TITLE
HOW DIFFERING WARM UP TYPES AFFECT SHORT POWER PERFORMANCE

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1. ABSTRACT

The purpose of this study was to compare the effects on short power performance with the use of three different warm up protocols, utilising static, dynamic and a combination of these exercises. Nine undergraduate students (mean age 21.6 +/- 1.0) performed three different warm up routines in random order on non-consecutive days. The warm up protocols consisted of 5 minutes jogging then 10 minutes static stretching, 10 minutes of dynamic exercise or 10 minutes using a combination of both these warm up types. Following each warm up session, subjects were tested with a countermovement jump on a jump mat then a 40 m sprint with the first 10 m tested for acceleration.

Analysis of the data suggested no significant difference between countermovement jumps after undertaking each of the warm ups. A significant difference was established between the dynamic and static warm up (P ≤ 0.05) within the 10 m acceleration run although no significance was found in any other comparisons. In the 40 m sprint there was a significant difference when dynamic was related to static and mixed (P ≤ 0.05), however there was no difference when static and mixed warm ups were compared.

The results from this study suggest that a dynamic warm up is the preferable warm up, although this is not consistent in all activities as indicated by the differing results in the countermovement jump, suggesting further exploration. Generally the static stretching and mixed warm ups gave lower results than the dynamic warm ups, suggesting that the use of static stretching may be detrimental to performance. Because the results of this study indicate a performance enhancement with the dynamic warm up, the use of static warm up routines as a preparation activity should be reassessed.
CHAPTER I

INTRODUCTION
1. INTRODUCTION

All coaches and athletes aim to perform as well as possible, to the top of their ability with many different methods being utilised to try and perform better. These included differing training methods, improved equipment and manipulating their techniques. One area that had previously been relatively un-researched was that of the best warm up type (Fletcher et al, 2004). It is well known and researched that warm ups are required pre exercise as this will reduce injuries and prepare the body for the activity about to be undertaken (Young et al, 2002). Limited research has been undertaken as to what the best warm up should be to give the best results. Differing warm ups may make a difference upon performance due to physiological adaptations and responses by the muscles.

The focus of this study aims to research these effects caused by differing warm ups on short power performance. This area is currently under a lot of research, with arguments as to the benefits and drawbacks of some warm ups upon performance. In recent years thoughts and practice of static stretching as a warm up have reduced, being replaced by the use of dynamic exercises and sports specific movements. It could be an important factor to know, as athletes are continuously aiming to perform better with the difference between success and failure being so small. This is shown well in the 100 m sprint where the difference between first and last can be just fractions of a second.

It is suggested by previous research that the dynamic warm up is likely to give significantly better results when compared to static stretching (McMillan et al, 2006; Young et al, 2002; Faigenbaum et al, 2005; Little et al, 2006; Fletcher et al, 2004; Power et al, 2004 and Kokkonen et al, 1998), although the result of the mixed warm up in relation is relatively uncertain. This is due to a lack of research in this specific area. There is an element of controversy towards whether a static stretch is detrimental to performance. If it does not reduce performance then the mixed warm up will have the benefits of the dynamic warm up and the static warm up, resulting in equal or better results than the dynamic warm up on its own.
If the static stretching and the combination warm up are lower than the dynamic warm up it could prove static stretching is detrimental and should not be included in any part of a warm up before short power performances.

This investigation will be undertaken looking at three different warm up conditions, these are; a static warm up, a dynamic warm up and a combination of the two warm up types. The experiment will take place in the National Indoor Athletics Centre (NIAC) at the University of Wales Institute, Cardiff (UWIC). This will eliminate environmental factors such as temperature and wind which could affect results.

The tests chosen for this experiment will include a countermovement jump which will aim to give a value of the participant’s lower body explosive strength and a 40 m sprint, which will also have the first 10 m being timed. The aim of this will be to give results of the subject’s acceleration and also their maximum speed. Prior to these tests the participants will have completed the differing warm ups which will begin with a 5 minute jogging pulse raiser. Then the different warm up protocols will be undertaken covering each major muscle used within the exercises, these warm ups will last for 10 minutes. After the tests the data will be analysed to see if there are any significant differences in performance between these warm ups, showing which gives the best results.

If a significant conclusion can be drawn from this study by finding a warm up that produces better performances, athletes will be able to structure their preparation before their sporting activity to help them get better results.
CHAPTER II

LITERATURE REVIEW
2. LITERATURE REVIEW

2.1 Warm ups in Sport

This paper is aimed to research which warm up type produces the better performance in short power events. It is well established that warm ups are needed before performance to reduce injury and prepare the body (Alter, 1998). Warm ups before exercise are universally accepted, with the objective of preparing the athlete physically and mentally for optimum performance (Young and Behm, 2002). It is suggested that the purpose of pre exercise warm up is to increase muscle and tendon suppleness, to stimulate blood flow, increase body temperature and enhance coordinated movement (Smith 1994).

Athletes and coaches are always trying to increase performance, so if evidence suggests that a different warm up gives better results, then this is likely to be of interest to them for future adaptations. An improper warm up before exercise, has been shown to increase the chances of injury, so reducing this factor is important for prevention (Freeman, 1997). The best type of warm up is not completely understood and still causes discussion. A warm up is considered to be essential for optimum performance though there is little relevant evidence supporting its effectiveness in many situations. As a result, warm up procedures are usually based on the trial and error experience of the athlete or coach, rather than on scientific study (Bishop, 2003).

2.2 Differing Warm ups

Many people use a static warm up prior to exercise which is thought to prepare the body for physical activity (Alter, 1998). This stemmed from the belief that static stretching will aid performance and decrease injury risk (Little et al, 2006). Unick (2005) suggests stretching will decrease muscle stiffness leading to an increased range of motion, reduce pain and injury and improve performance.
The National Strength and Conditioning Association (NSCA) guidelines state that stretching before competition will improve performance and functional ability, even though many studies suggest it being negative. However there is little scientific evidence to support its usefulness unless the activity involves positions with joints beyond normal ranges of motion, such as gymnastics (Knudson, 1999).

