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Comparison of an Active Warm-Up vs. Passive Warm-Up on Vertical Jump Performance

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ABSTRACT

Warm-ups are an essential element of exercise and sport performance. Although research has demonstrated benefits associated with active warm-ups, research investigating the effects of a passive warm-up on subsequent performance is limited. The purpose of this study is to compare the effects of an active, post-activation potentiation (PAP) warm-up to a passive warm-up on vertical jump performance.

Study participants were randomly assigned to one of two groups. Each group performed both the active and passive warm-ups, in reverse order, to control for order effect. Participants in this study consisted of 20 college students (men and women) between the ages of 18 and 35 years who were well-trained and anaerobically fit.

A repeated measures ANOVA revealed a statistically significant main effect difference in vertical jump measures (F=16.148, p<0.001). Further analysis of the results demonstrated that between the three treatments tested, control, active, passive, there was a statically significant difference between the active warm-up when compared to both the passive and control warm-ups (p=0.004; p<0.001). The results also indicated that there was practical significance between the active and passive treatment as well as the control group (partial eta squared=0.459).

In conclusion, an active warm-up prior to vertical jump testing appears to be superior to a passive warm-up. Physiologically the body may perform better following dynamic movements rather than through a passive increase in intramuscular temperature. Prior to athletic events, we recommend athletes perform warm-ups utilizing dynamic movements rather than using a heating system alone.

Keywords: lower body power, post-activation potentiation, strength and conditioning, warm-up.

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I. INTRODUCTION

Because warm-ups are utilized to improve subsequent performance, they aim to improve physiological changes such as improved maximal force, higher peak acceleration, and/or a faster rate of force development brought on through increased motor unit recruitment, increased activity of synergistic musculature, muscle spindle firing, as well as a reduced inhibition of the Golgi apparatus. According to the research, activating these effects might be achieved through warm-ups classified as either active, including jogging, calisthenics, cycling and swimming, or passive activities that simply aim to increase muscular temperature by means of hot showers or baths, saunas, diathermy, and heating pads1. Among the different active and passive warm-ups utilized, there are also less traditional methods of readying the body for activity that have demonstrated an increase in performance. These methods are referred to as Post-activation Potentiation (PAP) warm-ups. PAP is defined as an enhanced neuromuscular state observed after the execution of a high intensity exercise (Bishop, 2003; Smith *et al*., 2014). This form of muscle activation, PAP, has been shown to increase power output following a maximal, or near maximal muscle contraction (Smith *et al*., 2014; McBride *et al*., 2005; Xenofondos *et al*., 2010). The increased muscle twitch force is thought to be due to an increase in myosin light chain phosphorylation making actin-myosin more sensitive to Ca^{2+} during subsequent contractions (Sale, 2002; Hodgson *et al*., 2005). Adaptations of reflex activity in the spinal cord, following execution of a high intensity exercise, are also hypothesized to contribute to the PAP response (Chiu, *et al*., 2003; Gullich, & Schmidtbleicher, 1996; Hamada, Digby, & Macdougall, 2000). In order to maximize PAP, appropriate warm-up strategies are needed typically beginning with a 3–5-minute warm-up (Smith *et al*., 2014). Within that 3–5-minute warm-up window, muscular temperature will increase, decreasing resistance of muscles and joints, improving the release of oxygen from hemoglobin and myoglobin, increasing the speed of metabolic reactions, increasing the nerve conduction rate, and increasing thermoregulatory strain.

Alternatively, a passive warm-up may be a way to benefit from these adaptations without exhausting the body's energy substrates. Adaptations involving muscular temperature have demonstrated an improvement in power performance with its increase and elevated consistency, as well as shown to be detrimental to performance following its decrease. Because the practicality of PAP as well as the literature supporting its ability to directly enhance athletic performance is still lacking, the question arises regarding the merits of utilizing a passive warm-up. It would be prudent then, to establish if a basic physiological adaptation of increased muscular temperature can produce substantial power output to ready an athlete for play; or if the body needs more neuromuscular and muscular activation to optimize performance. Therefore, the purpose of this study is to compare an active PAP warm-up versus a passive warm-up on vertical jump performance.

A. Literature Review

Since the 1970s, the effects of static stretching have been scrutinized in being able to aptly ready the body for movement. A meta-analysis conducted by Fradkin et al. indicated that a warm-up indeed readies the body for movement, but its effectiveness depends on the type of warm-up and its similarities to the specific components of the proceeding movements (Fradkin *et al.*, 2010). That being said, a warm-up can vary depending on the sport, athletes, and coaches. The research suggests that static stretching is acutely detrimental to muscular performance. On the other hand, static stretching has been shown over time to increase range of motion, and overall strength throughout a full range of motion for better functionality (Young & Behm, 2002). Thus, the benefits of static stretching cannot be entirely overlooked.

