Acute physiological responses of resistance exercise of different movement velocities and intensities

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Acute physiological responses of resistance exercise after different movement velocities and intensities

1. INTRODUCTION

Over the last few decades people have realised the importance of physical exercise. More specifically people have turned over the last years in the combination of aerobic training with resistance training. Resistance training may include training with just the use of body weight exercises or the use of weights. The use of automated machines or free weights is preferred in order to target isolated muscle groups or large muscle groups, respectively. Through research over all those years, different resistance training protocols have been developed. Some engage the participants in lower intensities and some engage the participants in higher intensities. Intensity and volume of exercise derives from the amount of sets, repetitions, and weights that are used in each exercise.

A literature review by Hunter et al. (2017) has shown that even in older people, over 75 years old, exercise in high intensities is necessary because subjects had the same benefits in muscular function such as younger people at the age of 35. Moreover, high intensity exercise regulates body weight something which is essential for the good health of people. Furthermore, Fiatarone et al. (1999) showed that resistance training at high intensities is capable of extreme gains in strength even in men and women who are close to the age of 96 years old. Also, in another study (Ivey et al., 2000) researchers found that age does not play a significant role in terms of benefits gained from resistance exercise when they compared older and younger people in different strength training protocols.

According to the American College of Sports Medicine (ACSM) hypertrophic benefits are gained after training at 70%-100% 1RM for 8-12 repetitions per set for one to three sets per exercise. The rest that should occur between sets is 2-3 min when someone is training with multiple joint exercises (squat, bench press) and 1-2 min when someone is training on machines (leg extension, leg curl) (ACSM 2013).Moreover, if someone wants to maximize their strength benefits from exercise then he or she should train at an intensity of 80%-100% 1RM for 3-6 repetitions per set for three to six sets per exercise with the same amount of rest periods as mentioned before (Kraemer et al., 2002).

Another issue considered to be crucial in resistance training is the movement velocity of any given exercise during our test protocols. Many researchers over the years have tried to answer how the movement velocity affects the training responses or adaptations. In a review article the authors state that movement velocity bibliography is contradictory with many other researchers claiming that sometimes the effects of a slow velocity training are specific and other times general (Pereira & Gomes, 2003). Furthermore, it is shown that both slow and fast velocity training have the same effect on type-2 muscle fibers (Claflin et al., 2011). Advocating for the usual fast or normal velocity training protocols it is shown that for the same time under tension fast velocity training protocols cause greater muscle damage (Chapman et al., 2006). However, researchers until now have not tested the movement velocity in regard with the intensity of the exercises. Research has also shown that fast velocity resistance training along with circuit weight training results in increases of maximal oxygen uptake as well as an increase of strength (Bell et al., 1991). Moreover, a group that trained deliberately at maximal velocity developed greater gains and strength overall than a group that trained at slower speeds (González-Badilloet et al., 2014). Also, research has shown that eccentric fast velocity training results in greater hypertrophy and strength gains (Farthing & Chilibeck, 2003) but slow velocity training induces a greater metabolic stress and a hormone response than a fast velocity training session (Calixto et al., 2014). In regard of slow velocity training, research shows that there are velocity specific effects. For instance, when one is trained at slow velocities, that gives him or her an advantage when he or she must perform in a sport that requires slow movements (Kanehisa & Miyashita, 1983). Research has also shown that even when older individuals trained themselves at slow velocity with low intensity, they experienced an increase of muscle mass and strength (Watanabe, et al., 2014). Furthermore, training at slower speeds causes greater adaptive response than a normal speed training. However, when one trains at normal speeds but higher intensities the responses are even greater than those deriving from slow speeds (Schuenke et al., 2012). At this point we ask ourselves what would happen if one trained at slow speeds but on higher intensities? Lastly muscular strength does improve with low velocity training, but research shows that traditional training facilitates greater improvements (Rana et al., 2008).

Another field of study that has intrigued researchers over the last years is post-activation potentiation (PAP), more specific what are the factors that affect PAP and what is the best way to enhance it before an athletic event or to gain greater performance adaptations through training. A meta-analysis done by Wilson et al. (2013) showed that potentiation was optimal after multiple versus single sets performed at moderate intensities and moderate rest periods lengths 7-10 min. Moreover, the review article showed there must be a balance between fatigue and potentiation in order for the athlete to gain the maximal benefits deriving from that process. That balance is affected by numerous factors such as training experience, rest period length and exercise intensity. The meta-analysis examined the following factors: training status, volume, rest period length, conditioning activity and gender (Wilson et al., 2013). The movement velocity of the conditioning exercise was not taken into account. Furthermore, another study showed that in trained individuals there was a 1-3% increase in vertical jump and drop jump heights 5 minutes after 5 sets of 1 repetition at 90% of 1RM. On the contrary untrained individuals experienced a decline of 1-4% in performance. Researchers conclude that this happened due to the fatigue resistance demonstrated by the trained individuals over the untrained ones (Chiu et al., 2003).