Some research suggests that stretching provides an acute inhibition of maximal force production by the stretched muscle (Little et al, 2006). After exercise it is well agreed that it can reduce soreness and injury (Bishop, 2003). Most stretching programmes suggest holding a stretch between 6 and 30 seconds (Alter, 1998), they also suggests that holding for longer than 30 seconds causes problems as the session will end up lasting too long. However a study by Bandy and Irion (1994) suggests that 30 seconds of static stretching was as effective as the longer duration of 1 minute. Their report recommends two or three repetitions held for 10 seconds or one stretch held for 20-30 seconds. The change of flexibility is primarily due to connective tissues, whose permanent or plastic deformation is most favoured by low force, long duration stretching (Sapega et al, 1981). This is not always shown in the literature as some research looked at stretching warm ups where the stretches are held from 90 seconds up to an hour (Fletcher et al 2004). These are unlikely to be used by athletes for competition, causing the research to not be very beneficial.

Another common preparation prior to exercise is a dynamic warm up; this refers to the ability to use a range of joint movement in the performance of a physical activity at either normal or rapid speed (Alter, 1998). Professionals in the strength and conditioning community have increasingly suggested various dynamic warm ups as the best way to prepare athletes for the physical demands of their sport (Fletcher et al, 2005). McMillian et al, (2006) outline how the United States Army recently developed a dynamic warm up for use in the military. With static stretching removed from the warm up, they found that injury rate over the 9 week training period was significantly reduced and performance during testing was significantly increased.
The dynamic exercises used in a warm up should be appropriate to the movements that would be experienced in the sport (Brook, 2004). Jarver (2000) suggests drills should be completed over a distance of 10 -30 meters. Drills create patterns of movement, if executed properly lead to more efficient neuromuscular co-ordination and muscle warming to enhance performance (Jarver, 2000).

2.3 Applied Research

Most of the literature surrounding this area is recent and conducted within the last five years. This suggests it is a current issue that is still being researched. As studies are still being undertaken, this gives an indication that this area it is not yet fully understood and proven, especially with limited research published for a mixed warm up. Many studies have investigated the physiological responses to warm up, such as injury reduction, however relatively few studies have reported changes in performance following different warm ups (Bishop, 2003).

Some studies looked at specific sporting populations such as professional football players (Little et al, 2006) and trained rugby players (Fletcher et al, 2004). Although these produced valid results, the findings could only really be directed towards that particular specified population. In a study by Siatras (2003) they looked at the difference in approach speed within gymnastic vaulting due to differing warm ups, though they came to a valid conclusion, the results would only be able to benefit the minority of gymnasts aiming to increase approach speed.

A few studies give results that are more suited for the general population such as American military cadets (McMillan et al, 2006) and school children (Faigenbaum et al, 2005). These results can be related towards a larger population so will be beneficial to the general population rather than a specific sporting population. As warm ups are used within all sports and physical activities at all different levels and ages, then a study of a general population may give more beneficial results.
The studies reviewed look at the differences between a static warm up and a dynamic warm up with some studies adding a third warm up such as drop jumps (Faigenbaum et al, 2005) and no warm up (McMillan et al, 2006; and Little et al, 2006). Limited research has been undertaken to show the effects of mixing warm ups. Most studies have looked at warm ups exclusively with the same type of warm up exercises. In real situations athletes and coaches may use some stretches along with drills in preparation for performance, however limited articles have been conducted in reference to a warm up consisting of both static stretching and dynamic movements combined as a warm up. This may be a significant problem because many athletes will use a warm up that may have aspects of both warm up types, with no research to suggest if this is a positive or negative action upon their performance.

This is specifically highlighted by McMillian (2006) who suggest future research of warm up protocols that combine dynamic and static warm ups as it would add comparative value benefiting the research area, so they encourage them for future investigations. Very few studies have investigated this combined effect area. A study that looked reasonably close to this area was conducted by Church et al (2001) who combined a 10 minute circuit, utilising body weight exercises with static stretching and proprioceptive neuromuscular facilitation (PNF). The PNF warm up gave lower performances, so it was suggested that it inhibited the muscle therefore reducing the results. Their experiment does not use the dynamic warm up on its own to give comparisons to using no stretching, so it is more of a comparison between of static stretching and PNF rather than between static, dynamic and a combination of the two. It is indicated that a combination may not be detrimental on performance by Rosenbaum et al (1995), as their study indicated that reduced force and reduced rate of force returned to normal after 10 minutes of running. This suggests that stretching before exercise performance may not reduce power performance if followed by dynamic exercise that recreates the activity to be completed.
The majority of studies produced similar findings with some exceptions. It seems fairly well researched and proven that dynamic stretching gives better performance when compared to static stretching with this being found in a large number of studies (McMillan et al, 2006; Young et al, 2002; Faigenbaum et al, 2005; Little et al, 2006; Fletcher et al, 2004; Power et al, 2004 and Kokkonen et al, 1998).

The study by Little et al (2006) used no warm up as a test condition. Three out of their four measures showed no significant difference between static stretching and no warm up, recording similar results for each. This suggests that static stretching may not actually be detrimental to performance, instead it just had no benefit towards the performance. If it does not actively reduce performance when combined with dynamic activities the results of a combined session may be similar to dynamic on its own but have the advantage of the areas apart from performance, that stretching is thought to do, such as reducing the risks of injury and reduce muscle soreness (Alter, 1998), however this has not been researched. This is contradicted by Young et al (2002) as their study suggested that static stretching can significantly reduce performance. They suggest that a decrease of between 5% and 30% of strength and power production can occur, leading them not to recommend stretching before performance.