The overall consensus is that a warm-up using static stretching, is detrimental to performance for activities that are dependent on higher velocities and power for successful performance (Fradkin *et al*., 2010; Young & Behm, 2002; Talpey *et al*., 2014; Andre *et al*., 2014).

An alternative warm-up method that has been proposed is Post Activation Potentiation. PAP is defined as an enhanced neuromuscular state, which brings an increase in muscle force and power output in subsequent voluntary contractions (Robbins, 2005; McBride *et al*., 2005; McCann, & Flannagan, 2010; Baudry, & Duchateau, 2004). The PAP phenomenon has been explained as being due to the phosphorylation of myosin regulating light chains, increasing the Ca^{2+} influx, thus increasing cross bridge formations (Xenofondos *et al*., 2015; Smith, *et al*., 2013; Bevan, *et al*., 2010).

Research has indicated that conditioning background can play a significant role in benefiting from PAP warm-ups. In a study by Chiu *et al*. (2003), it was found that force and power parameters were significantly greater in well-trained individuals compared to less trained individuals. This can be attributed to the capacity of well-trained individuals being able to recruit more motor units with greater efficiency, synchronization, and at higher firing rates (Smith *et al*., 2014). Although, some research exists where recreationally fit athletes have also benefitted from a PAP warm-up. In a study by Linder *et al*. (2010), recreationally trained females produced significant improvements in 100m sprint times following a PAP warm-up.

Another important factor to consider in a PAP warm-up is the rest time. Because PAP can cause fatigue, it is important to use the optimal amount of rest time between maximal/near maximal voluntary contraction, and the subsequent power activity. Time must be provided in order for the energy substrates to be replenished. Yet if too much time passes, the twitch potentiation may decrease, so not to produce the desired effects (Hodgson *et al*., 2005; Smith *et al*., 2013). In one study by Bevan *et al*. (2010), participants rested at 4, 8, 12, 16 minutes between a PAP warm-up and subsequent sprint. This study found no significant effect between the rest times. In a study by Linder and colleagues (2010), a significant improvement in 100m sprint times was found following a period or 4 minutes rest. Another study by McBride *et al*. (2005), found a significant improvement in 40m dash times following 4 minutes of rest time. Chatzopoulos *et al*. (2007) found a significant increase in 30m dash times following a 5-minute rest time after a PAP protocol5. In a study by McCann and Flanagan (2010), a comparison between the 4- and 5-minute rest time showed no significant difference between the two.

The idea of a passive warm-up has surfaced, with the intention of conserving energy substrates normally used in an active warm-up, while still increasing intramuscular temperature (Bishop, 2003; Bergh, & Ekblom, 1979; De Ruiter, & De Hann, 2000; Kilduff *et al*., 2012).

In a study by Kilduf *et al*. (2012), Blizzard Jackets were used to maintain body temperature following an initial increase in temperature. One group of professional rugby players wore normal practice attire while resting for 15 minutes following the initial increase in temperature. A second group of professional rugby players rested in Blizzard Jackets. The results of this study showed significantly faster sprint times from the group wearing the blizzard jackets as compared to those who did not.

In another study conducted by Bergh and Ekbolm (1979), a superficial modality was used to heat the muscular temperature of four male subjects. An EMG recording of the Vastus Lateralis, Biceps Femoris, and Semimembranosus were recorded. The results showed higher jumping and sprinting performance with higher muscular temperature as compared to low muscular temperature.

PAP warm-up protocols seem to be more extensively researched, when compared to Passive warm-ups. Passive warm-up research appears to be lacking in terms of its overall usefulness in a practical setting with power-type activities. Therefore, the purpose of this study is to compare the effects of a PAP warm-up to a passive warm-up on vertical jump performance.

II. Methods

A. Participants

A priori power analysis was conducted indicating that approximately 20 participants were needed for this study. According to the available literature, the PAP phenomenon has been observed regardless of gender (Xenofondos *et al*., 2010; Ebben *et al*., 2000; Jensen, & Ebben, 2003). The research also indicates that anaerobically trained individuals respond well to a PAP warm-up (Chiu *et al*., 2003). For this study, an anaerobically trained person is defined as participating in activity 4–6 days a week for the past 6 months lasting 60 minutes with at least 75% of those activities being power activities. Thus, the participants in this study were anaerobically fit men and women from 18–35 years old. For the purposes of this study, being anaerobically trained was defined as having participated in exercise activity 4–6 days per week, for 60 minutes per session, with 75% of those activities requiring muscular power, for the past 6 months.