Up until now there is evidence to suggest that post exercise the post exercise is elevated. There are studies which suggest that EPOC levels are elevated both after aerobic exercise (Laforgia, Withers, & Gore, 2006), and resistance training (Thornton & Potteiger, 2002). However until now in all the protocols being used there is not evidence to suggest what would happen to EPOC levels when implementing slow velocity training. Therefore amongst the purposes of our studies was to investigate the post exercise oxygen consumption after slow velocity training.

The aim of our study is to examine the effects of three resistance training protocols of different movement velocities and training intensities on physiological responses. More specifically, to investigate the effect of the different movement velocities, on jumping performance and mobility, and energy expenditure. One of moderate intensity that should trigger hypertrophic adaptations executed both in multiple joint and single joint exercises in normal speed, one of higher intensity in order to facilitate muscular power adaptations executed on faster speed and one of high intensity but on a very slow movement velocity only for one set. We believe that it is of great importance for a training program to be found that promotes the same, if not more, benefits as other training programs, but takes significantly less time in terms of duration. Training programs of moderate intensity usually last about an hour with a frequency of 3 to 4 times per week. Training programs of higher intensity may stress even more the human body and we believe that those should last less than the traditional training programs both in time and frequency.

2. METHODS

Participants: Nine healthy adult male athletes, experienced in resistance training were chosen to participate in our study. Their previous experience in resistance training is of great importance in order to ensure a correct technique did not compromise the range of motion. We presumed that experienced participants may also have greater benefits from the post activation potentiation, as previous research has shown that trained individuals gain a plus of 1% to 3% in performance increase due to post activation potentiation over the untrained ones (Chiu et al., 2003).

Study Design

During the first assembly, anthropometrics features (body mass, body height, body fat percentage), basic metabolic rate, and maximal oxygen uptake (VO_{2max}) were determined.

On the second date of meeting the participants familiarized themselves with all the equipment that will be used during the test. Also, the 1RM assessment took place.

Lastly on the third, fourth and fifth visit participants performed randomly the three different resistance training protocols. The first exercise for every protocol was the half squat. Before and after the half squat exercise and also at the end of the exercise session participants performed with the following sequence: thigh circumference measurement, mobility measurement and vertical jump performance measurement. The training protocols and measurements that occurred were designed in that way in order for the PAP effect to occur five minutes after training. Also, oxygen consumption was predicted during the exercise session and measured during 30min recovery period in order to examine the energy expenditure of the exercise and the excess post exercise oxygen consumption (EPOC) during the recovery period.

Anthropometrics Features

Body Mass and Height: Body mass and height will be measured with bare feet and light clothes by using a Seca stadiometer - scale (Seca GmbH & Co.).

Body fat percentage: A seven-point skinfold measurement (Harpenden skinfold calliper), took place in order for the body fat percentage of each participant to be determined. Testers examined the tricep, chest, axilla, thigh, abdominal, supraspinale and subscapular. Tricep: At the level of the mid-point between the acromial (lateral edge of the acromion process, e.g. bony tip of shoulder) and the radiale (proximal and lateral border of the radius bone, approximately the elbow joint), on the midline of the posterior (back) surface of the arm (over the triceps muscle) is where the landmark was placed.

Energy Expenditure Assessments

VO2max Measurement: A protocol with a gradual increase of speed was used on a treadmill ergometer. The VO2max was determined for each participant with the use of a continuous test at which the participants started at a speed of 10km/h and speed increased every minute for 0.5km/h until exhaustion (Beltz et al., 2016). The measurement was completed when the participants deliberately stopped running due to exhaustion. Values of O_2 and CO_2 was analysed by gas analyser (VO2000) Medgraphics, United Kingdom) and values of heart rate were collected by using a Polar heart rate monitor (Polar, Finland). Volumes of exhaled gas was measured every 30s (breath-by-breath). As a VO_2max value was determined the highest point of oxygen uptake during the measurement at which the speed was be stable for 1 min.

BMR and RMR Assessment: All participants came fasted and without any previous activity in the lab in the morning (9:00-10:00). They plugged into a heart rate monitor and a gas analyser in order to measure heart rate frequency and oxygen uptake at rest. They rested themselves in a lying position for thirty minutes and then for the next 10 minutes the above-mentioned parameters were measured. The mean value of the recorded oxygen uptake values during the last 10 min measurement considered to be the basic metabolic rate (BMR). Additionally, oxygen consumption was measured 30 min after the end of each training session (RMR) in order to calculate the excess post exercise oxygen consumption (EPOC).

Oxygen Consumption during Exercise: Minute heart rate was measured during all the exercise protocols by using a heart rate monitor (Polar, Finland). Heart rate data was used to predict oxygen consumption during exercise by using the equation derived from the VO_2-HR relationship observed during the VO_2max measurement.

