

POST-ACTIVATION POTENTIATION AND VERTICAL JUMP PERFORMANCE

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## ABSTRACT

**TITLE:** Post-activation Potentiation and Vertical Jump Performance

**PURPOSE:** A technique used to enhance acute performance that involves a short, high intensity stimulus followed by a dynamic or isometric movement is referred to as post-activation potentiation (PAP). The acute performance increases have been attributed to both physiological and neurological factors. To date, research on this technique has not investigated the muscular activity during a dynamic vertical jump test of the upper leg muscles. The purpose of this study was to determine how using the PAP technique affects the direct force output of different types of vertical jumps as well as measuring differences with rate of force development curves from baseline outputs.

**METHODS:** Three male college-aged subjects underwent two days of testing. On the first session, subjects performed one maximum leg extension on the Cybex machine at speeds of 30, 60, 90, 120, 180 d/s. Force output and muscular activity of two quadriceps and two hamstring muscles were measured. On the second session, subjects performed a three-second maximum voluntary contraction of the leg extension

exercise. Following a rest period of either 30 seconds or 5 minutes, subjects performed a countermovement or squat jump. Force output from the force platform was measured along with muscular activity of the same muscles as day one. The order at which subjects performed leg extensions at different speeds on day one and the rest intervals and type of jump performed on day two were all randomized.

ANALYSIS: The resting interval between the maximum voluntary contractions and the speeds of leg extension were independent variables. The force output and muscular activity were the dependent variables. Repeated measures ANOVA tests were used to examine the effects of PAP on vertical jumping.

RESULTS: With each jump type and rest interval, the force development was divided into four parts for each of the four muscle groups. There were significant differences ( $p < 0.05$ ) found between the quarters of movement in the following muscles and jumps: Vastus Lateralis - squat jump control. Vastus Medialis - squat jump control, squat jump 30s. Biceps femoris - squat jump 30s. Semitendinosus - squat jump 30s, squat jump 5 minutes. There were no significant ( $p > 0.05$ ) differences found in force output

following both jump types and both resting intervals.  
However, the total force output from the countermovement jump increased by 7.9% after resting 30 seconds and by 12.9% after resting for 5 minutes following PAP.

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# **Chapter 1: Introduction**

## **Introduction**

It has been well documented that muscle strength and power performance is significantly affected by both neuromuscular and physiological adaptations. With different training techniques, there are both chronic and acute changes that happen within the muscle fiber. One technique aimed to acutely increase muscular performance is called Post-activation potentiation (PAP). With this technique, subjects perform a voluntary stimulus that is at or near maximum intensity for a short duration followed by some form of a performance measurement such as jumping or sprinting. For decades, coaches have tried to use this PAP technique in order to acutely improve the performance of their power and strength athletes. Research suggests that there are many possible factors that could lead to these performance changes.

The factors that have been attributed to performance changes are the increase in twitch and reflex potentiation. Folland et al found that twitch potentiation increased by 16% and reflex potentiation increased by 42% following five minutes of a 10-second maximum voluntary contraction (MVC). Investigators found that the 5-minute post PAP mark to be

the optimal condition for both twitch and reflex potentiation although both were elevated for 18 minutes following the stimulus (Folland et al, 2008). Researchers have also found that peak twitch in the knee extensor to be immediately elevated by 71% following a ten-second MVC. In this study, peak twitch decreased rapidly, falling to 44% and 31% after 30 and 60-second rest intervals respectively (Hamada et al, 2000).

When investigating how fast athletes and non-athletes can produce force in the knee extensor muscles, researchers found that athletes have a greater rate of force development within the first 50 ms of the movement. Also, in this study athletes were found to activate the 3 knee extension muscles that were measured in half of the time that non-athletes were able to. This led researchers to report that greater synchronization of these muscles could be a possible reason for the faster rate of force development (Tillin et al, 2010).

Not only is synchronization of the agonist muscles important for performance increases, the activation or lack thereof of the antagonist muscles should also be considered. Research has reported that the hamstring muscle group makes up 33% of overall electromyography activity during the knee extension exercise in athletes (Osternig et

al, 1986). Having a decrease in co-activation of the antagonist muscle group during movement could enhance performance. In an effort to decrease hamstring activation during knee extension, researchers put subjects through an MVC training program. After an 8 week training cycle, a 20% decrease in hamstring activity with an overall increase of MVC force of 32.8% was measured in the trained leg with improvements shown after just one week of training (Carolan et al, 1992).

