) identified five important factors of muscular strength in relation to enhancement of explosive power performance; strength in both fast and slow muscle actions, RFD capability, SSC ability and intermuscular skill and coordination. In order to see the greatest improvements each factor should be addressed, therefore a range of training modalities should be carefully executed in order to bring about the sought after adaptations for enhancement of performance.
2.6 Measuring Strength

Having identified both power and strength as being important components with regards to the VJ and trampolining it is necessary to identify the ways in which they can be measured. There are a number of reasons why strength tests are performed; they provide a basis from which the strength and conditioning coach or athletes coach is able to identify weaknesses in performance, compare or monitor groups of athletes, establish the appropriate training loads for a resistance training program and in turn monitor pre, inter and post program so as to see if it is having the desired impact. In addition strength tests can also be a useful tool when looking to return an injured player to sport.

When seeking to carry out any type of testing the viability needs to be considered. Many sporting clubs may not have access to specialised costly laboratory equipment such as dynamometers and force plates and therefore field tests are often used to measure muscular strength. As the measurement of maximum muscular strength the 1 repetition maximum (1RM) is commonly used throughout research and has been shown to be an accepted reliable and valid test for a range movements (Miller, 2012; McGuigan et al, 2013). This involves the athlete lifting the maximal load possible for a specific movement with correct technique.

There are a variety of 1RM tests that can be performed; bilateral back squat, unilateral back squat, bench press and machine leg press. The bilateral back squat requires an awareness of technique with athletes being required to get the top of their thighs parallel to the ground as specified by Beachle and Earle (2008). This may not be possible for all athletes and therefore there may be inconsistencies in testing. It may also take longer to administer such a test as if the athlete is less experienced the coach may need to guide them into the right postural positions. With regards to the current study it is assumed that not all gymnasts may have had access to such strength and conditioning facilities in order to develop such a technique. This also applies to the unilateral squat whereby knowledge of technique is required. The unilateral movement and to perform such a movement to a 1RM is not believed to be related to trampolining as this is a bilateral movement. There may also be a higher risk of injury due to it being an unfamiliar position for the gymnasts, in addition to there being no know published data to validate the use of such a test (Miller, 2012). The bench press is irrelevant to the current study as it is a measure of maximum upper body strength.
2.6.1 1RM Machine Leg Press

The machine leg press is both a valid and reliable test for assessing maximum lower body muscular strength (Miller, 2012). The use of a machine as opposed to free weights decreases the risk of injury and is often used to assess older athletes. Unlike the squat a low level of technique is required, the athlete is required to place their feet on the foot-plates with 90° flexion at the knee ensuring that the movement is performed without excessive lordosis of the lumbar spine. Rogers and Sherman (2001) identified that literature has shown the same benefits from the leg press compared to the squat with the leg press having a decreased risk of injury, easily performed technique and benefits in the context of both rehabilitation and the development of strength.

2.7 Measuring Power

With muscular power having been considered as a determinant of performance in those sports requiring explosive force production to perform movements such as jumping (Kawamori & Haff, 2004) it is important to measure or estimate power with a mechanically related test. The VJ is a field test most commonly used among researchers, and coaches to test the power and explosiveness of an athlete (Miller, 2012) due to the relatively quick and easy administration and relatively non-fatiguing nature (Carlock et al, 2004). For sports in which jumping and/or lower body power output is crucial (e.g. weightlifting, trampolining, basketball) results can be used to determine the effectiveness of a program (Umberger, 1998), predict a weightlifters ability, monitor fluctuations in an athletes performance throughout a season or programme allowing alterations to be made if necessary, all without the need to perform a 1RM regularly (Carlock et al, 2004). There are two main VJ used; squat jump (SJ) and countermovement jump (CMJ). The SJ involves the athlete starting from a squat position, from this position they propel themselves vertical into the air as high as possible. The SJ does not involve the muscles being pre-stretched as the movement starts from a static position; this is not the case when performing a jump on the trampoline there is also a downward phase, therefore it is important to look at the CMJ as a means of testing leg power.
2.7.1 CMJ and SSC

The CMJ begins with a downward phase whereby flexion of the hip, knee and ankle eccentrically loads the muscles; this is followed by an almost immediate concentric contraction with extension of the hip, knee and ankle, resulting in a VJ (Umberger, 1998). This eccentric-concentric relationship is known as the Stretch-Shortening Cycle (SSC). During the eccentric phase elastic energy is stored and muscle spindle stimulation occurs resulting in maximum power production during the concentric phase (Newton & Kraemer, 1994). Potach (2004) identified that the shorter the contact time between eccentric and concentric contraction, the greater the force production as the energy stored is fully utilised, too long and the energy will dissipate as heat. The CMJ gains more height than that of the SJ due to the utilisation of the stored elastic energy and neural augmentation of the muscles (Baker, 1996). In order to increase VJ performance the contractile muscular elements should be trained or the efficiency of the SSC should be improved (Baker, 1996). This is why many programs use plyometric training as a means of improving power; these types of activities utilise the SSC enabling a muscle(s) to reach maximal force in the shortest time (Baechle & Earle, 2008), therefore reducing the ground contact time.