Pre and Post Assessments

Thigh Circumference: Measurement of thigh circumference was performed approximately 15cm proximal to the superior pole of the patella. The thigh circumference was measured in cm using a measurement tape.

Goniometry - Range of motion evaluation: The range of motion of hip and ankle joints was measured using a goniometer. During the lying position small pieces of tape were put on the ankle joint, hip joint, knee joint thus creating a parallel line with the ground. At first, we asked from the athlete to perform ankle adduction. The goniometer was placed directly on top of the little piece of ankle tape. The athlete performed this movement for three times with about 30s rest between efforts. Later the athlete performed ankle flexion again for three efforts. In order for the athlete to perform hip flexion the goniometer was placed directly on top of the small piece of tape located on his hip joint. Another person helped holding the non-performing leg to stay stable by applying pressure on the thigh and generally on the hip area. While performing hip flexion the goniometer followed the course of the leg always aiming for the small piece of tape which was placed on the knee joint. We asked from the athlete to hold that position for a few seconds in order for an accurate measurement to be recorded. The athlete after a small rest of 30s performed the movement another 2 times, 3 times in total. When ready the athlete was placed in the prone position and pressure was used on his bicep femoris and hip area in order for him to perform hip adduction. Same as before the goniometer followed the course of the leg aiming for the small piece of tape which was placed on the knee joint. Mobility was tested on the dominant side of each athlete. (Boone, Azen, 1979).

Sit and Reach test: Participants will sit on the floor with legs stretched out straight ahead. Shoes will be removed and the soles of the feet will be placed flat against the box. Both knees must be locked and if necessary, pushed down, flat to the floor. With palms facing downwards and hands placed on top of each other, participants must reach forward along the measuring line, as far as possible. After one or two attempts for familiarization the participants must reach forward and hold their last position for one to two seconds while the distance is recorded. (Boone & Azen, 1979);

Countermovement Jump Test: Immediately after the mobility test took place, participants were asked to step on the force plate with shoes on (Bertec force plate). Weight must be evenly distributed in both legs at shoulder length apart. Hands were placed on the hips and stayed there throughout the test. When all was ready the participant squatted down until the half squat position and then immediately jumped explosively vertically and landed on the force plate with both feet hitting the plate at the same time. Take off was from both legs without any initial steps or shuffling. The best result of at least three efforts was recorded. (Linthorne, 2001). A Bertec, (Bertec U.S.A.) force plate was used to measure the jump performance of the athletes. As said immediately after the mobility test and with no rest the athletes placed themselves on the force plate and executed 3 consecutive countermovement jumps. Rest was 30 seconds between each jump. (Linthorne, 2001).

Resistance Training Protocols

All participants performed three different resistance training protocols. All three protocols consisted of the same training volume but were executed at different intensities. On the first training protocol, subjects trained at 70% of 1RM for 1 set for 8 repetitions per set at medium velocity (80 BPM tempo). On the second training protocol subjects trained at 80% of 1RM for 4 sets for 5 repetitions per set at fast velocity (200 BPM tempo). Lastly the participants trained again at 80% of 1RM for 1 set for 3 repetitions but at a very slow tempo (30 BPM) which is 8 seconds of total movement. In all three training protocols the same five exercises were executed which are: half squat, knee extension in a machine, knee flexion in a machine, bench press and rowing exercise in a machine.

A metronome was used to set the movement velocity during the three different exercise protocols. The metronome tempo was set to 30 bpm for slow velocity training (SVT), 80 bpm for medium velocity training (MVT), and 200 bpm for fast velocity training (FVT). Each contraction phase (eccentric and concentric) consisted of 4 beats, thus 4 beats down and 4 beats up. These tempos are equivalent approximately to 4 seconds down and 4 seconds up (8-second lift) for slow, 1.5 seconds down and 1.5 seconds up (3-second lift) for medium, and 0.6 second down and 0.6 second up (1.2-second lift) for fast. No pause was allowed at the transition of contraction phase (from eccentric to concentric or concentric to eccentric).

Statistical analysis

To analyse the data from all measurements the statistical package SPSS version 21.0 was used. Participants had the exact same measurements before starting training under different velocities. One Way Anova was carried out in order to see if there were any significant differences within the subjects. We conducted a Spearman correlation in all post half squat data in order to examine the correlation between variables in regard with the movement velocity of the exercise. The point of significance was defined when $p \leq 0.05$.