2.4 Methodological Considerations

Most warm up experiments used a sample size of between 10 and 16, this will allow for reliable statistical analysis. If any less are used there will be a reduction in the reliability when related to the population. Some tests have used more, up to 70 subjects (Faigenbaum et al, 2005). More subjects will produce stronger results but practically testing this large number can be very difficult. So within this experiment their should be a balance between having enough subjects to give significant results but not too many that its not practical to test that number of subjects, around 10 subjects would give a good sample size to draw valid conclusions.
Most research on comparisons of warm ups began with a pulse raiser which was for a duration of about 5 minutes either on a cycle ergometer or jogging, some did not use a pulse raiser and went straight into the planned warm up. Although within these papers no pulse raiser resulted in only the warm up that is being tested affecting the performance, a pulse raiser is recommended by many researchers because it increases the heart rate needed for exercise. As this research aims to look at muscular power with maximal sprints its important that the cardio vascular system is prepared. As it is not the cardiovascular system being tested this should have limited effects on the overall results, however to reduce the effects upon the results it would need to be standardized and part of each warm up, the duration and intensity will be the same for each experiment completed. Most athletes will begin a warm up with a pulse raiser, so to replicate a normal warm up a pulse raiser should be utilised in this study. A gentle pace for a time of 5 minutes should be used, as a pulse raiser should not involve fatigue because it has been shown to hinder local muscular performance (McMillian et al, 2006)

The warm up activities range throughout the literature with the actual movements and stretches used, however they all aim towards the same results. Warm ups using stretches to lengthen the muscles were used for the static warm up and movements to recreate the activity were used for dynamic warm ups, though the exercises were different, the same muscles were being used. Some used different warm up protocols such as drop jumping (Faigenbaum et al, 2005) and no warm up (McMillan et al,(2006); and Little et al, (2006). However conducting exercise without a warm up may be considered unethical as most literature suggests a warm up must be completed to reduce the risk of injury. A weakness present in some studies, who published their warm up, was that they were not always even, with McMillan et al, (2006) using sixteen dynamic warm up exercises and only 9 static stretches. This immediately suggests an uneven test as to get accurate results the warm ups should be of similar duration and intensity on each muscle, otherwise these factors may affect the results.
The tests used throughout the literature follow no consistency and are varied. They are used to test certain variables including speed, power, agility and flexibility. There are many different tests; however they are chosen specifically to measure a certain variable. Tests should be chosen that measure the variable being looked at and are suited to the subject’s experience and performance levels.

2.5 Statistical Procedure

Some of the previous papers used 2 testing procedures then used a t-test to analyse (Kokkonen et al, 1998). This test uses the major assumption that the variability within the groups are equal (Salkind, 2000). This assumption is removed if the sample is large enough, however small sample sizes can lead to indefinite results and conclusions (Salkind, 2000). This type of statistical analysis is not the most common throughout the literature. The common method used is a repeated measures analysis of variance (ANOVA). An ANOVA is a parametric statistical technique used to determine whether significant differences exist among the means from three or more sets of sample data (Vincent, 1999). The reason for a repeated measure ANOVA is because the participants will be tested more than once (Salkind, 2000). The ANOVA compares the variability among the groups means, the between group variability with the variability of scores within the group, giving an F score. If the between group variability exceeds the variability of scores within the group by more than would be expected by chance alone, it may be concluded that a group differs significantly to another (Vincent, 1999). A significant F score alone does not specify which groups differ from one another; it only indicates there are differences somewhere. To identify the groups that differ significantly from one another, a post hoc test must be performed (Salkind, 2000). The significance used by most papers is set at $P \leq 0.05$. This will indicate a 95% certainty of the results being valid and reliable.
2.6 Summary

Although much of the research is strong there are some weaknesses within the data, the biggest being the missing research of people using more than one type of warm up in preparation to sporting activity. This is a problem as it may suggest the athletes are not getting the best of a warm up if a combination is seen to perform better, especially as previous research by Little et al (2006) may suggest that stretching may not be detrimental to performance. The research also generally looks at testing within specific sporting groups so general studies utilising a range of sports may be required to evaluate a general sporting population.

Links can be made within the research and ideas can be generated such as dynamic stretching being beneficial and static detrimental, though the contradictions between static stretching actually decreasing performance or just having no positive effects is an area not agreed upon. If it does not reduce performance then the mixed warm up will have the benefits of the dynamic warm up and the static warm up, resulting in equal or better results than the dynamic warm up on its own. If the combination is lower than the dynamic warm up it could prove static stretching is detrimental and should not be included in any part of a warm up before short power performances. The result of the mixed warm up in relation is relatively uncertain, due to the lack of research. With many people using both static stretching and dynamic warm ups it is not known the effects this is having upon performance. Therefore research is required upon the area in between the two looking into combinations of warm ups.

2.7 Research Problem

After concluding the current literature this paper specifically aims to answer the question; How differing warm up types effects short power performance. The three different warm up protocols that will be tested are a static warm up, a dynamic warm up and a combination of the two warm up types. They will be analysed after completing three tests which will be a countermovement jump and a 40 m sprint for speed, with the first 10 m being timed for acceleration.
2.8 Hypothesis

After concluding the literature a number of hypotheses can be suggested as to the outcome of the research question.

- **H1** A dynamic warm up will produce a significantly different performance compared to a static warm up

- **H2** A dynamic warm up will produce a significantly different performance compared to a mixed warm up

- **H3** A static warm up will produce a significantly different performance compared to a mixed warm up

2.8.1 Null Hypothesis

- **N1** A dynamic warm up will produce no difference compared to a static warm up

- **N2** A dynamic warm up will produce no difference compared to a mixed warm up

- **N3** A static warm up will produce no difference compared to a mixed warm up
3 METHOD

3.1 Experimental Approach to the Problem

Within this study the aims were to compare the effects of different warm up protocols looking at three different warm up conditions, which were; static warm up, dynamic warm up and a combination of the two warm up types covering each major muscle used within the exercises. A group of undergraduate students performed 3 different warm up protocols in a random order on non consecutive days. All participants conducted a standard pulse raising activity prior to the selected warm up. Following each warm up, the participants completed 2 tests chosen to look at the power of the lower body. This study allowed comparisons to be made to the effectiveness of different warm ups on power performance. A pilot study to ensure the method was successful was conducted on the 9th December 2008, with any weaknesses encountered causing adaptations to the protocol to increase the reliability and validity of the study.