The post-activation potentiation technique has been aimed at making these acute changes of increased muscle synchronization, decreased co-activation, increased twitch and reflex potentiation in an effort to increase muscular performance. To date, there has not been a study directly investigating the changes occurring in the rate of force development in vertical jumping techniques following an MVC stimulation.

## **Chapter 2: Methodology**

### **Purpose of Research**

The purpose of this research is to investigate the role that post-activation potentiation plays in the rate of force development during vertical jumps.

Specifically, researchers will be measuring both agonist and antagonist muscles during different jumping techniques and MVC stimulations to find if there are changes in co-activation of the knee flexors and extensors. The methods of this study will be presented in the following arrangement: 1) Subject recruitment, 2) Equipment, 3) Experimental protocol.

### **Subjects**

A total of 15 subjects will be recruited for this study. In order to meet the testing criteria, subjects must be between the ages of 18 and 24 years, have not suffered any lower body injury in the past 6 months, and must not be on any medications that would affect a resistance training exercise. Subjects will be recruited by asking strength and conditioning coaches if any of their athletes would like to participate. Along with the testing criteria, subjects must have current knowledge of the maximum amount of weight that they can barbell back squat. Research has shown that athletes with different strength levels have responded differently to PAP techniques (Gourgoulis et al, 2003). Researchers will consult with the athletes' coaches to insure that these back squat numbers are being obtained accurately.

## **Equipment**

The machine that all subjects will perform their maximum voluntary contractions on is a Cybex isokinetic strength-training machine. Subjects will be strapped in the machine so that the hip and knee angles will be 100 and 90 degrees respectively. During the vertical jump tests, subjects will be starting on a portable AMTI force platform. Electromyography signals will be measured from a Delsys EMG recording unit. In order to collect the EMG and force production data, Biopac and Acknowledge software will be utilized.

## **Experimental Protocol**

This study consists of two days of testing for each subject. These experimental sessions are isokinetic strength of the leg extension exercise, and measuring the effects post-activation potentiation of countermovement and squat jumps.

### **Day 1 - isokinetic strength of the leg extension exercise**

To insure subjects are not previously fatigued, they should not perform a lower body workout at least 24 hours prior to this day of testing. The investigator will spend about 15 minutes going through the testing protocols in order to insure that the subject is familiar with the exercise. This time will also allow the subject to fill out

the questionnaire and sign the consent form for the study. Once the subject understands the nature of the study, meets the criteria, and signs the consent form, surface electrodes will be taped on the skin over the upper leg muscles of the subject's dominant leg. The seat of the leg extension will be adjusted so the knee joint of the subject is lined up with the axis of rotation of the Cybex machine. Once the subject is comfortable with the exercise and the surface electrodes are in place, they will perform 2 warm-up sets of 10 reps of knee extension at 50% intensity. Only the dominant leg will perform the exercise. The subject will have a 90 second rest between the two warm-up sets.

After warming up, the subject will rest for two minutes to insure adequate recovery. Then, the subject will perform a maximum voluntary contraction (MVC) for 3 seconds while the Cybex machine is fixed in place with the subject's dominant knee at 90 degrees. Only the dominant leg will perform the exercise. Investigators will measure the surface electromyography signals during this MVC in order to compare the signals to the working repetitions at different speeds. After this MVC measurement, the subject will rest for 2 minutes to insure adequate recovery. The subject will then perform one, maximum effort leg extension at speeds of 30, 60, 90, 120, and 180 degrees per second.

The order at which the subjects perform the different speeds will be randomized. Subjects will remain seated in the Cybex during the 90-second rest period in between these repetitions. Surface EMG activity of both quadriceps and hamstrings will be measured during the testing repetitions.

**Day 2 (48 hours after day 1) - measuring post-activation potentiation and jumping performance**

To insure that subjects are not previously fatigued, they should not perform a lower body workout at least 24 hours prior to this day of testing. The session will begin with a 5-minute overview of the countermovement and squat jump techniques along with a general overview of the PAP and jumping protocol. A proper countermovement jump consists of subjects bending at the waist and hips with arms straight and reaching backwards and then rapidly extending the knees and hips to jump while reaching the arms overhead. A proper squat jump consists of subjects putting their hands on their waists and slightly bends at the hips and knees and pause. After pausing, subjects rapidly extend hips and knees to jump while keeping the hands on the waist. For the use of post-activation potentiation, investigators will use a 3-second MVC leg extension with both legs on the Cybex with the knees fixed at 90 degrees. Once subjects are familiar with the



different techniques, surface electrodes will be taped on skin over the knee flexor and extensor muscles of the subject's dominant leg. Subjects will then perform one warm-up set of 10 repetitions of the leg extension on the Cybex machine with 50% intensity. The seat will be adjusted so the knee joint of the subject is lined up with the axis of rotation of the Cybex machine. Subjects will then perform one warm-up set consisting of two countermovement jumps and two squat jumps at 50% of maximum intensity.