2.8 Trampolining, Strength and Power

To date there has not been any research carried out that has looked into the relationships between strength, power and jump height in trampolining. Farquharson (2012) identified strength and power to be important pre-requisites with regards to generating height and maintaining an efficient position in the trampoline bed, however no research can be found that evidences the effect of different levels of strength and power on trampoline jump height.

Atilgan (2013) looked at the effects of trampoline training on jump, leg strength and static and dynamic balance of boys. It should however be noted that the study was carried out on prepubescent boys who did not exercise regularly however results are still interesting to note although currently limited in their use in relation to the present study. 15 boys took part in a 12-week trampoline training program two days a week for one and a half hour sessions. Results showed significant differences in vertical jump and static and dynamic balance after the 12 weeks whereas the control group showed no differences in any of the performance parameters. It is interesting to note that no significant differences were found in leg strength. However, it is unclear as to whether these results can fully be attributed to
the trampoline training or whether adaptations could have been brought about by general exercise as the participants weren’t exercising regularly.

The study by Atilgan (2013) used both a full sized trampoline and a mini-trampoline. Although there is no known literature looking into strength, power and jump height in trampolining there has been some research with the use of mini-trampolines. Ross and Hudson (1997) carried out a 5-week mini-trampoline program on eight intercollegiate female basketball players with all completing at least 500 jumps over this period. Results showed a mean increase of 3.3cm in jump height, this increase may prove beneficial when trying to gain possession in a game. Interestingly the player with highest starting jump, decreased height post intervention and the player with the most jumping skill did not show any difference in jump height. This may imply that for certain levels of experience a jump-training programme alone is not significant enough stimulus to bring about adaptation. It is also important to note that the sample size for this study is small and it cannot be assumed that this is the case for all basketball players or indeed other sports that involve jumping.

Both Ross and Hudson (1997) and Crowther et al (2007) identified that jumping on a mini-trampoline requires a smaller knee Range of Motion (ROM), this makes greater use of the SSC mechanism by reducing the loss of elastic energy and aiding speed of movement resulting in greater maximum leg power. Crowther et al (2007) established a greater enhancement of SSC mechanism when performing the Depth Jump (DJ) and Counter Movement Jump (CMJ) on a mini-trampoline as opposed to jumping on the ground. Both studies identified the reduced crouch or reduced ROM as being an effective feature of plyometric training (power training).

Tillinghast (1966) looked at the effects of a nine week college physical education class in trampolining on cardiovascular efficiency, leg power, vertical jump height, and leg strength. Twenty students attended two sessions a week for a thirty minute period. Results showed a significant increase in leg power and leg strength. There were no improvements in vertical jump or cardiovascular efficiency. Data also revealed an average weight increase of 1.95 pounds with the authors identifying that an increased in body weight may lead to increase leg power with the force of muscular contraction of the activity being at least two-thirds of maximum whereby an increase in strength will occur when such contraction is elicited.
Brees (1961) also studied the effects of five weeks of trampoline training on speed, endurance, vertical jump, agility and broad jump with the use of high school basketball players. There were three groups; control group who only participated in the testing, the trampoline group who spent three minutes a day jumping as high as possible and the last group spent three minutes a day jumping on the floor as high as possible. Both the trampoline group and floor jumping group showed significant improvements in vertical jump height and shuttle run, however the trampoline group also showed improvements in the agility run. These results imply that although similar, the exercises may bring about slightly different physiological adaptations.

2.9 Rationale

From the review of literature it is evident that the body can endure up to eight times body weight when jumping on a trampoline (Grossman, 1974; Vaughan, 1980; Glitsch & Henrichs, 1992; Kraft, 2001) and a large amount of muscular activity has been seen throughout a ten bounce skill routine (Smout & Swift, 1968). In addition it is clear that strength in the trampoline bed is imperative to jump performance and the utilisation of the beds recoil through powerful triple extension allows performers to gain an important height advantage (Farquharson, 2012). Research has shown that improvements in the VJ have been significant through both strength and power training but more importantly the combination of the two provides far greater adaptations. Farquharson (2012) identified strength and power to be important pre-requisites to trampoline jumping however there has been no known literature that has evidenced the influence or relationship of strength and power on jump height. The research to support the use of strength and power training to improve VJ height is extensive however such literature within trampolining is scarce to non-existent.
2.10 Aim of Study

Therefore the aim of this investigation was to identify the relationships between jump height on a trampoline and measure of lower limb strength and power.

2.10.1 Hypotheses

- There will be a positive correlation between trampoline jump height and strength (1RM)
- There will be a positive correlation between trampoline jump height and power (CMJ)
- There will be a positive relationship between those who strength train and trampoline jump height
- There will be a positive relationship between those how power train and trampoline jump height
- There will be a positive relationship between strength, power and trampoline jump height

2.10.2 Null Hypotheses

- There will be no correlation between trampoline jump height and strength (1RM)
- There will be no correlation between trampoline jump height and power (CMJ)
- There will be no relationship between those who strength train and trampoline jump height
- There will be no relationship between those how power train and trampoline jump height
- There will be no relationship between strength, power and trampoline jump height
CHAPTER THREE

METHODOLOGY AND RESEARCH DESIGN
3.0 Methodology

3.1 Participants

Eight participants were recruited for the study; four males and four females (age 19.38 ± 1.19 years; stature 169.29 ± 13.07 cm; mass 70.24 ± 12.53 kg). All participants were a minimum of 18 years of age and had been injury free for at least the last two months prior to the testing being undertaken. All participants were competing at national level (minimum requirement of a nine somersault routine) or above and training regularly; at least two sessions a week. All of the participants recruited for this study are currently training at Cardiff Metropolitan University and were informed that all of their details and results from the study would remain anonymous.