3.2 Participants

Nine participants volunteered from the University of Wales Institute, Cardiff (UWIC) to take part within this study. One participant partially withdrew because of injury or other adverse experiences. The participants volunteering for this study were healthy sports students from a variety of sports who have competed at county level or above, with the final sample consisting of nine students (9 Male). The mean age of participants who completed all study procedures was 21.6 +/- 1.0. All of the participants participated in regular training at least three times a week. They also had previous experience with the equipment due to attending compulsory undergraduate lectures based on the tests.
The methods and procedures used in this study were approved by the UWIC Research Ethics Committee (UREC) for use of human subjects at the university. Participants gave written and oral consent and were required to sign and date a consent form (appendix A). Also a physical activity readiness questionnaire (PAR-Q) was completed before beginning the experiment (appendix B).

Participants were randomly assigned the order in which to complete the three warm up protocols; static warm up, dynamic warm up and a combination of the two, they were also directed to wear suitable attire.

3.3 Equipment

The experiment took place in the National Indoor Athletics Centre (NIAC) at the University of Wales Institute, Cardiff (UWIC). This facility provided an indoor area so the results were not affected by weather and the conditions were the same each time tests were conducted. The facility was designed for sprinting, so the risk of slipping and causing injury was reduced.

There are a number of pieces of equipment needed for this study, they included, a tape measure used to mark the running distance, a stop watch to ensure the length of warm ups and time between tests remained the same. Finally light gates (Smartspeed, FusionSport, Australia) were used to give accurate timing over 20m and 40m and a vertical jump mat was used to asses jump height.

3.4 Procedure

The warm ups lasted for 10 minutes which ensured the warm ups were similar length but also avoid fatigue. Each test was separated by a minimum of 24 hours, so that the results were not affected by each other. The sessions aimed to be as close together to reduce the effects that individuals training for their sports may have upon the results.
The main large muscles used in sprinting are the gluteus maximus, quadriceps femoris, hamstrings, calves and in the upper body the arms and shoulders (Newsholme et al 1985). This group of muscles also covers the main muscles used within jumping. For this reason the warm ups ensured they covered all these major muscles to ensure the risk of strains and muscle tears is efficiently reduced. Each warm up session lasted 10 minutes and was supervised by the investigator. The warm up sessions were performed in a random order.

Aside from the static stretching/dynamic aspects of the warm up, the sessions followed the exact same procedure, consisting of the following:

- 5 minutes jogging around the indoor athletics track, approximately 800 m.
- The different stretch protocols were completed.
- Following the warm ups there was a three minute break in which if the participant felt any part of their body required further warming up they could do so. This was monitored to ensure they only did exercises that fit with the warm up being tested, such as only stretches if it was static warm up being tested on that occasion.
- A series of three jumps was conducted with a gap of 30 seconds between the start of each jump. The test was repeated three times.
- After the final jump, 90 seconds rest was to be given before the first sprint.
- The athlete performed a sprint over a distance of 40 m. This sprint also had the first 10 m being timed.
- After each run a 2 minute recovery period was given in order to prepare for the next sprint and limit fatigue. Again the test was repeated three times.

This organised time between each test resulted in from finishing the warm up to finishing the tests took just 10 minutes, this resulted in the reduction of the participant cooling down or the tests acting as a warm up and affecting the results.
3.5 Warm up Protocols

3.5.1 Static Stretching

Within the static stretch warm up, five stretches (Table 1) were conducted using the major muscles needed for sprinting and jumping. Most stretching programmes suggest holding a stretch between 6 and 30 seconds (Alter 1998). The participant performed each stretch in a slow deliberate manner with proper body alignment as suggested by Faigenbaum et al (2005). The stretches were held for 10 seconds at the point of discomfort, and then relaxed for 5 seconds. Participants then repeated the stretch before changing to the other limb. When the combination of warm ups was conducted this was reduced to 1 repetition.

**Table 1.** The stretching exercises used within the static warm up

<table>
<thead>
<tr>
<th>Stretching Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gluteus maximus stretch- Lie on back with one leg extended, pull the other leg towards the chest by the knee.</td>
</tr>
<tr>
<td>2. Quadriceps femoris stretch- Stand holding onto something for balance, flex one knee and raise the heel to your Gluteus maximus.</td>
</tr>
<tr>
<td>3. Hamstrings stretch- Sit on the floor with one leg straight with the other bent at the knee with the heel touching the inside of the opposite thigh. Stretch down to hold the ankle.</td>
</tr>
<tr>
<td>4. Calve stretch- Lean forward against a wall with one leg bent forward and the other leg extended. Keep the rear foot flat on the floor with both feet pointing forwards. Bend the arms and lean towards the wall.</td>
</tr>
<tr>
<td>5. Arms stretch- Flex one arm overhead next to your ear with the hand by the shoulder blade. Grasp the elbow with the other hand and pull the elbow behind the head.</td>
</tr>
</tbody>
</table>
3.5.2 Dynamic Warm up

The dynamic warm up consisted of controlled movements through the active range of motion for each joint (Fletcher et al., 1998). Five drills were conducted (Table 2) to utilise all the main muscles used within sprinting and jumping. Each drill moved the muscles through the motions likely to be encountered within the activity. These drills were being completed over a distance of 10 meters at jogging pace which is the suggested distance by Jarver (2000). Each drill was being repeated twice to ensure the muscle was warm.