After warming up, subjects will rest for two minutes. Then, subjects will perform one maximum countermovement jump, rest two minutes and then perform one maximum squat jump. During these two jumps, surface EMG signals and force output will be measured in order to gain a baseline measurement for further comparison of other jumps. After these two maximum jumps, subjects will rest for 3 minutes will they are being placed on the Cybex machine.

Subjects will then perform a two-legged MVC for 3 seconds with the Cybex fixed at 90-degree knee angles. After this two-legged MVC, subjects will rest for either 30 seconds or 5 minutes before performing a maximum effort jump. After jumping, subjects will rest for 3 minutes to insure adequate recovery. The MVC measurement - resting interval - vertical jump technique - 3 minute rest sequence

will be repeated until the subject has performed both the countermovement jump and squat jump technique with resting intervals of 30 seconds and 5 minutes. The order in which the subjects perform the jumps with different resting intervals will be randomized. Including the two maximum jumps used as a baseline measurement, there are a total of 6 jumps and 4 maximum voluntary contractions.

### **Chapter 3: Analysis**

During the MVC to vertical jump protocol on the second day of testing, a portable AMTI force platform was used to collect voltage output. The subject was wearing Delsys EMG units on the upper leg muscles that were recording muscular activity during the testing.

It was the researchers original intention to divide the jump into 50 ms intervals in order to compare the data to previous literature that utilized leg extensions, however, given the time length of jumping techniques and lack of activity per 50 ms, a different measurement protocol was used.

Researchers divided the subject's entire jump into four segmental parts and analyzed force output and muscular activity for each quarter of movement. The derivative measurement was calculated using Acqknowledge software

while the subject was standing on the force platform. As soon as the force output measurement changed from the derivative indicating the subject changing their center of mass, the start of movement was marked. The end of the movement was defined as subjects reaching their peak voltage output on the force platform. From the start of the jump to the peak of voltage output contained quarters one through four. The quarters of movement are as follows: 0-25% of movement equals Q1, 26-50% equals Q2, 51-75% equals Q3, and 75-100% of movement equals Q4.

After defining the quarters parameters of each movement, integrated EMG signals were measured for each of the four muscles for each of the four quarters as well as voltage output from the force platform.

To analyze the data, repeated measures testing from SPSS software was used obtain all of the statistics for this study. The common alpha level of 0.05 was used to determine significant values. Due to the number of subjects used, LSD post hoc analysis was performed.

## Chapter 4: Results

Once the data was analyzed using SPSS software, the results were transferred over to Microsoft Excel in order to organize the data into visuals.

The following figure displays the mean total voltage from the force platform during the countermovement jump of control, 30-second interval and 5-minute interval.