Prior to the any testing being carried out Cardiff School of Sport Research Ethics Committee granted ethical approval (Appendix A) for this research project thus allowing data collection to commence. Participants were required to read an information sheet (Appendix B) outlining the study and what was required of them, participants were given the opportunity to have any questions they may have answered. Participants were then required to complete an informed consent form (Appendix C) whereby it was agreed that their time was entirely voluntary and they were free to withdraw at any stage without reason. Finally participants were asked to fill out a questionnaire (Appendix D).

Prior to performance and trampoline testing, participants' stature and mass were recorded; stature was measured using a stadiometre (Leicester height measure, MKI, Leicester, England) and a set of portable scales (Seca, 770, Hamburg, Germany).

3.2 Questionnaire

Each participant was required to fill out a questionnaire providing details of their trampolining history, current competition status and training in the average week. The questionnaire also required participants to detail their strength and power training experience, if any and in addition any further training that they carried out on a regular basis that had not been mentioned previously. This allowed further analysis to be made as to the impact of different levels or experience of strength and power training on the performance of the three testing protocols.
3.3 Testing Protocols

There were three tests executed during this study; 1) ten straight jumps on a trampoline, 2) three vertical jumps performed on a contact mat, 3) 1RM leg press.

All tests were carried out in the National Indoor Athletic Centre (NIAC) at Cardiff Metropolitan University.

All participants performed the tests in the same order. Participants attended two sessions; the first session involved performing ten straight jumps on a trampoline, they were then given a five-minute rest period followed by the performance of three vertical jumps in the form of the Countermovement Jump (CMJ). Participants were permitted a two-minute rest period in between each jump. The second session required the participant to achieve a 1RM leg press.

3.3.1 Test 1- Ten Straight Jumps

All participants performed their ten straight jumps on the same trampoline (Eurotramp, Premium 4x4, Weilheim an der Teck, Germany). Participants were permitted two warm up attempts consisting of ten straight bounces each time to familiarise themselves with the trampoline, they were instructed not to bounce at their absolute maximal height until the ten testing jumps in order to prevent fatigue. A HD camcorder (Panasonic, HX-WA30, Osaka, Japan) on a tripod was positioned at a height and distance away from the trampoline that allowed full vision of the maximum depression of the trampoline bed, and maximum height of the trampolinist at the top of their jump. Trampolinists were instructed to jump as high as they could whilst maintaining control and staying central to the cross on the trampoline. They were instructed to perform ten straight jumps commencing with an arm set; this is the preparatory arm movement required at all competition levels (British Gymnastics, 2013) to show when the performer is starting their routine, or in this case when they were starting their jumps. All ten jumps were to be completed after a maximum of seven in-jumps as maximum height should be achieved within this time.
3.3.2 Test 2- Vertical Jump (CMJ)

Participants performed their vertical jumps after having performed their ten straight bounces on the trampoline; as a consequence they were already warmed up. A contact mat (SmartJump, Fusion Sport, Brisbane, Australia) was placed on a flat surface. Participants were instructed to perform a maximum CMJ with their hands on their hips whilst barefooted. Each participant was required to perform three vertical jumps with a two-minute rest period in between each jump. A PDA system connected to the contact mat provided readings for both jump height and flight time for each participant.

3.3.3 Test 3- 1RM Leg Press

The same leg press machine (Hammer Strength, Linear leg press, USA) in the athletics gym in NIAC at Cardiff Metropolitan University was used for all participants. The 1RM testing protocol (Appendix E) as described by Baechle and Earle (2008) was used. All participants were instructed on how to use the leg press machine safely and were shown the correct technique. The 1RM testing protocol was then carried out with the highest leg press with correct technique being recorded.

3.4 Data Collection and Analysis

The ten straight jumps for each participant were analysed using the Dartfish 6.0 program for Windows. When the straight jumps were recorded, a metre stick was first placed by the trampoline, this was to allow calibration when analysing the data within Dartfish 6.0. Firstly depth the participants sunk into the trampoline was measured; this was measured from the maximum point that the trampolinist reached at the bottom of the trampoline bed, to the point at which the trampolinists’ feet had just left the trampoline. Secondly the jump height was measured; this was the point at which the feet had left the trampoline to the point where maximum height was reached, with the maximum height being measured from the participants’ feet. The depths and heights were recorded for each of the ten jumps for all eight participants.