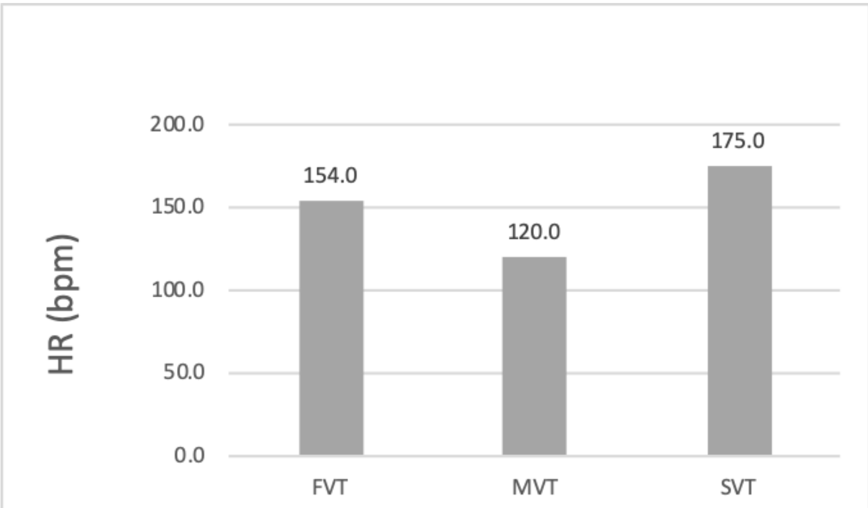
3. RESULTS

1. ENERGY EXPENDITURE

Heart Rate During Exercise

One-Way Anova for repeated measures showed that HR during exercise was not statistical different between the FVT and SVT ($p \geq 0.05$) training protocol. However, there were statistical differences between the MVT and the FVT and SVT protocols ($p \leq 0.05$). Data that are presented on graph one, show us the average HR that was recorded during each exercise protocol. Graph one represents the average heart rate values during the execution of all three training protocols (FVT, MVT and SVT).

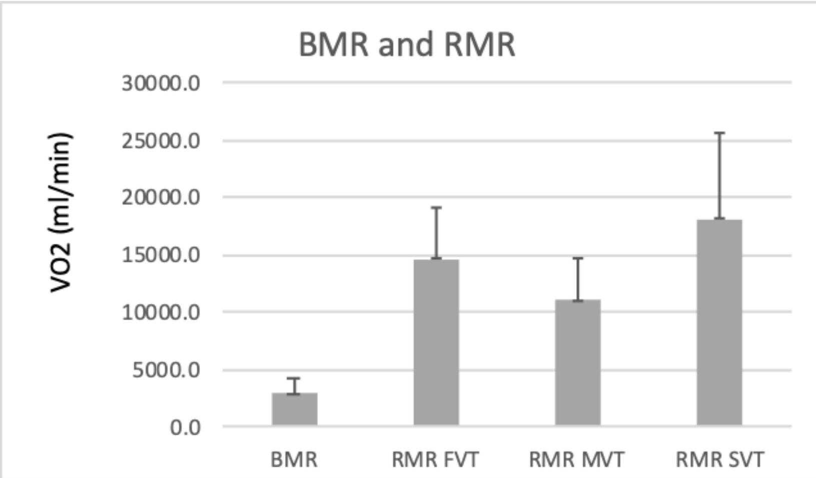
Graph 1: Average HR during FVT (Fast Velocity training), MVT, (Medium Velocity Training) SVT (Slow Velocity Training) protocols.



Basic Metabolic Rate and Resting Metabolic Rate

One Way Anova for repeated measures revealed that there were statistical differences between the basic metabolic rate (BMR) and the recovery resting metabolic rate (RMR) after all exercise protocols $p \leq 0.05$. Specifically, an increase of RMR was observed following all the resistance training protocols. Participants demonstrated a higher increase of RMR values especially when they trained at the SVT protocol rather than the other two. There were no statistical differences between the FVT and SVT protocol ($p \geq 0.05$) but there were statistical differences between the MVT protocol, SVT and FVT ($p \leq 0.05$). Graph two represents the elevated metabolic rate values during post exercise recovery after the FVT, MVT and SVT.

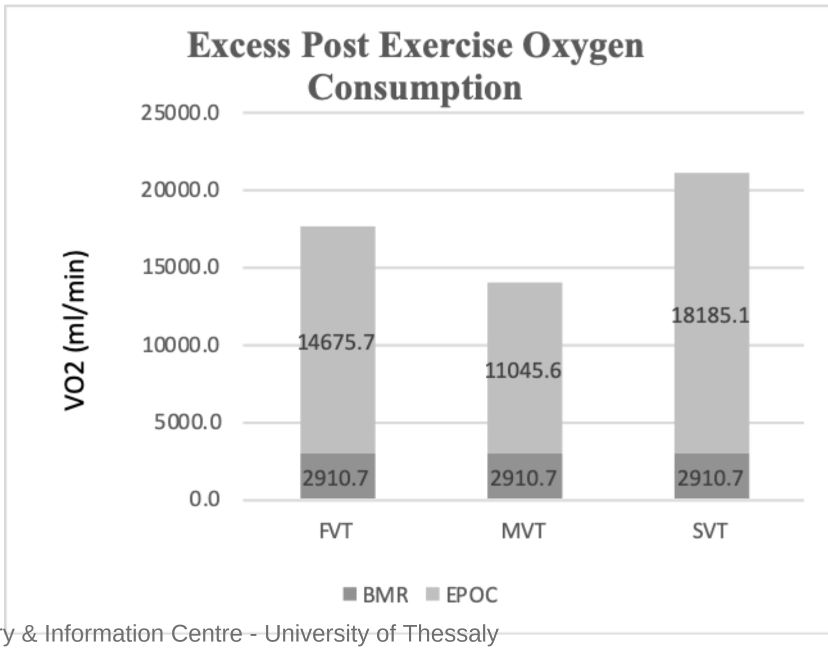
Graph 2: BMR and RMR after FVT (Fast Velocity training), MVT, (Medium Velocity Training) SVT (Slow Velocity Training) protocols.