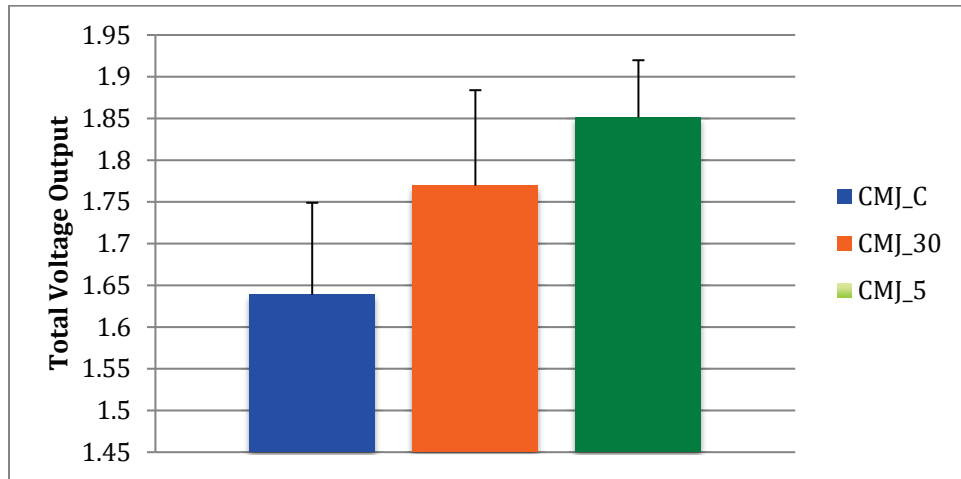


Figure 1

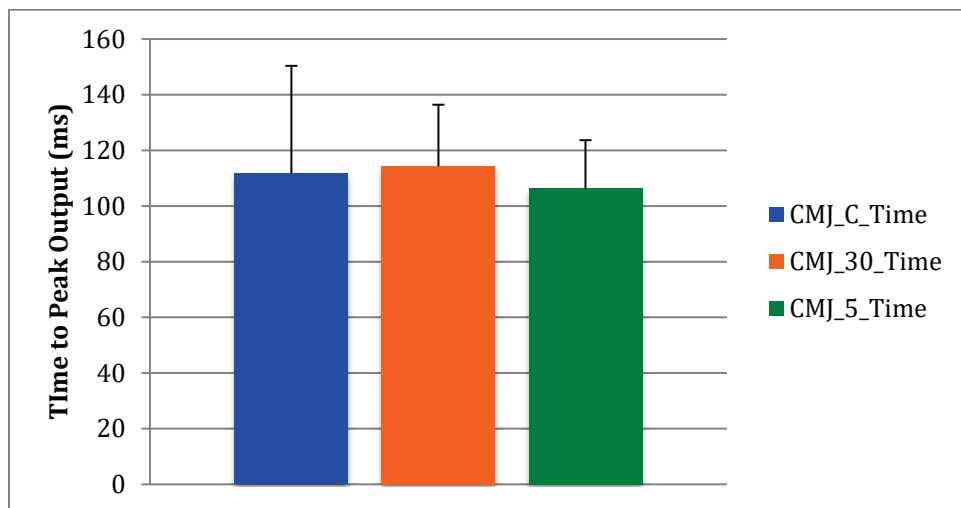


Figure 2

Figure 2 shows the mean time it took subjects to reach peak voltage output for the countermovement jump for control and time interval conditions.