The data for all three tests for each participant were recorded in the same Microsoft Excel document; results from the questionnaires were also added to this. Data was inputted into Statistics Package for the Social Science (SPSS) and each variable was tested for normality. Normality was assumed if the value was greater than 0.05. A Pearson Correlation (O’Donoghue, 2012) was carried out for participants; stature, mass, 1RM, best jump height, average jump height, max depth, max height, average depth, average height.
A Pearson’s correlation was also carried out for the years and hours a week spent strength and power training with the three testing protocols. Significance was accepted for the value $p<0.05$ with the correlation or ‘$r$’ value of one being a perfect correlation, zero being no correlation and minus one being a perfect negative correlation (O’Donoghue, 2012). $R^2$ values also known as common variance values were also calculated for each variable. An Independent T-test was carried out to assess if there were any significant differences between those who do and those who don’t power train. As there was only one participant in the no strength training group it was not possible to run an independent T-test and therefore the percentage of difference in the means was calculated.
CHAPTER FOUR

RESULTS
4.0 Results

A test of normality was carried out with a value greater than 0.05 meaning that normality could be assumed; in this case the value was greater than 0.05 and therefore it could be assumed that the data was normally distributed. This lead to two parametric tests being performed; a Pearson's correlation and an Independent T- test.

4.1 Pearson's Correlation

A Pearson’s correlation was performed with significance being accepted at the value P<0.05. An R value of one showed a significant positive relationship and a value of minus one showed a significant negative relationship. R² values were also calculated to show the common variance. Results for the key variables assessed; trampoline jump height and depth, 1RM and CMJ jump are shown in Table 1.

Table 1. Pearson’s correlation (N=8) for trampoline height and depth, 1RM and CMJ

<table>
<thead>
<tr>
<th>Variable</th>
<th>Max D</th>
<th>Max H</th>
<th>Ave D</th>
<th>Ave H</th>
</tr>
</thead>
<tbody>
<tr>
<td>One RM</td>
<td>R / R²</td>
<td>0.501 / 0.251</td>
<td>0.798* / 0.637</td>
<td>0.223 / 0.050</td>
</tr>
<tr>
<td>Best JH</td>
<td>R / R²</td>
<td>0.291 / 0.085</td>
<td>0.557 / 0.310</td>
<td>0.337 / 0.114</td>
</tr>
<tr>
<td>Ave JH</td>
<td>R / R²</td>
<td>0.322 / 0.104</td>
<td>0.582 / 0.339</td>
<td>0.348 / 0.121</td>
</tr>
</tbody>
</table>

* = Significant correlation (p<0.05)

There was a significant relationship between the 1RM and maximum height on the trampoline for all participants (R=0.798, p<0.05, R²= 0.637). There were no significant correlations found between any of the other variables (p>0.05) shown in Table 1.

There was a significant relationship between stature and mass (R= 0.727, p<0.05, R²= 0.529). Correlations were significant between stature and; maximum depth, maximum height, average depth (R= 0.860, R²= 0.740; R= 0.813, R²= 0.661; R= 0.806, R²= 0.650 respectively) with p<0.05 for all variables. Additionally significant correlations were seen between mass and; maximum depth, average depth (R= 0.738, R²= 0.545; R=0.778, R²= 0.605) p<0.05 for all variables.
The Pearson’s correlation was also used to see if there was a relationship between the data received from the questionnaires and the 1RM, CMJ and trampoline height and depths. The years participants had been power training PT for and the hours a week they spent PT showed no significant correlations between any of the testing variables (p>0.05). However, the years participants had been strength training (ST) and the hours a week they spent ST did show significant correlations (N=7); these are shown in Table 2.

Table 2. Correlation between time spent ST and the testing variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>ST hrs/week</th>
<th>Time ST (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One RM</td>
<td>R / R²</td>
<td>0.878* / 0.770</td>
</tr>
<tr>
<td>Best JH</td>
<td>R / R²</td>
<td>0.515 / 0.265</td>
</tr>
<tr>
<td>Ave JH</td>
<td>R / R²</td>
<td>0.556 / 0.309</td>
</tr>
<tr>
<td>Max D</td>
<td>R / R²</td>
<td>0.752 / 0.567</td>
</tr>
<tr>
<td>Max H</td>
<td>R / R²</td>
<td>0.886* / 0.785</td>
</tr>
</tbody>
</table>

* = significant at p<0.05

It can be seen from Table 2, that the years spent ST very strongly correlates with the best and average CMJ with 92% and 89% common variance respectively. In addition it can be seen that the number of hours spent ST a week shows a strong positive correlation with both 1RM and maximum trampoline jump height.

4.2 Group Differences

Results from the questionnaire showed that not all participants did strength and power training and therefore an independent T-test was carried out to see if there was a statistically significant difference between the results for those who did do PT (N=4) and those who didn’t do PT(N=4). With those who did (N=7) and those who didn’t (N=1) do strength training it wasn’t possible to run an independent T-test as there was only one participant who didn’t ST and therefore a percentage difference was calculated from the means of the two groups.
4.2.1 Strength Training: Percentage of Difference

The means of each group (Strength training- ST and no strength training- NST) were used to calculate the percentage of difference; results are show in Table 3.

Table 3. Percentage (%) difference between means of the ST and NST groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>ST</th>
<th>NST</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1RM</td>
<td>208.93</td>
<td>200</td>
<td>4.37</td>
</tr>
<tr>
<td>Best JH</td>
<td>34.83</td>
<td>36.96</td>
<td>-5.92</td>
</tr>
<tr>
<td>Max H</td>
<td>2.82</td>
<td>2.3</td>
<td>20.36</td>
</tr>
<tr>
<td>Max D</td>
<td>0.89</td>
<td>0.77</td>
<td>14.61</td>
</tr>
</tbody>
</table>

The greatest percentage difference was seen in the maximum trampoline jump with those who did ST having an over 20% increase in their mean jump height than that of the NST group. The participant who did not ST had a higher CMJ than the mean of the ST group. The percentage of difference between groups for the 1RM was unremarkable.