Excess Post Exercise Oxygen Consumption (EPOC)

One Way Anova for Repeated measures revealed that the excess post exercise oxygen consumption (EPOC) had greater values when the participants executed the SVT protocol. Statistical analysis revealed that there were again no statistical differences between the SVT and FVT protocol ($p \geq 0.05$) but there were statistical differences between the MVT training protocol, SVT and FVT ($p \leq 0.05$). Graph three represents the excess post oxygen consumption after training at fast , medium and slow velocity respectively.

Graph 3: EPOC after FVT (Fast Velocity training), MVT, (Medium Velocity Training) SVT (Slow Velocity Training) protocols.



2. JUMP PERFORMANCE COUNTER MOVEMENT JUMP)

Post Half Squat Exercise Correlation

Medium Velocity: The Spearman correlation coefficient revealed that when subjects performed the exercise in medium velocity, there was a strong negative relationship between the thigh circumference and hip extension (r =-.855, p=.003), meaning that while the thigh circumference is increasing, participants lost mobility of their hip. Furthermore, the results indicated that there is a strong positive relationship between thigh circumference and impulse during the counter movement jump (r=.957, p=.000). That indicates that while thigh circumference is increasing, participants gained in power thus increasing their impulse during the jump. However, the results also revealed a strong negative relationship between hip extension and impulse (r=-.873, p=.002) indicating that while participants lost in hip mobility their impulse increased during the counter movement jump.

Furthermore, more correlations came up. As thigh circumference increased, the jump height during the counter movement jump (r=.749, p=.20) also increased, when hip flexion increased hip extension (r=.815 p=.007)) also increased. Moreover, a strong negative relationship was found between hip extension and jump height (r=-.806 p=.009) meaning that while mobility of the hip increased jump height decreased. Furthermore, a strong relationship was found between hip extension and the power output during the eccentric phase of the jump (r=.706 p=.034)) but a negative relationship between hip extension and the concentric phase of the jump (r=-.647 p=.060) meaning that while hip mobility is increased participants were able to produce more power in the eccentric phase of the jump rather than in the concentric phase of the jump. A strong relationship was found between ankle flexion and impulse (r=.716 p=.030) as well as with maximum power (r=.748 p=.020) produced during the jump which means that while ankle flexion increased the athletes gained in impulse and power during the jump. Strong positive relationships were found between Take Off Velocity and Power Max with (r =.681 p=.044).

Fast Velocity: The Spearman correlation coefficient revealed that when subjects performed the exercise in fast velocity, a strong relationship between Jump Height and Take off Velocity was found (r =.917, p=.001) meaning that while jump height is increasing so does the instantaneous take off velocity. Moreover, a strong relationship was found between Jump height with maximum power output (r=.850, p=.004), power during the concentric phase of the jump (r=.833, p=.005) and maximum velocity developed during the jump (r=.983 p=.000) meaning that while jump height increased participants demonstrated also increases in the right above mentioned performance markers. Furthermore, a strong relationship was found between take off velocity with power during the concentric phase of the jump and maximum velocity (r=.850, p=.004) and (r=.833, p=.002) respectively. Lastly, a positive strong relationship was established between maximum power and maximum velocity during the counter movement jump (r=.900 p=.001). We assumed that the results are statistically significant when $p \leq 0.005$ meaning that the results mentioned above met our criteria.

Furthermore, thigh circumference was found to have a negative relationship with the sit and reach test (r=-.812, p=.008) and a positive relationship with impulse (r=.727, p=.027). Moreover, a negative relationship developed between ankle flexion and power during the concentric phase of the jump (r=-.767 p=.016). Jump height marker along with impulse marker had a strong positive relationship (r=.711, p=.032) and impulse had also a positive strong relationship with maximum velocity that was developed during the counter movement jump post half squat exercise (r=.711, p=.032). A strong positive relationship was developed between the take-off velocity and maximum power output (r=.800, p=.010), maximum power output with power during the concentric phase of the jump (r=.683, p=0.42).