All the participants in this study were required to complete a wellness questionnaire determining their physical readiness, as well as the nutritional and supplement intake of each participant. Participants were also required to be free of injury for the past 6 months and abstain from any additional lower body resistance training throughout the duration of the study.

B. Instrumentation

1) Vertec

A “Vertec” measurement apparatus was used to assess the participants’ vertical jump (Senoh Corp., Matsuhidai, Matsudo-shi, Chiba, Japan). After conducting their own warm-up, the reach height of each participant was obtained by keeping the shoulders square and the reach arm (chosen by the participant being tested) was raised straight upward. A 3-minute recovery was provided between subsequent jumps. The best of three jumps was recorded.

2) Whirlpool

A stainless steel 110 Gallon Mobile Sports Hydrotherapy Whirlpool Tub was used in the passive warm-up session in order to raise the temperature of the participants’ musculature prior to the vertical jump (Whitehall Manufacturing, City of Industry, CA, USA). Pilot testing using a 21-gauge, 1 inch catheter thermocouple was inserted in the Vastus Lateralis muscle, along with an electro thermometer, to determine the appropriate time and water temperature required in the Whirlpool in order to raise intramuscular temperature 3 degrees and increase potential for muscle power (IT021, Physitemp Instrument, Inc., Clifton, NJ; Iso-Thermax; Columbus Instruments, Columbus OH Bishop, 2003). Based on these results it was determined that the participants would sit in the tub for a total of 20 minutes with the temperature of the water measuring 40 degrees Celsius. The tub was cleaned, and the water mixed with iodine prior to every participant’s session.

C. Protocol

University IRB approval was given prior to the start of this study. A repeated measures ANOVA was used to analyze the results. The participants were randomly divided into two groups (“Group A” and “Group B”). Group A first participated in the active warm-up session, then the passive warm-up (on non-consecutive days). Group B participated in the passive warm-up session first, followed by the active warm-up (also on non-consecutive days). There were 3 total sessions, a familiarization/control session, an active warm-up session, and a passive warm-up session.

All participants began the study with the familiarization/control session. During this time, the participants were required to fill out a Physical Activity Readiness Questionnaire (PAR-Q). Once complete, their vertical jump height was measured, without being provided a warm-up. This series of jumps also served as a vertical jump test familiarization, which was sufficient due to the training status required of the participants (Evaristo *et al*., 2013; Moir *et al*., 2005). After testing for vertical jump, the participants predicted 1RM back squat was obtained using the Brzycki Equation (Brzycki, 1993).

The active warm-up session consisted of a 10-minute stationary bike at 70 rpm and a self-selected resistance, followed by dynamic exercises Linder *et al*., 2010; Racinais *et al*., 2004). The bike and dynamic exercises were then followed by 4 minutes of active rest (Kilduff *et al*., 2007; Wilson *et al*., 2010; Linder *et al*., 2010; Nibali *et al*., 2013). After the 4 minutes of active rest, participants performed one set of 3 reps of a loaded jump squat at 10% of their predicted 1RM back squat (McBride *et al*., 2005; Gullich, & Schmidtbleicher, 1996; Stone *et al*., 2003). Participants then rested an additional 4 minutes, which was followed by a vertical jump test using the aforementioned protocol (Kilduff *et al*., 2007; McCann, & Flanagan, 2010).

The passive warm-up session required the subjects to sit in a hot tub for 20 minutes with the temperature of the water at 40 degrees Celsius, determined via prior pilot testing. Following the passive temperature raise, subjects' vertical jump height was tested using the protocol previously outlined (Kilduff *et al*., 2007; McCann, & Flanagan, 2010).

D. Statistical Analysis

Statistical analyses were conducted using Statistical Package for Social Science software version 25.0 (SPSS, Inc., Chicago, IL, USA). All data were subjected to standard data screening procedures for missing values, outliers, and testing for normality, both overall and within each group. Given the small sample size, standard imputation and accommodation were used, and small departures from normality were tolerated. The primary analysis was repeated measures design and was conducted using repeated measures ANOVA. Alpha was set at a value of 0.05 for this study.