4.2.2 Power Training: Independent T-test

An Independent T-test was carried out to see if there were any statistically significant differences for each testing variable between those who PT (N=4) and those who do not PT (N=4). The Levene’s test for equality of variance significance value was greater than 0.05 and therefore equal variances were assumed. Results showed that there was a statistically significant difference in the maximum and average height jumped by those who did PT and those who did not. The means for the maximum height jumped by both groups is displayed in Figure 2.
* Significant difference between group (p<0.05)

Figure 2. Means of the maximum height jumped for PT and NPT groups

Although there wasn’t a statistically significant difference between the two groups (PT and NPT) for 1RM and best CMJ, the PT group did show higher means for both variables as seen in Figures 3 and 4.

Figure 3. Means of the 1RM for PT and NPT groups
Figure 4. Means for the best CMJ for PT and NPT groups
CHAPTER FIVE

DISCUSSION
5.0 Discussion

5.1 Aim and Key Findings of the Investigation

The main aim of the study was to determine if there was a relationship between jump height on a trampoline and strength and power characteristics as assessed by the 1RM and CMJ. A questionnaire was also utilised to determine the strength and power training history of the trampolinist and if these can be seen as having any significant relationships or differences to those who do not undertake such training.

The key findings of this investigation were; the 1RM leg press is significantly correlated to trampoline jump height, implying that those who are stronger jump higher on a trampoline. Results showed that the CMJ is unrelated to trampoline jump height. Additionally stature is significantly related to trampoline height and depth, and mass is significantly related to trampoline depth.

5.2 Relationship between Stature, Mass and Trampoline Jumps

In this study stature and mass showed a significant relationship, generally those who are taller are going to weigh more than those who are shorter. Both stature and mass showed a significant relationship with maximum depth reached in the trampoline bed, this is also unsurprising as those who are heavier will depress and stretch the bed and springs further than those who are lighter. Trampoline depth displayed a significant correlation with trampoline height; this implies that the further the trampoline bed is depressed, the greater the recoil from the springs and bed and therefore the higher the resultant jump. A significant correlation was also seen between stature and trampoline height; as stature and mass were correlated and trampoline height and depth were correlated, it may be drawn from the results of this study that generally those of a greater stature and mass will create a greater depth and therefore a higher resultant jump than those who are of a smaller nature. These findings concur with that of the research carried out by Kraft (2001) whereby the trampoline bed depth was measured for a range of different body masses (20-90kg) at a range of heights (bed at rest-4.0m), results showed that those with a greater mass had a longer contact time with the bed depressing it further than those who were lighter. Although the current literature with regards to the physical demands of trampolining is limited, the findings from this study concur with that of Kraft (2001) agreeing that the greater the mass, the greater the depression, and therefore the higher the resultant jump.
5.3 Relationship between Strength, Power and Trampoline Jumps

Gymnast’s strength as tested by the 1RM, and power as tested by the CMJ were entered into a Pearson’s Correlation to see if there were any significant relationships between the strength and power results and the height and depths of the trampoline jumps. As can be seen from Table 1, there was only one significant relationship; 1RM and maximum trampoline jump height. No other significant correlations were found between any of the variables, showing there to be no relationship between the CMJ and jumping on a trampoline.

From the literature reviewed earlier in this study it was evident that although improvements in the CMJ could be brought about through strength and power training, the CMJ did not correlate with increases in strength (Häkkinen et al, 1987; Baker, 1994; Baker, 1996). This may also be supported by the current study as there was found to be no correlation between the CMJ and any of the other testing variables. With there being no relationship between the CMJ and the height jumped on a trampoline but a statistically significant relationship between the jump height and 1RM leg press this may imply the muscular contraction used for the strength activity is more closely related to those contractions on a trampoline than are used for the CMJ. The CMJ uses the SSC whereby the shorter the time between eccentric and concentric contraction the greater the force production due to efficient elastic energy reutilisation (Potach, 2004). The time for force exertion during jumping movements has been reported at less than 250 milliseconds (Kawamori & Haff, 2004; Marques, 2010; Haff & Nimphius, 2012) however for trampoline jumps Kraft (2001) reported contact times upwards of 300 milliseconds. Due to this longer contact time the transition between eccentric and concentric contraction is longer, therefore the SSC becomes inefficient and the elastic energy cannot be utilised and is lost (Potach, 2004). From the current study, Kraft (2001) and the research with regards to contact times for the SSC it can be seen that the contact time in the trampoline bed is longer than that spent generating force in the CMJ and therefore the time for force application on the trampoline is more related to the strength portion of the force-velocity curve (Figure 1) than that of the power portion. It may be that concentric strength is more important during a trampoline jump due to the longer contact time and this is why the 1RM leg press was related and the CMJ was not.
As previously stated by Umberger, 1998 and Crowther at al, 2007, the types of training and exercises used should mimic the muscular contraction wanting to be developed. And although the CMJ can be improved through strength and power training, the lack of relationship between this and the trampoline jump height gives evidence that although the movements seem to have biomechanically similar characteristics, the motor qualities are independent (Marques et al, 2008) and the contact times differ, therefore it cannot be assumed that both movements share the same neural qualities. This was the case with Marques et al, 2008 who found that although the squat and CMJ share similar biomechanics there was no association between the improvements in squat strength with any of the CMJ tasks.