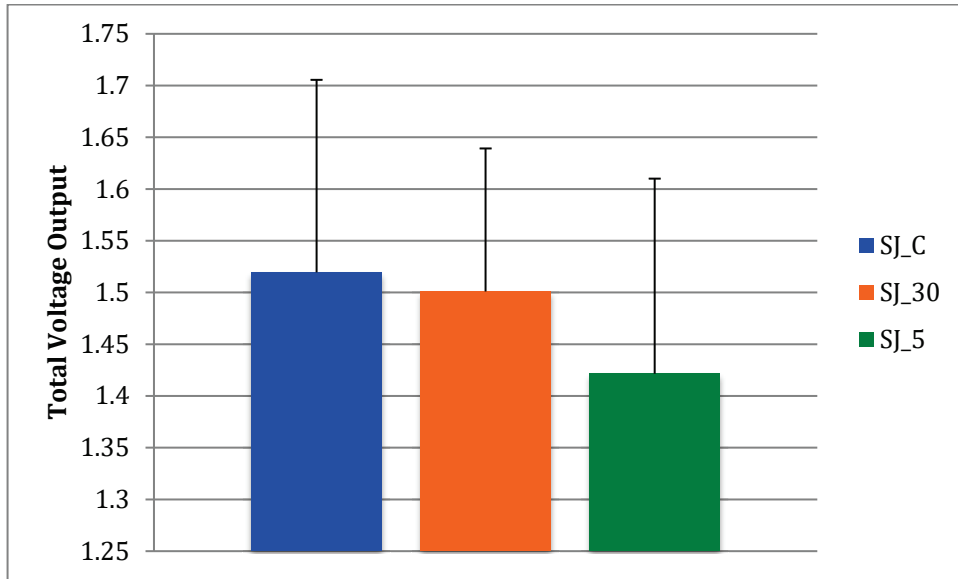


Figure 3

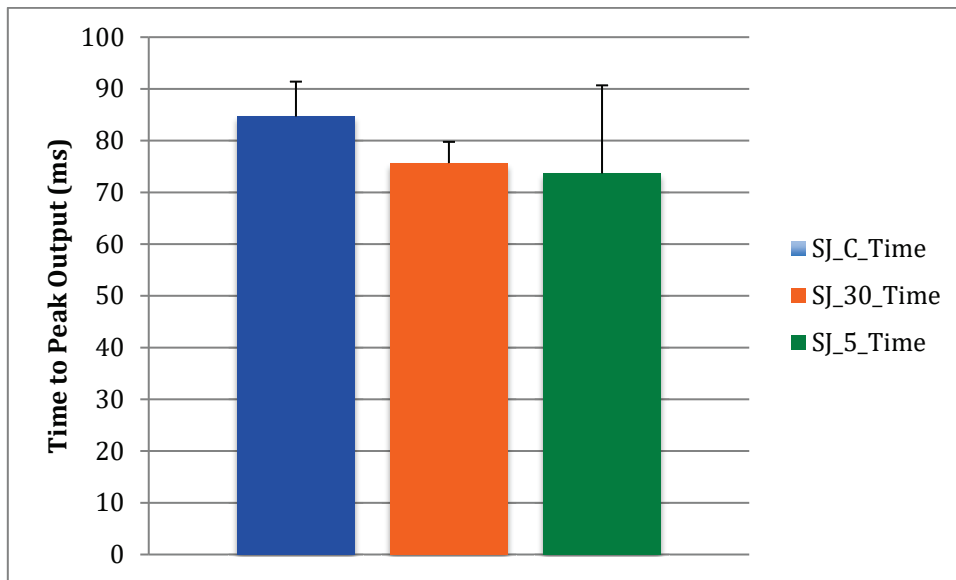


Figure 4

Figures 3 and 4 show the mean voltage output among the squat jump technique with the three trials and the mean time until subjects reached peak force output with the control jump, 30 second interval and 5 minute interval.

The following three figures show the integrated muscular activity of the vastus medialis for each of the four quarters of the jumping movement. Graphs 5 and 6 are during the countermovement jump and graph 7 is during the squat jump.