Slow Velocity: The Spearman correlation coefficient revealed that when subjects performed the exercise in slow velocity, a strong but negative relationship between thigh circumference and Sit & Reach test was found (r =-.845, p=.004) meaning that while participants increased their thigh circumference they lost on mobility. Furthermore, there is a strong positive relationship between thigh circumference and impulse performance on the counter movement jump (r=.853, p=.003) which means that while the athletes gained on thigh circumference, they also gained on impulse thus jump performance. Moreover, Jump Height and concentric power output had a strong positive relationship (r =.833, p=.005). Also take off velocity and maximum power output both have a strong relationship with the maximum velocity being developed during the counter movement jump (r=.908, p=.001) and (r=.833, p=.002), respectively. We assumed that the results are statistically significant when p≤0.005 meaning that the results mentioned above met our criteria.

Furthermore, a strong relationship between Hip Flexion and Ankle Extension (r =.744, p=.022) and also Hip extension developed strong but negative relationships with take-off velocity, maximum power output during the counter movement jump and maximum velocity during the counter movement jump (r=-.730, p=.026: r=-.762, p=.017) r=-.686, p=.041, respectively). A strong positive relationship was found between ankle flexion and power output during the eccentric phase of the jump (r=.800, p=.010) and jump height marker demonstrated a positive relationship with maximum velocity and maximum power output during the counter movement jump (r=.817, p=.007: r=.783, p=.013, respectively). Take off velocity developed a positive strong relationship with maximum power output r=.740, p=.023 and maximum power output developed strong positive relationship with concentric power output marker during the jump effort (r=.800, p=.010). Lastly, the same happened with velocity max developing a strong positive relationship with concentric power output marker during the jump effort (r=.767, p=.016).

Post Training Correlation

Fast Velocity: The Spearman correlation coefficient revealed that when subjects performed the exercises in fast velocity, a strong relationship was found between ankle extension and Jump height (r=-.717, p=.030) as well as between ankle extension and impulse during the counter movement jump (r=-.937, p=.000). Furthermore, Jump Height had a strong relationship with impulse (r=.711, p=.032), take off velocity (r= .845, p=.004), Power Max (r= .900, p=.001), CON Power (r=.783, p=.013) and Velocity Max (r=.983, p=.000) Moreover, take off velocity had a strong relationship with Power Max (r= .845, p=.004), CON Power (r= .787, p=.012) and Velocity Max (r= .887, p=.001) during the counter movement jump. Maximum power is strongly correlated with Velocity Max (r=.867, p=.002). There is a statistical difference in all of the above-mentioned correlations since p≤0.005.

Medium Velocity: The Spearman correlation coefficient revealed that when subjects performed the exercises in medium velocity, a strong relationship was found between thigh circumference and impulse r=.745, p=.021 Furthermore, test score in the sit & reach test was strongly correlated with Power Max r= -.750, p=.020 and eccentric power during the jump r=-.833, p=.005 In addition, hip flexion was correlated with eccentric power during the jump r=.711. A strong relationship was found between hip extension and jump height r=-.783, p=.013 and Take off Velocity r= -.979, p=.000 and Velocity Max r=-.824, p=.006. Jump height was correlated with Take Off Velocity r= 778, p=.014 concentric Power r= .817, p=.007 and Velocity Max r= .740, p=.023 Take off velocity was correlated with Velocity Max r=.810, p=.008 as well as concentric power was correlated with Velocity Max r=.689, p=.040 There is a statistical difference in all of the above-mentioned correlations since p≤0.005.

Slow Velocity: The Spearman correlation coefficient revealed that when subjects performed the exercises in slow velocity, a strong relationship was found between thigh circumference and Sit & Reach r=-.733, p=.025 and Impulse r=.753, p=.019. Furthermore, hip flexion was strongly correlated with hip extension r=.744, p=.022 and Ankle Extension r=.853, p=.003. A strong correlation was found between hip extension and Ankle Flexion r=.711, p=.032 and Ankle Extension r=.857, p=.003. Moreover, ankle flexion was strongly correlated with Ankle Extension r=.728, p=.026. Jump height was strongly correlated with Power Max r=.845, p=.004 concentric power r=.895, p=.001 and maximum velocity developed during the jump r=.762. , p=.017. Take off velocity was correlated with Power Max r=.736, p=.024 and Velocity Max r= .854, p=.003. Lastly maximum power was correlated with concentric Power r=.800, p=.010 and maximum velocity r=.817, p=.007