Some studies had been conducted demonstrating that improvements in the VJ have been brought about through the use of trampoline training programs (Brees, 1961, Ross & Hudson, 1997; Atilgan, 2013), however none of these studies were carried out using trampolinists and from the current study this may not be the case as CMJ is not seen as having any relationship with that of jumping on a trampoline. Improvements may be seen in non-trampolinists when using a trampoline to improve the CMJ as they are untrained in the activity, although it may not be fair to assume that the same would occur with elite trampolinist or in fact that the improvement of the CMJ would bring about an improvement in trampoline jumping. Interesting Tillinghast (1966) as previously mentioned, carried out a study on a physical education class using a trampoline program, and though not trampolinists the results showed there to be no improvements in VJ but showed significant improvements in leg strength and power. This concurs with the findings of the current study whereby a relationship is seen between jumping on a trampoline and leg strength.

5.4 Strength and Power Training

A Pearson’s correlation was performed to identify if there were any significant relationships between the testing variables and the years and hours a week spent PT. Results showed no significant relationships between any of the testing variables. This result may provide more evidence to support the bigger influence of strength in relation to trampoline jump height and measures of strength. However it should also be noted that there was an equal split between those who did (N=4) and did not PT (N=4) whereas there was only one participant out of the eight who did not ST, this may have an influenced these results.
As with the PT group a Pearson’s correlation was implemented to identify any significant relationships between the testing variables and the years and hours a week spent ST. Results are shown in Table 2, significant relationships are seen between the number of hours spent ST in a week and the 1RM and maximum height jumped. It would be expected that those who undertake more ST would be stronger and this is the case. These results also concur with those previously identified whereby strength correlates with trampoline jump height, with the number of hours spent a week ST correlating with the maximum jump height. This provides greater evidence to support trampoline jump height being more related to the strength portion of the force-velocity curve being rather than the power portion. The number of years spent ST showed a significant relationship with the best and average CMJ. Strength is a key component of power and therefore those who have been ST for a number of years will have developed a base level of strength which may also influence their power output thus showing some relationship between strength and power.

An independent T-test was performed to see if there were any significant differences between those who do PT (N=4) and those who don’t PT (N=4) between the three tests (1RM, CMJ and trampoline jumps). Results showed there to be a significant difference in those who did PT to those who didn’t PT for maximum and average height jumped. However as previously identified there is a significant relationship between stature and mass and trampoline jump height and when looking at the means of both groups, the PT group had a higher stature and mass than that of the NPT group and therefore it cannot be assumed that the improvements in jump height are due to the power training or whether it is just because the PT group were heavier. The significant correlation between the PT group and the maximum and average height jumped does not imply causality.

The independent T-test showed that the 1RM results were approaching significant for the PT group having a better 1RM than the NPT group. This may show that although the measure of power was not related to jump height there is a relationship between strength and power with those who undertake PT showing higher results for the strength measure than those who do not. The best CMJ height reached, although not statically significant, was higher for the PT group than the NPT group, this is to be expected as the CMJ was the measure used for power.

It wasn’t possible for an independent T-test to be carried out for the ST group as there was only one participant who didn’t ST and therefore the percentage difference of the means was calculated (Table 3). Results indicated that there was an over 20% difference in the
mean maximum jump heights between the two groups, it also showed there to only be around 4% difference between the 1RM’s between groups. It may be possible that those who do more ST may not be benefiting from the full effects of such training and the intensities and exercises they are performing at may not be sufficient enough to bring about physiological adaptations. Similarly with the PT groups having an equal split for the number of participants, the effect of only one participant not doing ST may have an impact on the reliability of the results. It cannot be determined if those who ST have a better jump height or whether this is once again attributed to the mean stature and mass being higher for that group. Similarly the NST group had a higher mean for their CMJ than the ST group however as there was only one participant, them having a higher CMJ than the mean of the rest of the group does not provide a strong evidence base from which to assume that those who ST have a lower CMJ as one person does not reflect the true mean of a group if there were more participants then stronger evidence may suggest this to be the case however this cannot be concluded from this study.

5.5 Practical Implications

This research area is currently lacking the knowledge surrounding the biomechanical and physiological demands placed on the trampolinists and therefore there isn’t a clear evidence base in which to prescribe effective training programs. There is currently no literature that can be found that looks into the relationship between trampoline jump height and strength and power. With the use of elite trampolinists, it may be possible to use the 1RM test as a prediction of the jump height potential of the individual and vice versa, as a means of talent identification. It may also be possible to use other strength tests as a predictor of trampoline jump potential as the stronger people in this study jumped higher, although more research is needed to determine if this is the case.

Additionally, even though there was not seen to be a relationship between power and any of the other testing variables, it can be seen that those who PT had higher means across all tests (1RM, CMJ, trampoline jumps) when compared to those who do not PT. This may be taken into consideration when looking at prescribing training programs.