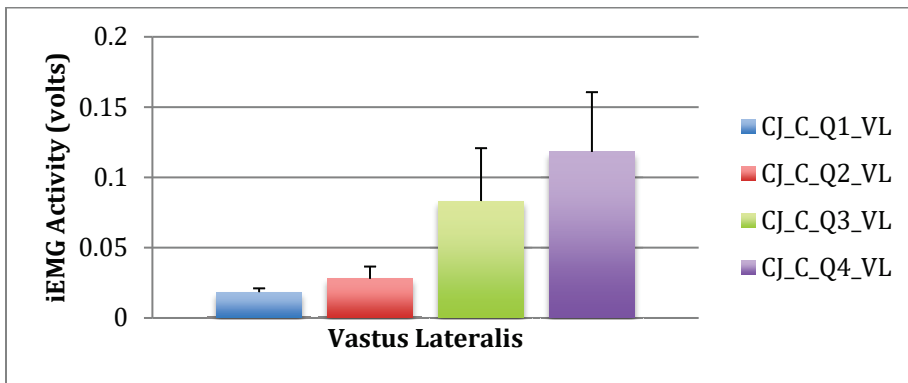


Figure 5

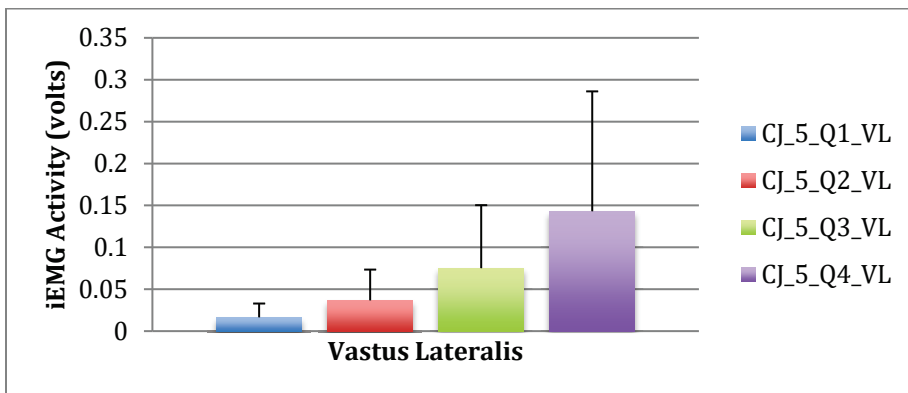


Figure 6

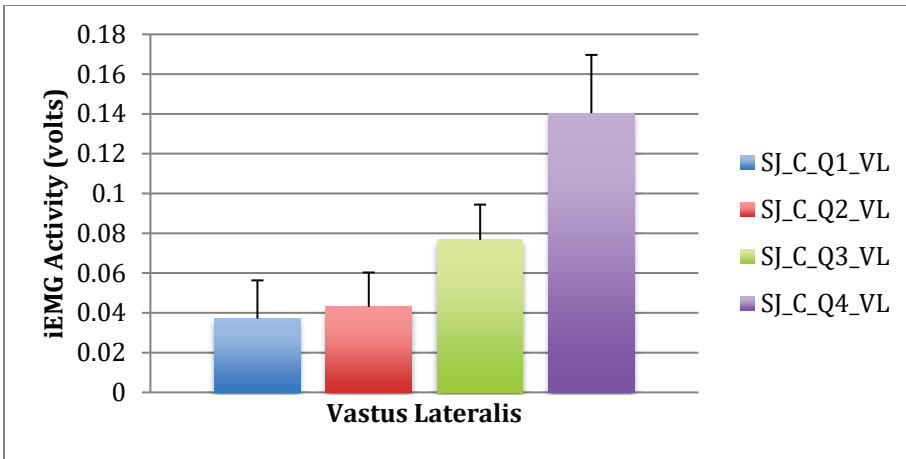


Figure 7

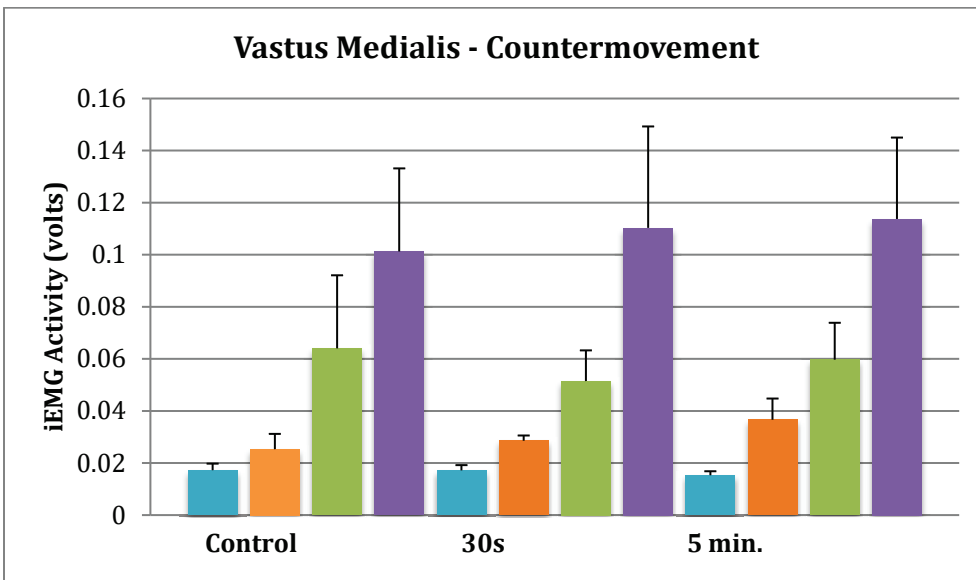


Figure 8

Figure number 8 shows the integrated EMG activity of the vastus medialis during all three countermovement jumps. The order of the jumps shown are control, 30 second interval and 5 minute interval.

The following two figures are from the integrated EMG activity of the vastus medialis during the squat jump technique with the control measure and 30-second interval respectively.