**Table 2.** The stretching exercises used within the dynamic warm up

<table>
<thead>
<tr>
<th>Dynamic Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gluteus maximus drill- High knee drill, jogging while emphasising lifting the knees so that the femur is at a 90 degree angle to the body. As many as possible were conducted within the set distance. Participant remains high with upright posture and on toes.</td>
</tr>
<tr>
<td>2. Quadriceps drill- (Leg flicks). Jog with straight legs flicking forward each time. Participant remains high with upright posture and on toes.</td>
</tr>
<tr>
<td>3. Hamstrings drill- (Heel flicks). Jogging with heels flicking up towards gluteus maximus. Femur remains in line with the body. Participant remains high with upright posture and on toes.</td>
</tr>
<tr>
<td>4. Calve drill- Bouncing on the toes. Walking while rolling the foot from heel up to being on the toes. Participant remains upright and tall throughout.</td>
</tr>
<tr>
<td>5. Arm drill- Arm rotations. Arms rotate around the shoulder joint. Around the maximum range with the arm brushing the ear each time.</td>
</tr>
</tbody>
</table>
3.5.3 Combination Warm up

With the combination of the warm ups both the static and dynamic warm up were utilised. The two different warm ups were put together to form the protocol. As each the static and dynamic warm ups used two repetitions, within this warm up protocol only one repetition of each exercise was used. This allowed for the combined warm up to have the same number of exercises as the other two, meaning the time of the warm up was similar to the previous. This was decided as it is important for each major muscle to have a combination of static and dynamic. Without this would mean that different muscles may have experienced different warm ups i.e. the hamstring had a static warm up only and the calves had a purely dynamic warm up. As this warm up aims to look at the effects of a combination of warm ups it’s important to ensure each muscle is exposed to each warm up type.

3.6 Testing Protocols

3.6.1 Countermovement Jump Protocol

The counter movement jump test followed the protocol published by the Australian sports commission (2000), the participant began by standing on the contact mat with their hands on their hips and had to remain on the hips for the duration of the jump. They then aimed to jump to a maximum height, including a dip or countermovement directly before taking off. The participant had too land on the balls of their feet in an upright extended position with full extension at the hips, knees and ankles. Once contact had been made the knees were allowed to bend to soften the impact of landing. If the knees were to bend before landing a falsely elevated flight time would have been recorded.
The participant performed a sprint over a distance of 40 m. This sprint also had the first 10 m being timed. This gave results of the participant’s acceleration and also their maximum speed. The test procedure is conducted as suggested by the Australian sports commission (2000). It started with the timing gates being set at the correct positions with a clear starting and finishing line. The starting position was standing with their preferred foot on the start line. They started when ready, eliminating reaction times. The participant broke the first light gate starting the timer. They sprinted as fast as possible towards the other gates stopping the time. They had to ensure they did not slow down before reaching the final gate. After each run a 2 minute recovery period was given in order to prepare for the next sprint and limit fatigue.

### 3.7 Data Analysis

The results were recorded electronically using Microsoft Excel and the data was analysed using the Statistical Package Social Sciences (SPSS, Inc. Chicago, IL). Descriptive statistics including the mean score and standard deviation of the results for each condition of the test were calculated.

Sprint performance was reported as seconds (s) and the countermovement jump results were reported as centimetres (cm). A repeated measures ANOVA was performed on the results to analyse differences between measures following the three differing warm up protocols. When a significant $F$ value was achieved, post hoc comparisons were completed using a Bonferroni Test to identify specific differences between trials. Statistical significance was set at $p \leq 0.05$. 
3.8 Ethical Consideration

The participants who agreed to take part understood that they were able to leave at any point and careful consideration has been given to the individual's privacy. For this reason their results remained confidential and not specified to each individual, although it could form the basis of eventual scientific publications or presentations. All consent and medical questionnaires remained confidential with any issues arising being discussed with only the participant involved.
CHAPTER IV

RESULTS
4. RESULTS

The results from this study suggest that there are differences within the means of the different warm up protocols in each test. Significances are shown to be within the 10 m acceleration run and within the 40 m sprint times. No significance is reported within the countermovement jumps.

4.1 Countermovement Jump

Figure 1 illustrates the countermovement jump height after completing differing warm up protocols. Mean height for each warm up was recorded as dynamic (40.54 +/- 5.73 cm), static (40.49 +/- 6.81 cm) and mixed (39.50 +/- 5.20 cm). This represents little variance in height and standard deviation within each warm up condition. Overall the standard deviation was reasonably high suggesting a large variance between participants; however this large variance is present throughout all of the warm up conditions.

**Figure 1.** The mean and standard deviation for the counter movement jump height for the three warm ups tested
Table 3 indicates where the significance lies between the warm up conditions for the counter movement jump. It shows the significant differences between each group when groups are compared. This high level of non-significance suggests that there is no significant difference between the two sets of data.

Table 3. The significance comparisons for the counter movement jump height for the three warm ups tested

<table>
<thead>
<tr>
<th>Warm up Conditions (CMJ)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>1.000</td>
</tr>
<tr>
<td>1-3</td>
<td>0.287</td>
</tr>
<tr>
<td>2-3</td>
<td>0.640</td>
</tr>
</tbody>
</table>

4.2 10 m Acceleration Run

Figure 2 shows the 10 m acceleration sprint speed after completing the differing warm up protocols. Mean height for each warm up was recorded as dynamic (1.77 +/- 0.08 s), static (1.81 +/- 0.08 s) and mixed (1.77 +/- 0.05 s). There is a slight variance in time and standard deviation within each warm up condition. It suggests a slight difference between static and dynamic and no difference between mixed and dynamic. Overall the standard deviation was very small and similar throughout the conditions, suggesting limited variance between the participants throughout all of warm up conditions.
Figure 2. The mean and standard deviation for the 10m acceleration for the three warm ups tested

Table 4 illustrates where the significance lies between warm up conditions for the 10 m acceleration run. It shows the significant differences between each group when groups are compared. It is suggested that there is a significant difference between conditions one and two (P < 0.05), but illustrate no significant difference when conditions one and two are compared to condition 3.

Table 4. The significance comparisons for the 10 m acceleration for the three warm ups tested

<table>
<thead>
<tr>
<th>Warm up Conditions (10m)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>0.000</td>
</tr>
<tr>
<td>1-3</td>
<td>0.250</td>
</tr>
<tr>
<td>2-3</td>
<td>0.237</td>
</tr>
</tbody>
</table>
4.3 40m Sprint

Figure 3 shows the 40 m sprint speed after completing the differing warm up protocols. Mean height for each warm up was recorded as dynamic (5.52 +/- 0.25 s), static (5.62 +/- 0.27 s) and mixed (5.64 +/- 0.27 s). There is a variance in speed and a minimal difference in standard deviation within each warm up condition. It suggests a slight difference between static and dynamic and also between mixed and dynamic. Overall the standard deviation was very small and similar throughout the conditions, suggesting limited variance between the participants throughout all of warm up conditions.