As previously mentioned strength has been show to have a clear relationship with trampoline jump height and with strength being the fundamental component of power (Stone et al, 2003; Carlock et al, 2004; Haff & Nimphius, 2012) this may imply that through the prescription of strength training activities adaptations may also be brought about in power based activities. Previous research has also identified that there is a greater
improvement brought about through the combined use of strength and power training programs as opposed to the use of strength training alone. This may be taken into consideration when prescriptions are made with a combination of the two possibly maximising the potential for development of the jump height reached by the trampolinist. However from the results of this study it is evident that the contact time on the trampoline is greater than that of the time to generate force in the CMJ and therefore training programs should mainly focus on development of the strength portion of the force-velocity curve over that of the power section as these are more closely related. It may also be advantageous to develop concentric strength as this becomes more important with a longer contact time and is more prevalent in the 1RM leg press. From the results of this study; strength should be prioritised over power.

5.6 Limitations

Although this study used all elite level trampolinists the use of only eight participants limits the use of the results somewhat. It cannot be said that the eight trampolinists show a true reflection of the larger population or indeed that the results would be true for a variety of trampoline abilities. With results lacking in statistical power and the wide confidence intervals further research would be required in order to validate the current findings.

The use of the Dartfish 6.0 program in order to calculate the jump height and depth for the trampoline jumps; although providing the ability to calibrate with the use of a metre stick there is a degree of error when using such a measure, the distance the camera is placed away from the trampoline may also have an impact on the perceived height of the performer although all trampoline jumps were recorded in the same session so as to ensure the camera was in the same position for all participants. When determining the heights and depths for all participants there is a degree of perspective error that can occur as although it is stated in the method how the different contact moments were determined this may still be largely down to the researchers perception as to the exact points where the trampolinist has contacted and left the trampoline bed.

Questionnaires were given to all participants. When participants’ were recruited for the study their strength and power training history was not a selection criterion and therefore a questionnaire was employed to gain this extra information. When it came to analysing this information it was evident that the uneven spread of those who did and didn’t ST made it difficult to draw positive conclusions from the results. Therefore the selection of a range of participants based on their strength and power training history may have been beneficial
so as to make a fair comparison between those who do and don’t PT and those who do and don’t ST.

5.7 Implications for Future Research

There is not known to be any other research study of this nature and therefore this investigation can provide a base for further research however additional investigations are required to confirm or reject the results of the current study.

Further investigations need to made into the relationship between strength and power training on jump height. This can be further developed by using a large population and splitting into separate strength and power and non-strength and non-power training groups in order to make a detailed comparison.

A variety of conditioning programs or individual exercises could be employed to observe the affects they have on trampoline jump height and determine those which bring about the greatest improvements. Although this study identified that 1RM leg press and trampoline jump height are related it did not identify the cause and effects, research needs to be carried out to identify if increasing the 1RM of a performer would increase their jump height.

A biomechanical analysis of the trampoline jump could be carried out to observe the differences in technique in order to determine the most effective position in order to optimise trampoline jump height.

The same investigation could be carried out for different levels of trampolinist to see if the same conclusions can be drawn. This may also provide the opportunity for better strength and conditioning programs to be implemented earlier on in a gymnast’s development and may lead to a greater base from which to develop height and skill.
CHAPTER SIX

CONCLUSION
6.0 Conclusion

From this investigation it is evident that the knowledge and research surrounding the physical demands of trampolining is very limited and that there does not seem to be a clear evidence base from which to prescribe strength and conditioning programs. The aim of this investigation was to identify if there were any clear relationships between trampoline jump height and strength and power as measured by a 1RM and CMJ.

Results from this investigation found that stature and mass have a large impact on the depth and height reached by the individual; in addition the depth has a significant impact on the resultant height that the individual can reach. Interestingly the CMJ was not found to have relationship with trampoline jump height whereas the 1RM showed a significant relationship. Although it may seem that strength has a greater impact on trampoline jump height than that of power, the uneven distribution of those who did and didn’t strength train makes it difficult to determine the true meaning of these results. It is however evident that those who power trained had higher means for each of the testing protocols than those who did not implying that there may be some rationale for the use of power training to impact trampoline performance. The results from this investigation would imply that strength training should be prioritised over that of power training in order to develop trampoline jump height with future research possibly leading to the inclusion of some power based training to further optimise performance.

Due to the limited research with regards to trampolining this investigation does provide a pathway for future research with a view to validate the results of this study, overcome the limitations and further develop the knowledge surrounding the impact of different strength and conditioning programs in order to best enhance trampoline performance.
REFERENCES


Farquharson, R. (2012). The demands of gymnastic trampolining from touch down to take off. A physical preparation perspective. *SportEX Medicine, 53*, 14-19


Smout, P & Swift, R. (1968). The fitness requirements of trampolining. *British Journal of Sport Medicine, 3*, 169-177


APPENDIX A

ETHICAL APPROVAL
Date: 18/03/14

To: Kirsty Briggs

Project reference number: 13/05/039U

Your project was recommended for approval by myself as supervisor and formally approved at the Cardiff School of Sport Research Ethics Committee meeting of 29th May 2013.