III. Results

This study was a comparison of an active warm-up versus a passive warm-up on vertical jump height in well-trained anaerobically fit individuals. The active PAP warm-up session required the participants to perform 3 loaded jump squats at 10% of their predicted back squat 1RM prior to a vertical jump test. The passive session consisted of sitting in a warm whirlpool for 20 minutes at 40 degrees Celsius prior to a Vertec jump height test. It was hypothesized that there would be a significant difference, both statistically, and practically, between the PAP warm-up and Passive Warm-up protocols in terms of power output measured by vertical jump.

The repeated measures ANOVA revealed a statistically significant main effect difference in vertical jump measures ($F=16.148$, $p<0.001$; see in Table I). Mean vertical jump scores were, Control: 57.61cm (22.68 inches); Active: 66.24cm (26.08 inches); and Passive: 60.7cm (23.9 inches). The results also indicated that there was practical significance between the active and passive treatment as well as the control group (partial eta squared=0.459; Tolson, 1980; see in Table I).

TABLE I: Repeated Measures Analysis of Variance for Warm-Up Effects

Source	Sum of Squares	df	Mean Squares	F	Sig.	Partial Eta Squared	Power
Condition	107.2	2	53.6	16.14	0	0.459	0.999

Further analysis of the results demonstrated that between the three treatments tested, control, active, passive, there was a statically significant difference between the active warm-up when compared to both the passive and control warm-ups ($p=0.004$; $p<0.001$; see in Table II).

TABLE II: Pairwise Comparisons for Warm-up Protocols

(I)Condition	(J)Condition	Mean Difference (I-J)	Std. Error	Sig. b.	95% Confidence interval for Difference b	
					Lower Bound	Upper Bound
1	2	-3.2	0.664 0.463	0	-4.94	-1.46
	3	-1		0.131	-2.21	0.216
2	1	3.2	0.664	0	1.46	4.94
	3	2.2	0.583	0.004	0.669	3.73
3	1	1	0.463	0.131	-.216	2.21
	2	-2.2	0.583	0.004	-3.73	-0.67

[a]Condition 1=Control; Condition 2=Active Warm-up; Condition 3=Passive Warm-up.

The results of this study indicate that a warm-up that increases cross bridge formation due to the PAP phenomenon may produce greater acute power output when compared to both a passive warm-up, as well as no warm-up at all. This suggests that prior to activity, a PAP warm-up would likely be the most appropriate approach to elicit higher power output. Although, a passive warm-up may still increase power production when compared to no warm-up at all.

IV. Discussion

The purpose of this study was to compare the effects of a PAP warm-up to a passive warm-up on vertical jump performance. The results indicated that the PAP warm-up produced greater power output than the passive warm-up. Although there is little research comparing the two warm-ups, our findings are consistent with research reporting PAP effects to be superior to other warm-up protocols (Robbins, 2005; McBride *et al*., 2005; Chatzopoulos *et al*., 2007; Sale, 2002; Smith *et al*., 2014; Bevan *et al*., 2010). A significant difference was found not only between the active warm-up and a passive warm-up, but also when compared to the control group. From a practical standpoint, these findings might be used to give an athlete the upper hand in a sporting event, given the vertical jump height mean differences.

The results of this study also fall in line with previous research. For example, Denke *et al*. reported a 2.4 cm increase in vertical jump height using a jump squat load at 20% of 1RM (Deneke *et al*., 2010). Future research might address the jump squat load. Our decision to utilize 10% was due to the results of a study conducted by Stone *et al*. indicating the optimal load for a loaded jump squat is 10%, and that increasing load produced lower power outputs (Stone *et al*., 2003). Also consistent with prior research, Passive temperature effects may be superior to a control group, but they do not appear to be superior to a PAP warm-up (Bishop, 2003; Kilduff *et al*., 2013; Bergh, & Ekblom, 1979; Mohr *et al*., 2004). Future research might also investigate the effects of an abbreviated PAP, or active warm-up preceded by a passive warm-up in comparison to other approaches. The population used in our study was anaerobically fit. However, we did not control specific power-type athletes such as jumpers, sprinters, or others. Whether or not different types of athletes would respond differently to the protocols used, should also be studied.

An initial limitation to this study was the lack of prior research in the area of Passive warm-up. Due to the lack of evidence, we conducted our own pilot study in order to establish parameters for our passive session. A second limitation in this study was that we did not specify within our population of anaerobically fit individuals. Future research may investigate the differences between different types of anaerobically trained individuals.

V. Conclusion

Strength and Conditioning professionals may want to consider giving priority to PAP warm-ups, as opposed to passive warm-ups. Although, a passive warm-up is likely superior to using no warm-up at all, the increased cross bridge formation shown by the PAP phenomenon appears to be optimal for performance.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

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