Figure 3. The mean and standard deviation for the 40 m sprint time for the three warm ups tested
Table 5 illustrates where the significance lies between warm up conditions for the 40 m sprint. It shows the significant differences between each group when groups are compared. This suggests that there is a significant difference between conditions one and two and also between conditions one and three ($P < 0.05$). However there is no significant difference when condition two is compared to condition 3.

**Table 5.** The significance comparisons for the 40 m sprint time for the three warm ups tested

<table>
<thead>
<tr>
<th>Warm up Conditions (40m)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>0.000</td>
</tr>
<tr>
<td>1-3</td>
<td>0.003</td>
</tr>
<tr>
<td>2-3</td>
<td>1.000</td>
</tr>
</tbody>
</table>
CHAPTER V
DISCUSSION
5. DISCUSSION

5.1 Findings

The results from this study indicate that there are differences in performance as a result of utilising different warm up protocols. Significant differences were shown to be present within the 10 m acceleration run and within the 40 m sprint times. No significance was reported within the countermovement jumps.

All nine participants successfully completed the countermovement jump three times after each of the three warm up conditions. Each participant’s results were calculated to give a mean of their performance, from which the mean, standard deviation and an ANOVA were completed comparing each warm up condition.

Mean height for each warm up was recorded for the countermovement jump as dynamic (40.54 +/- 5.73 cm), static (40.49 +/- 6.81 cm) and mixed (39.50 +/- 5.20 cm). Though only slightly different, dynamic had the best average performance followed by static and then mixed. However once a repeated measures ANOVA and post hoc test were completed it was determined that no significant difference was attained between comparison of any of the groups. The significance levels were very high especially between static and dynamic (P = 1.000). The standard deviation in each group was relatively high up to 16.8% either way. This suggests a large variance between subjects; however this high standard deviation is the same throughout all three conditions so it will not make any difference upon the final results. For this part of the experiment all of the hypothesis must be ignored with the entire null hypothesis being accepted as no significant difference was found.

Shortly following the countermovement jumps all the participants undertook the 40 m sprint with the first 10 m being tested for acceleration. Again each participant’s results were averaged and the same tests undertaken as the jumps. Mean 10 m time for each warm up was recorded as dynamic (1.77 s +/- 0.08 s), static (1.81 s +/- 0.08 s) and mixed (1.77 s +/- 0.05 s). Again the dynamic exercise gave the fastest results but this time followed by mixed and then static.
Once the repeated measures ANOVA and post hoc test were completed it is suggested that there is a significant difference between the conditions of dynamic and static warm ups ($P \leq 0.05$). There was no significant difference when dynamic and static were compared to mixed. The standard deviation within each warm up is very small, again this is seen in all warm ups showing limited variance between the subjects throughout all of warm up conditions. For the 10 m acceleration run H1 can be accepted, however H2 and H3 must be ignored and the null hypothesis accepted.

When the results from the whole 40 m sprint were analysed mean height for each warm up was recorded as dynamic (5.52 +/- 0.25 s), static (5.62 +/- 0.27 s) and mixed (5.64 +/- 0.27 s). As with all of the tests dynamic warm up had the best mean, followed by mixed then static. After statistical analysis it was shown that there was a significant difference between dynamic and static ($P < 0.05$) and also between dynamic and mixed ($P \leq 0.05$). However there was no significant difference when static is compared too mixed. The standard deviation within each warm up was also very small, again this is seen in all warm ups suggesting limited variance between the participants throughout all of warm up conditions. For the 40 m sprint H1 and H2 can be accepted with H3 being rejected for the null hypothesis.

5.2 Comparison to Literature

These results in part agree with the literature. The 40 m sprint and the 10 m acceleration run had significantly better times when using the dynamic warm up when compared to the use of a static warm up. The mixed warm up for the runs is unable to be compared to literature due to lack of previous research. However it is confirmed that it gave significantly lower performances in the 40 m sprint when compared to the dynamic warm up suggesting that the static aspect of the warm up reduced the performance, this is because it had the dynamic aspect so the performance would be of equal levels if static was not detrimental. Results overall indicating the dynamic warm up is the best method of pre exercise warm up.
Rosenbaum et al (1995) looked at performance after stretching, their study indicated that reduced force and reduced rate of force returned to normal after 10 minutes of running. If these results for the mixed warm up are compared to this study then it could be suggested that the mixed warm up may have given different results if it was longer, with 10 minutes of dynamic exercise being conducted after the static stretching rather than the complete warm up being 10 minutes long which is was a mixture throughout. However in this study it can be concluded that with warm ups of the same duration a mixed warm up will give a lower performance over a 40 m sprint.

In relation to the countermovement jump the dynamic warm up gave a slightly higher mean, however this was not supported with any significance even though some other studies found that the dynamic warm up gave significantly better results. In relation to this study it can be said that differing warm ups do not affect countermovement jump performance. There is an element of controversy within the studies looking at warm ups on jump height. Young (2003) found significantly lower results due to a static stretch warm up, with Church et al (2001) finding mixed results depending on what stretching was used. Further discrepancies are suggested because Unick et al (2005) and this study found no differences at all. These may not be able to be compared directly due to different warm up protocols being used, as Unick et al (2005) used just female subjects and Young (2003) used just male subjects, possibly suggesting gender differences.

Previous research has often performed the stretches for much longer durations than normally used in competition. Such long stretching times may cause neural and excessive mechanical force inhibitory mechanisms (Fowles, 2000). The amount of stretching that must be performed to see the immediate effects of muscle stiffness is unknown (Unick 2005). It is possible that the duration of stretching of just 10 seconds which was thought to recreate a normal athletes warm up, may have been too small for the muscles elastic properties to change. Although this may be questioned as a significant difference was found in this study within the sprints. Research also indicating static stretching is detrimental often used slow actions such as one repetition maximum (Little et al 2006).
As there was no significance within this test but there was in the sprints it can be suggested that jumping performance is not related to sprint speed. These results may be due to a systematic bias. This may be because the countermovement jump was the first test, so the effects of this test may have affected the results of the other tests. As this was the first test Rosenbaum et al (1995) theory of reduced rate of force returning to normal after 10 minutes of exercise, can be challenged because if any detrimental effect of static stretching reduces over time then the countermovement jump is the most likely to have shown a detrimental effect upon performance.