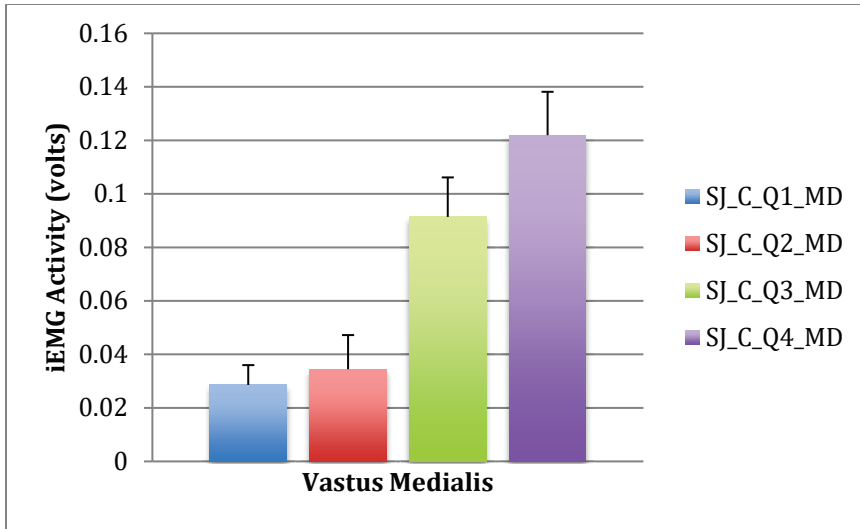


Figure 9

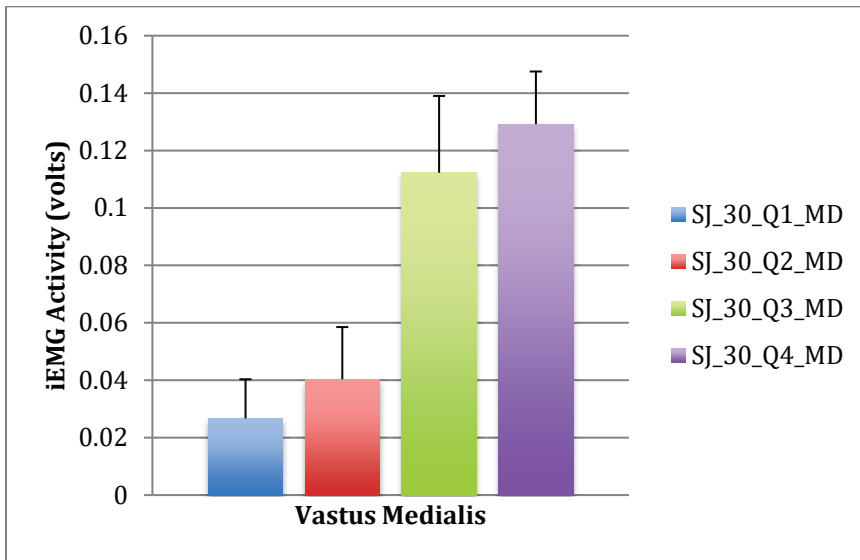


Figure 10



The only significant measurement found within the biceps femoris EMG activity was during the squat jump technique after 30 seconds following an MVC. Figure 11 depicts an increase at the second quarter of movement.

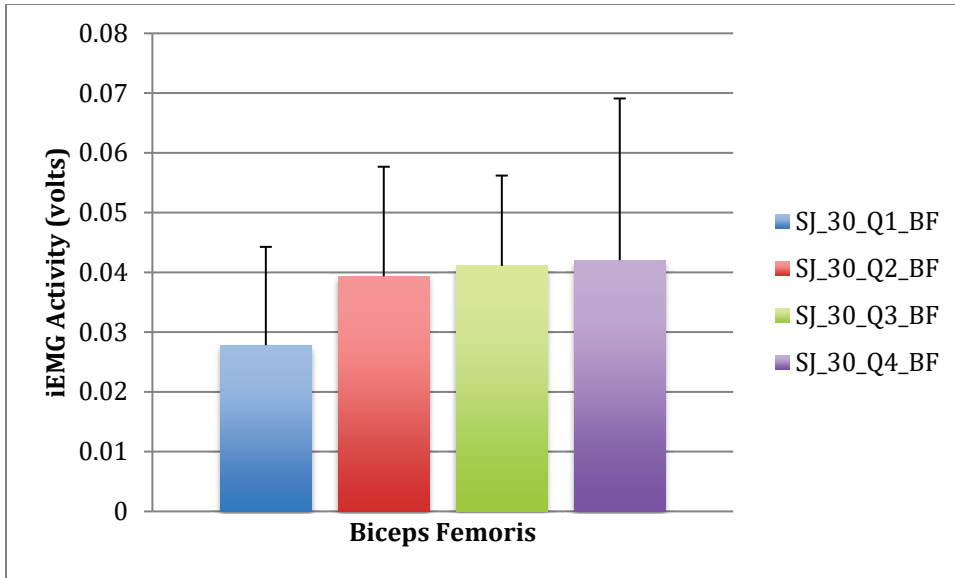


Figure 11

The significant differences found in the semitendinosus muscular activity was measured in the squat jump during both types of jumps following an MVC. Figure 12 depicts the four quarters of the 30 second interval then the four quarters of the 5 minute interval.