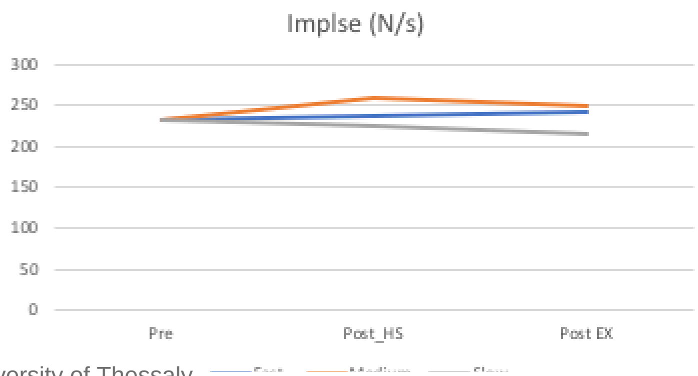
Jump Height

The results revealed that there was a continuous increase of the Jump Height value during and after the execution of the fast velocity protocol. However statistical analysis revealed that this increase is not statistically significant (p≥0.05). Furthermore, results revealed that after the athletes trained at a medium velocity their jump height score at first increased and post training the value decreased. However, those results are not statistical important (p≥0.05). Lastly during the execution of the slow velocity protocol, the athletes demonstrated a decrease of their jump height test score and statistical analysis revealed that this was statistically significant (p≤0.05).

Graph 4: Demonstrating the Jump Height values after FVT, MVT and SVT

Impulse

The results showed that there was a continuous increase of the value during and after the execution of the fast velocity training protocol but not statistically significant (p≥0.05). During the execution of the medium velocity protocol there was



Graph 5: Demonstrating the impulse values after FVT, MVT and SVT

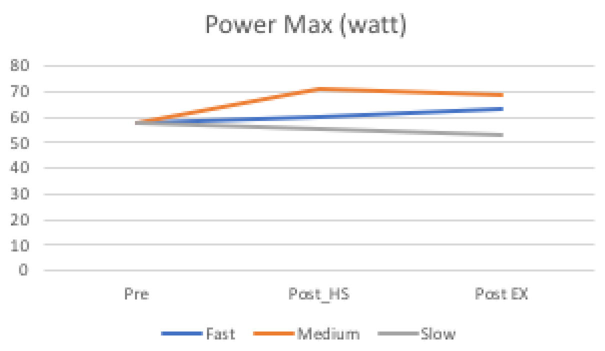
an increase and after the training a decrease of the impulse value but was not statistically important ($p \geq 0.05$). When the athletes executed the slow velocity protocol the impulse value steadily decreased through the whole training. Statistical analysis revealed that this was statistically significant ($p \leq 0.05$).

Take off Velocity

The results revealed that there was a continuous increase of the take-off velocity value during and after the execution of the fast velocity protocol. However statistical analysis revealed that this increase is not statistically significant ($p \geq 0.05$). Furthermore, results revealed that after the athletes trained at a medium velocity their take off velocity at first increased and post training the value decreased. However, those results are not statistical significant ($p \geq 0.05$). Lastly during the execution of the slow velocity protocol, the athletes demonstrated a decrease of their take off velocity during the counter-movement jump and statistical analysis revealed that this was statistically significant ($p \leq 0.05$).

Power Maximum

The results revealed that there was a continuous increase of maximum power in counter-movement jump during and after the execution of the fast velocity protocol. However, statistical analysis revealed that this increase is not statistically significant ($p \geq 0.05$). Furthermore, results revealed that after the athletes trained at a medium velocity their maximum power at first increased and post training the value decreased. However, those results are not statistical significant ($p \geq 0.05$). Lastly, during the execution of the slow velocity protocol the athletes demonstrated a decrease of their maximum power during the counter-movement jump and statistical analysis revealed that this was statistically significant ($p \leq 0.05$).



Graph 6: Demonstrating the Power Max values after FVT, MVT and SVT

Concentric Power

The results revealed that there was a continuous increase of power during the concentric phase of the jump, during and after the execution of the fast velocity protocol. However statistical analysis revealed that this increase is not statistically significant ($p \geq 0.05$). Furthermore, results revealed that after the athletes trained at a medium velocity their power during the concentric phase at first increased and post training the value decreased. However, those results are not statistical significant ($p \geq 0.05$). Lastly during the execution of the slow velocity protocol, the athletes demonstrated an increase of their power after the half squat exercise and a decrease post training.

4. DISCUSSION

All of the training protocols were executed in different movement velocities and different intensities. Up until now any research done on movement velocity (Pereira & Gomes, 2003) did not use the same amount of training load. It seemed imperative to us to try and match the training load of each individual in all three different protocols. In order to succeed we used the weight percentage that derived from 1RM multiplied it with the total reps of each protocols and then multiplied the number that came up with the total time of each repetition**.**

We know that in order for an athlete to gain muscle hypertrophy he or she should train at a range from 8 to 12 repetitions and an intensity from 60% to 80% of 1RM (ACSM 2013). Taking that into account for the medium velocity protocol the athletes completed 8 total repetitions, on the fast velocity protocol the athletes completed 20 total repetitions and lastly on the slow velocity protocol the athletes completed 3 total repetitions. In that way we ensured that the athletes remained for the same time under tension totally and they lifted totally the same amount of weight. In other research until now whereas researchers tried to investigate the movement velocity and what the outcome would be, training load was not taken into account. (Pereira & Gomes, 2003) . Table one represents the total work of all athletes during training at all three training protocols.