The results may have been different if the tests were conducted in a different order. Ideally the countermovement jump and sprint tests should be completed on separate days but this was not possible due to time restraints. The differing effects from warm ups on countermovement jumps in this study suggest future research is needed.

5.3 Scientific Reasons for Results

In a review article looking at warm up literature by Bishop (2003) suggestions are made for reasons why a dynamic warm up may improve short term performance. The majority of the reasons stated were suggested to be due to temperature, they included reduced stiffness within the muscles and joints, changes in the force velocity relationship, higher rate of nerve impulses, improved glycolysis and high energy phosphate degradation. This higher core muscle temperature is due to the dynamic warm up being much more active (Fletcher et al 2004), also a dynamic warm up has the benefit of the built in walk back recovery. An active warm up is reported to reduce muscle stiffness by breaking the bonds between actin and myosin filaments (Bishop, 2003) although this is not likely to be a significant factor as Taylor et al (1997) also suggests static stretching has the same effect.
As well as these temperature related suggestions McMillian et al (2006) reported possible neuromuscular reasons that could have been activated by the dynamic warm up that could potentially increase power and agility performance. The first of these was called postactivation potentiation, described as an increase in muscle twitch force and rate of force development following a conditioning contractile activity, which is thought to improve power and agility performance. However when postactivation potentiation and its role in performance was reviewed by Sale, (2002) the optimal levels were unknown and with many contradictions and variations there was a demand for future trial and error experiments.

McMillian et al (2006) suggests a second neuromuscular adaptation which was post-contraction sensory discharge which is increased neural activity measured in the dorsal roots following contraction, which Enoka (2002) suggests may enable a quicker and stronger response to change in muscle length, again this is not fully understood and it is suggested further research is required. A final suggestion for improved performance is given by Fletcher et al, (2004) who suggest a dynamic warm up gives the rehearsal of movement in a more specific pattern than static stretching. It may be that the dynamic movement rehearses the movement pattern co-ordination allowing muscles to be exited earlier and faster.

With the results from the mixed warm up it can be noted that static stretching was detrimental to performance as the mixed warm up will have had all the same benefits of the dynamic warm up, however the actual performances were lower which must have been a result of the static warm up. This reduced performance due to pre exercise static stretching has a number of suggestions when compared to the dynamic warm up. It is thought that stretching causes an increase in length of the tendon, causing a short period where the force of the muscle is taking up this excess in the tendon rather than causing movement, which could reduce performance (Kokkonen et al, 1998). This idea of a change in tendon structure is also suggested by Kubo et al (2001) but this research does not suggest the length changes rather that the tendon becomes more resistant, resulting in a lower rate of force production and a delay in muscle activation.
Another explanation is given by Behm (2001) who suggests reduced neural activation is caused by repeated stretching reducing the number of motor units being available for contraction. These neuromuscular adaptations are supported by Rosenbaum et al (1995) who used electromyography (EMG) to prove a decrease of fibre excitation within the muscle contraction after stretching.

Throughout this experiment neuromuscular measurements were not taken, their effects upon performance due to differing warm ups can only be taken as suggestions. Future research would need measurements of these to make stronger conclusions. This is indicated by Knudson et al (2001) who hypothesised that the decrease in vertical jump performance in their study was a result of a decrease in neuromuscular transmission, because they found no difference in the kinematics of the movement.

Although stretching is shown to be negative on performance pre-exercise it should be noted that it may not apply to stretching at other times. Improved performance has been related to regular stretching and flexibility. In an evaluation article by Shrier (2004), it is concluded that regular stretching improves force, jump height, and speed; although there is no evidence that it improves economy. This shows that there are times when stretching is beneficial, though pre-exercise stretching should be avoided.

5.4 Weaknesses

Throughout this research a number of weaknesses appeared, mainly regarding the participants involved within the testing. All the participants who were tested in the study were male. Although the experiment was not restricted to a gender, this single gender occurred due to chance as to who was willing and able to be a participant. Although the long term history of the participants was confirmed, including medical history and that they fitted the criteria of study being a healthy sports student, their short term history was not considered. This short term history may have affected the results; this may include hydration, recent food intake and recent physical activity participation especially as the sessions were at different times of the day.
These could be reduced by monitoring and structuring their diet, ensuring no physical activity is completed prior to testing and that the testing took place at the same time of each day.

Minor injuries may have affected the results, though some injuries would stop the participant from being tested minor injuries such as muscle soreness and slight pain may affect the outcomes. This could be reduced by ensuring a suitable time frame before which does not include physical activity.

Participants were instructed to wear similar kit to all testing sessions, however some did not follow this throughout the sessions with participants wearing different shoes and people wearing trousers instead of shorts, possible solutions could include participants only being able to take part in the same clothes each time or have a standardised kit for all participants to wear.

Some sessions had more participants than others as some had a single participant while other sessions had a number of people waiting to be tested. Single participants may have performed differently to when a number of participants were present. Although the results remained confidential so competitiveness with results was reduced, confidence and motivation may be affected by the presence of others, (Russell, 1983). By running all sessions either with the same people present or with the participant being on their own could reduce this aspect causing variance on results.

Although the participant numbers were reasonable the study would benefit by having a larger sample size. This will enable it to carry a greater weight and show stronger representations within the general population.
Once the data was collected it made a difference on the significant values how the raw data was sorted. If the participants best performance were used then no significance was found, however when an average was taken a significance was found. This suggests a weakness throughout all of the data including published work. To reduce this, all research should make it clear how the data was organised so that the same method can be utilised in all research throughout the area.