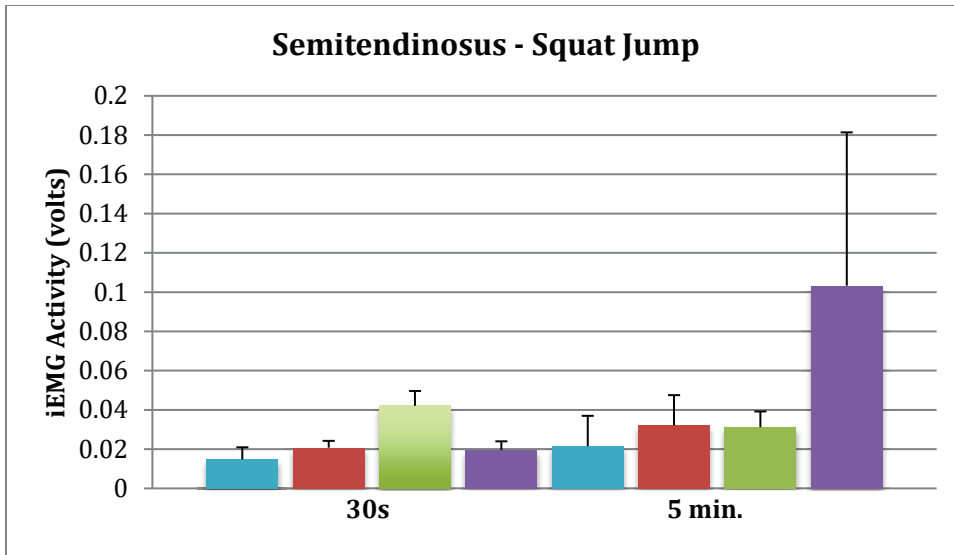


Figure 12

Table 1 summarizes the significant measurements from the muscular activities for all three protocols (control, 30-second interval, 5-minute interval) and all four muscles. The table also depicts with quarters of movement showed significant changes following post hoc analysis.

Muscle	Jump Type	Rest Interval	Sig.	F Value	Pairwise	Mean Dif.	Sig. b	
Vastus Lateralis	Countermovement	C	0.049	4.815				
		5	0.041	5.259				
	Squat Jump	C	0.001	21.194				
						Q2,Q3	0.034	0.0001
					Q2,Q4	0.097	0.022	
Vastus Medialis	Countermovement	C	0.04	5.274				
		30	0.047	4.83				
		5	0.008	10.811				
		C	0.0001	38.266				
						Q1,Q3	-0.063	0.016
						Q1,Q4	-0.093	0.016
						Q2,Q3	-0.057	0.01
						Q2,Q4	-0.087	0.014
		30	0.003	15.341				
					Q1,Q4	-0.102	0.025	
					Q2,Q4	-0.089	0.03	
Biceps Femoris	Squat Jump	30						
					Q1,Q2	-0.012	0.026	
					Q1,Q3	-0.013	0.011	
Semitendinosus	Squat Jump	30	0.027	6.4				
					Q1,Q3	-0.027	0.03	
		5						
					Q1,Q2	-0.11	0.017	

Table 1

## **Chapter 5: Discussion**

Although the measurement of mean voltage output during vertical jumping techniques did not show significant differences, the data shows promising trends for the use of PAP techniques. During the countermovement jumps, subjects on average increased mean force output by 7.9% following 30 seconds of a three second MVC. After 5 minutes following an MVC, the subjects improved mean force output by 12.9%. If more subjects are used and continue to have these types of improvements, the numbers should show significant changes to force output. Researchers speculate that these changes were found in the countermovement jump because the movement is more explosive in nature compared to the squat jump and an increase in neural activation from PAP could be maximized with faster movements as opposed to the slower squat jump.

During the squat jump technique, the average force output decreased with both rest intervals following an MVC. The time to reach peak output did decrease by 10.6% after 30 seconds and 12.9% after 5 minutes respectively. This could be a significant change if more subjects follow the testing protocol.

These increase in force output and faster peak times could potentially increase the performance of the athlete. Athletic development does not always rely on producing the most force. For instance, athletes whose sport demands short and powerful movements (fast change of direction) could benefit from decreasing their time to peak force even if it means sacrificing overall force output.

Based on muscular activities throughout the four quarters of movement, it is clear that the data from this study shows that quarters 3 and 4 consistently show the most muscular activity. This is logical due to the nature of human movements. For instance, during jumping or sprinting, an athlete should be at their peak velocity right at toe-off. In order to have peak velocity, muscular activity must increase from the start of movement. In this particular study, the biceps femoris showed a significant increase of EMG activity during the third quarter the squat jump after 30 seconds. This could logically help the subject extend their hip at a faster rate and therefore jump higher since hip extension plays a large role in proper jumping technique.

There are many possibilities for future research in this field of PAP and acute performance. It would be of great use to coaches if there were correlations between

what type of sport an athlete is involved in (maximum strength, power) and how they respond to PAP. This could help maximize the programming of their training.

Also, further studies can further expand on this research in order to see if certain PAP protocols improve the first two quarters of muscular activity. As previously stated, if athletes can get more EMG activity within the first two quarters of movement, theoretically, their rate of force development would be greater. This is not just important for athletes. The population who is at risk for falling could utilize greater RFD. If this population can produce force at a faster rate, they can recover from perturbation.

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