1RM Half Squat (kg)	**Work % 1RM**	**Work % 1RM**	**Work % 1RM**	**20 Reps (total kg)**	**8 Reps (total kg)**	**3 Reps (total kg)**	**Total Work (kg/s)**	**Total Work (kg/s)**	**Total Work (kg/s)**
	Half Squat Fast	**Half Squat Med**	**Half Squat Slow**	**Half Squat Fast**	**Half Squat Med**	**Half Squat Slow**	**Half Squat Fast**	**Half Squat Med**	**Half Squat Slow**
180	144	135	144	2880	1080	432	3456	3456	3456
175	140	131	140	2800	1050	420	3360	3360	3360
175	140	131	140	2800	1050	420	3360	3360	3360
180	144	135	144	2880	1080	432	3456	3456	3456
115	92	86	92	1840	690	276	2208	2208	2208
180	144	135	144	2880	1080	432	3456	3456	3456

Table 1: Total work of athletes during all training protocols. The athletes performed the same amount of work between all training protocols.

Energy Expenditure During Exercise and Recovery

Heart rate was measured during the exercise and after it, while the athletes underwent the RMR test. Heart rate is being used as an indicator of exercise intensity. Heart rate indicated that the athletes underwent under vigorous exercise when they trained at fast and slow velocity contrary to when they trained with medium movement velocity. The results showed that average heart rate was higher when athletes trained at slow velocity meaning that they underwent a much vigorous strain even from when they completed 20 total repetitions in the fast movement velocity protocol. Moreover, elevated heart rate had an impact on mean energy expenditure as well as an impact on EPOC. Energy expenditure was higher in the slow velocity protocol rather than the other two protocols and EPOC was also superior in the slow velocity protocol in contrary to the fast and medium velocity protocol. Literature has shown that when intensity increases so does EPOC (Børscheim and Bahr, 2011), (Thornton & Potteiger, 2002). In a study done by Thornton et. al, the results indicated that whether the participants trained at higher intensities (85% -8RM) or at lower intensities (45%-8RM) the outcomes regarding EPOC were similar when the participants were engaged in resistance training programs.

The main difference between our study with other studies is that we tried to investigate the physiological responses after implementing different movement velocities during resistance training exercises. Other than that, to the best of our knowledge there is not a study being done where athletes or the participants were asked to perform the movement velocity at such a slow tempo. Other studies that investigated EPOC used regular training protocols (Thornton & Potteiger, 2002).

As said above post exercise oxygen consumption had elevated values because of the resistance training program. Resistance training exercise is shown to produce similar outcomes regarding EPOC, regardless of intensities. However, during our study EPOC levels were more elevated after the athletes trained at the SVT protocol. Thus, we conclude that maybe the slow movement velocity produced a more strenuous stimulus leading to a superior post exercise oxygen consumption.

Jump Performance

Results revealed that there were no statistical differences between all pre-exercises jump performance measurements. Post half squat exercise results indicated that there was an increase in jump performance measurable values but that was not of statistical importance. Literature until now suggests that athletes may gain from post activation potentiation when trained at moderate intensities over multiple sets. (Wilson et al., 2013) Also athletes may gain from PAP when they are trained enough over the untrained ones (Wilson et al., 2013). Although our participants fit those criteria and we did notice an increase on jump performance parameters, that increase was not statistically significant when it came down to training at fast and medium movement velocities. However, when our athletes performed the given exercises in slow velocity there was a decrease on jump performance parameters. The results were statistically significant. It seems that when working out in slow velocities there is a negative performance effect on PAP. To our knowledge there has not been any study conducted which investigates the post activation potentiation after slow velocity resistance training.

The study that we conducted used nine trained track and field athletes with experience in executing resistance training programs. Moreover, we tried to investigate the physiological responses on the acute effect after completing each training protocol on all three different movement velocities. The results showed that there was an increase an increase on jump performance markers after executing the FVT post the half squat exercise and post training. Moreover, after execution of the MVT post half squat there was an increase of jump performance markers but a decrease of jump performance markers. However, those results were not statistically significant. We are inclined to believe that had we been using more participants we would have enhanced the results and maybe achieved significance.

Conclusions

One main conclusion from our study is that post training at slow velocity EPOC levels were more elevated than when training at FVT and MVT protocols. Although there was an increase of EPOC, when athletes trained at the SVT protocol there was a decrease of their jump performance. Furthermore, both above mentioned results met with statistical significance.

When athletes trained at FVT and MVT there also was an increase of post exercise oxygen consumption inferior however to SVT protocol. Moreover, there was an increase of jump performance while training at FVT post half squat and post training. Although these results agree with other research, in our study those results were not statistically significant. Jump performance was also increased post half squat in the MVT but not post training where there was a decrease. Results of the MVT protocol regarding jump performance were not statistically significant.

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