5.5 Future Research

This study could be developed further with some future directions and slight modifications. Firstly measures could be taken to reduce the mentioned weaknesses. Gender was meant to be mixed within the study, however as this did not happen the research could benefit by also including females performance after differing warm ups. With the mean age of 21.6 +/- 1.0 the age range was very limited. A further study could include participants of a much larger age range, which may increase the size of the population the findings can be related too.

As the warm ups affected the countermovement jump differently to sprinting, a study could look at a larger range of activities to see how warm ups may affect different areas, allowing a broader range of activities to understand the most beneficial warm up. As well as different activities a study could look further in depth at the different warm ups, to give a stronger understanding of the most effective warm up, this may include manipulating the duration and the activities included within the warm up.
5.6 Practical Applications

Overall this study will be constructive upon the current literature as it fills some gaps in the suggested future research indicated by McMillian (2006) and compared the use of a combined warm up giving significant results that follow the trends with power performances in the 10 m acceleration and the 40 m sprint. The dynamic warm up had the best mean in the countermovement jump, but this was not significant, which does not follow the trends of research, suggesting direction should be made to analyse other activities to understand the best warm up for each activity.

5.7 Conclusion

The countermovement jump suggested results against the majority of studies, however there are a few that found similar results, this suggests the need of further research as there is controversy to the effects that differing warm ups have on this activity.

The acceleration and sprint performance of active sports undergraduates can be improved by using a dynamic warm up. The use of static stretching seems to decrease the participant’s performance. Athletes should be aware of these possible static stretching negative effects, as well as the possible improvements by utilising a dynamic warm up. It should be remembered that these results are means recorded from a number of participants, not all participants followed this trend, as a few had a lower performance after the dynamic warm up and better results with the static warm up. Therefore it can be concluded that most sports performers will benefit from a solely dynamic warm up when competing in power performances, rather than use static warm up activities. However care should be taken for the small number of people who do not follow the trend and show the positive benefits as shown in this study.
CHAPTER VI
REFERENCES
6. REFERENCES


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Fletcher, I. and Jones, B. (2004). The effect of different warm up stretch protocols on 20m sprint performance in trained rugby players, *Journal of strength and conditioning research, 2*, 885- 888


Young, W. and Behm, D. (2002). Should static stretching be used during warm up for strength and power activities, *Strength and conditioning journal, 24*, 33-37

APPENDIX A
Subject: ___________________________ Sex: M / F
Date of birth: ______________________

Investigator: Graham Filer

Title of the Study: How different warm up effects power performance

Objectives and Procedures to be Employed
Prior to reading and considering the information below it is important that you are aware that the exercise test and measurement techniques have been examined by an ethics committee, which has accepted that the proposed study is suitable for use with consenting, human subjects.

Objectives
The main aims of this study are;
1) To analysis different warm ups and report whether they have any effect on power performance.
2) Is there an optimum warm up for power performance?

Exercise Protocol
Subjects will be performing a different standardized warm up on three separate occasions. These warm ups will include a static, a dynamic and a combination of the two. Once the warm up has been completed the subject shall perform a countermovement jump on a jump mat. This will be repeated three times. Directly after this the subject will run over a distance of 40m being timed over the first 10m for acceleration and the full 40m for their speed using the smart speed timing equipment. This will be repeated three times.

Potential Risks
The risks outlined below will only apply to a small amount of the subjects. However, it is important you are made aware of the possible outcomes in order to provide written, informed consent to participate in this study.

During Exercise
The symptoms that you as a subject may experience while participating are unlikely to be encountered; however these must be mentioned for Health and Safety reasons. They are Strains, muscle and non-muscular injuries from improper movement or technique

Following Exercise
The symptoms that you as a subject may experience include light-headedness, disorientation, feeling faint and nauseous. These may be caused by physical exertion. By conducting a proper warm down these should be avoided.

Benefits
In becoming involved in this study you will enable me to collect data which forms part of a physiology dissertation research question. The findings will provide more understanding of whether different warm ups have any influence on power performance.

The Data Collected
All data that will be collected will remain anonymous will be handled with completed confidence.

I have been made fully aware of the risks and benefits involved from partaking in the present study. I understand that I am free to withdraw from the study at any time and that the results of the study will be treated anonymously and with total confidentiality.

Signed________________________                               Date  ________________________

NB – The University and its staff accept no liability for any matters arising, either directly or indirectly, from the information and recommendations given to you as a result of the outcomes of your test. It is the responsibility of the athlete to ensure that the Sport Scientist is aware of any medical conditions or other information that might affect either the test itself or the interpretation of the results and subsequent recommendations.
APPENDIX B
Physical Activity Readiness Questionnaire (PAR-Q)

Name-________________________________________________________

D.O.B-________________________

This questionnaire is designed to assess your physical fitness to ensure your suitability to partake in exercise tests. Please read the questions carefully and circle YES or NO to each question. Circle whichever applies best to you.

1) Has your doctor ever said you have heart trouble?                                                YES / NO
2) Do you suffer with asthma or any breathing problems?                                              YES / NO
3) Do you feel pains in your chest when you partake in physical activity?                          YES / NO
4) Do you have a bone or joint problem that could be made worse by a change in your physical activity?  YES / NO
5) Has a doctor ever said your blood pressure was too high?                                        YES / NO
6) Do you lose your balance because of dizziness or do you ever lose consciousness?            YES / NO
7) Are you unaccustomed to physical activity?                                                      YES / NO
8) Are you currently taking any medications?                                                         YES / NO
9) Is there a good physical reason not mentioned, why you should not take part in a fitness test?    YES / NO

If you answered yes to any questions, please give more details;
_____________________________________________________________________________
_____________________________________________________________________________

If you answered NO to all questions above, it gives an indication that you may participate in physical testing. You answered NO to the above questions; however this is no guarantee that you will have a normal response to exercise. If your health situation changes before partaking in the testing, please notify the investigator.

______________________        _____________________        _____________________
Subjects Name       Signature                                   Date

______________________        _____________________        _____________________
Investigators Name   Signature                                   Date