Yours sincerely

[Signature]

Rob Meyers
Supervisor
APPENDIX B

INFORMATION SHEET
Title of the project: *The relationship between; strength, power and trampoline jump height.*

**Participant information sheet**

*Please be aware that this study is looking for volunteers and your participation is entirely voluntary, should you wish to withdraw you can do so at any time without reason.*

**What’s this about?**
This study aims to see if there are relationships between how high you jump on a trampoline, the height of your vertical jump and the amount of weight you can leg press. In essence it is looking to compare strength and power in relation to trampoline jump height.

**What will I have to do?**
You will only be required to attend two sessions;

1. You will be asked to complete a questionnaire which will include such details as your height, weight, trampoline experience and strength and power training experience. You will then be video recorded performing 10 straight jumps to your maximum height. This will allow for your ‘flight time’ or jump height to be calculated.
2. The second session will involve you performing a 1RM leg press and three vertical jumps of which the best height will be used.

A warm up will be carried out for each test and you will be coached through the correct technique at each stage.

**I’m interested can I take part?**
As long as you are a National level performer or are able to complete a 9 somersault routine, train on a regular basis (at least twice a week) and are free from injury. If you have had an injury that has prevented you from training regularly in the last month then unfortunately you are unsuitable for this study.

**Are there any risks?**
Risks are kept to a minimum however accidents can still happen. Warms ups are to be followed prior to any activity in order to minimise the chance of injury. The trampoline will be checked by a qualified coach prior to any testing and safety mats will be put in place. Please pay attention to any instructions given to you especially during the 1RM leg press session as equipment may be unfamiliar and the improper use of these machines/incorrect technique can cause injury.

**What are the benefits?**
You will be able to gain an insight into the way in which dissertation testing is carried out which may help you in the future. You will find out the flight time of your highest jump, your vertical jump height and what your 1RM leg press is. Through this you will also learn about the 1RM testing protocol.

**Confidentiality...**
Your name and contact details will only be used in the case of an emergency or to contact you with regards to the session times. None of your contact details will be shared with any other party and the results from this study are anonymous.

**Who do I contact?**
If you would like any further information or are interested in taking part in this study please contact me:

Kirsty Briggs: st2000600@outlook.uwic.ac.uk
APPENDIX C

INFORMED CONSENT
Participant consent form

Reference number:

Participant name or student ID number:

Title of project: The relationship between; strength, power and trampoline jump height.

Name of researcher: Kirsty Briggs

Participant to complete this section: Please initial each box

1. I confirm that I have read and understand the information sheet for the above 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 I am free to withdraw at any time, without giving reason.

3. I agree to be video recorded.

4. I agree to take part in the above study.

Signature of participant ____________________________ Date___________

Name of person taking consent ____________________________

Signature of person taking consent ____________________________
APPENDIX D

QUESTIONNAIRE
Questionnaire

Participant name:

1. How long have you been trampolining for? (Years/months)

2. What level do you currently compete at? (Fig A/B, Nat C, minimum requirements- 9 somersaults)

3. How long have you been competing at this level for? (Years/months)

4. How many days a week on average do you do trampoline specific training?

5. How many hours a week on average is this?

6. Do you do any strength training? Yes/No If no please skip to Q10

7. If yes, how often do you do strength training in an average week? (Number of days and hours)

8. Please give examples of the types of exercises you do e.g. resistance machines

9. How long have you been doing strength training? (Years/months/weeks)

10. Do you do any power training? Yes/No If no please skip to Q14

11. If yes, how often do you do power training in an average week? (Number of days and hours)

12. Please provide details of the types of exercises e.g. plyometrics.

13. How long have you been doing power training? (Years/months/weeks)

14. Do you do any other training that has not been mentioned above? Yes/No

15. If yes, please provide further details e.g. what type of training it is and how often do you do it?
APPENDIX E

1RM Testing Protocol
1RM TESTING PROTOCOL

1. Instruct the athlete to warm up with a light resistance that easily allows 5 to 10 repetitions.
2. Provide a 1-minute rest period.
3. Estimate a warm-up load that will allow the athlete to complete three to five repetitions by adding
   - 10 to 20 pounds (4-9 kg) or 5% to 10% for upper body exercise or
   - 30 to 40 pounds (14-18 kg) or 10% to 20% for lower body exercise.
4. Provide a 2-minute rest period.
5. Estimate a conservative, near-maximal load that will allow the athlete to complete two to three repetitions by adding
   - 10 to 20 pounds (4-9 kg) or 5% to 10% for upper body exercise or
   - 30 to 40 pounds (14-18 kg) or 10% to 20% for lower body exercise.
6. Provide a 2- to 4-minute rest period.
7. Make a load increase:
   - 10 to 20 pounds (4-9 kg) or 5% to 10% for upper body exercise or
   - 30 to 40 pounds (14-18 kg) or 10% to 20% for lower body exercise.
8. Instruct the athlete to attempt a 1RM.
9. If the athlete was successful, provide a 2- to 4-minute rest period and go back to step 7.

If the athlete failed, provide a 2- to 4-minute rest period, then decrease the load by subtracting
   - 5 to 10 pounds (2-4 kg) or 2.5% to 5% for upper body exercise or
   - 15 to 20 pounds (7-9 kg) or 5% to 10% for lower body exercise

AND then go back to step 8.

Continue increasing or decreasing the load until the athlete can complete one repetition with proper exercise technique. Ideally, the athlete’s 1RM will be measured within three to five testing sets.