EFFECT OF INTER-REPETITION REST ON KINETIC AND KINEMATIC VARIABLES IN THE POWER CLEAN

A Thesis
by
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FOREWORD

The research detailed in this thesis will be submitted as two separate research articles to the *Journal of Strength and Conditioning Research*, the official journal of the National Strength and Conditioning Association. The thesis has been prepared according to the guidelines set forth by the Graduate School of Appalachian State University.

ABSTRACT

EFFECT OF INTER-REPETITION REST ON KINETIC AND KINEMATIC VARIABLES IN THE POWER CLEAN (May 2011)

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Manipulations of inter-repetition rest (IRR) periods during training could result in various levels of fatigue and manifest changes to lifting mechanics. Therefore, the purpose of these investigations was to examine the effect of IRR on kinetic and kinematic variables in the power clean during a multiple set exercise protocol. Ten male, recreational weightlifters participated in this study (age = 23.6 ± 0.37 years; body mass = 80.36 ± 0.90 kilogram; height = 177 ± 0.52 centimeters; power clean 1 repetition max (RM)/body mass = 1.39 ± 0.01; mean ± standard error). Session 1 consisted of documentation and determination of a 1RM in the power clean. In a randomized order, sessions 2-4 involved subjects performing 3 sets x 6 repetitions (Rep) at 80% of 1RM with 0 (P0), 20 (P20), or 40 seconds (P40) of IRR with 3 minutes rest between sets. Power, force, and velocity were obtained during each protocol and peak values were analyzed during experiment one. Horizontal displacement was obtained during each protocol and average curves were analyzed during experiment two. Peak power significantly decreased by approximately 14.94% (Rep 1: 4563.98 ± 655.08 Watts (W), Rep 6: 3881.98 ± 502.08 W) during protocol P0 in comparison to a decrease of

5.76% (Rep 1: 4303.22 ± 566.92 W, Rep 6: 4055.18 ± 581.90 W) during P20 and a decrease of 4.08% (Rep 1: 4549.13 ± 658.52 W, Rep 6: 4363.13 ± 476.01 W) during P40. Peak force significantly decreased by 7.15% (Rep 1: 2861.35 ± 246.76 Newtons (N), Rep 6: 2656.59 ± 225.21 N) during protocol P0 in comparison to a decrease of 2.88% (Rep 1: 2810.79 ± 326.94 N, Rep 6: 2729.78 ± 284.62 N) during protocol P20 and an increase of 0.04% (Rep 1: 2860.80 ± 322.88 N, Rep 6: 2862.12 ± 280.21 N) during P40. Peak velocity significantly decreased by 9.07% (Rep 1: 1.97 ± 0.15 meters/second (m/s), Rep 6: 1.79 ± 0.11 m/s) during protocol P0 in comparison to a decrease of 3.86% (Rep 1: 1.89 ± 0.13 m/s, Rep 6: 1.82 ± 0.12 m/s) during P20 and a decrease of 1.89% (Rep 1: 1.93 ± 0.17 m/s, Rep 6: 1.89 ± 0.14 m/s) during P40. Significant differences were found in horizontal displacement between repetition 1 and 6 for the first and second set of P0. During the first set of P0, the catch position in repetition 6 is in a significantly more forward position as compared to repetition 1. In addition, during the second set of P0 the first pull is significantly more forward during repetition 6 as compared to repetition 1. During the third set of P0, position values approached significance during the first and second pull phases of the lift. In contrast, when examining the bar path in P20 no significant differences from repetition 1 to 6 were found. Significant differences were found in horizontal displacement between repetition 1 and 6 for the second and third set of P40. These results demonstrate longer IRR periods allow for greater maintenance of kinetic and kinematic variables in the power clean during a multiple set exercise protocol. The addition of IRR periods may allow for a greater volume of training while reinforcing proper movement mechanics.

DEDICATION

To my thesis committee chairperson, Dr. Travis N. Triplett, thank you for all of your guidance during my graduate career at Appalachian State University. You have always been a great teacher and friend. You are an inspiration, and I hope to be half the mentor to my future students as you were to me.

To the members of my thesis committee Dr. Jeffrey M. McBride and Dr. Alan Utter, thank you for your excellent review and support throughout the entire process. Dr. McBride, I am grateful for your time, expertise, and critical analysis. Not only have you taught me biomechanics, but what it takes to become a great researcher. Dr. Utter, I appreciate your continual insight and appreciation for research. I would also like to extend my gratitude to Dr. Robert Johnson and Dr. Lanay Mudd who assisted with questions regarding statistical analysis. To my fellow graduate students Chris Parchmann, Brian Pratt, Marcus Lawrence, Jared Skinner, and James Snyder, your assistance and your time is much appreciated.

To my family, Mom, Dad, and Ashley, whose unconditional love and support has provided me with the tools to succeed. I thank you for staying by my side for this roller coaster of a ride. Your guidance and unconditional love will always be cherished. I am very fortunate to have you all and hope to live up to your expectations.

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INTRODUCTION

The ability to generate power is the main determinant of performance in sports requiring high forces over a short time period (2, 3, 33, 47, 48). Power is the product of muscular force and velocity (Power = Force x Velocity) and maximal power output occurs at percentages of maximal force and velocity (54). Training at the percentage that maximizes power has been shown to result in the greatest adaptations to muscular power (42). Furthermore, the ability to display proper technique is also associated with high power outputs. Muscular power and exercise technique are impaired during states of fatigue; therefore training methods that minimize fatigue are of interest for the development of muscular power.

Recently, one training method that has been shown to maintain kinetic and kinematic variables during resistance exercise is inter-repetition rest (IRR) during a multiple repetition protocol. This method of training employs taking brief period of rest (15-45 seconds) between repetitions. To date, only two studies have examined the effect of IRR on resistance exercise performance. Haff et al. (32) demonstrated a cluster set configuration to produce significantly higher barbell velocities than a traditional set at 90% and 120% of 1 repetition maximum (RM) during the clean pull. Additionally, the cluster set resulted in significantly higher barbell displacement when compared to the traditional set at 120% intensity (32). Lawton et al. (44) demonstrated greater power output per repetition in the bench press exercise with the use of IRR when compared to continuous repetitions. Furthermore, the IRR protocols significantly increased total power output by 21-25% when compared with the continuous set configuration (44). These studies give insight to the use of IRR for the maintenance of kinetic and kinematic variables during resistance exercise; however these studies are limited in that they observed these changes during a single set protocol

It is unknown the effects of IRR on exercise performance during a multiple set and repetition protocol in the power clean. Therefore, the purpose of this study was to examine the effects of IRR on: 1) kinetic and kinematic variables in the power clean during a multiple set exercise protocol and 2) bar path in the power clean over multiple repetitions.

Experiment 1 will examine the effects of IRR on kinetic and kinematic variables in the power clean during a multiple set exercise protocol. This experiment will provide insight into the effect of fatigue on power, force, and velocity in the power clean during a multiple set and repetition protocol. To date, no study has examined the effect of multiple, continuous repetitions on power output in the power clean exercise. Furthermore, no study has examined the effect of IRR over multiple sets and repetitions. The data presented in this experiment is different in nature than the data presented in experiment 2. Experiment 2 will examine the effects of IRR on bar path in the power clean over multiple repetitions. This will be the first study to examine bar path in the power clean exercise over multiple repetitions, and examine bar path in the power clean exercise between IRR protocols. These experiments have been presented separately due to the specific nature of the variables investigated and diverse audiences that will disseminate the results of each experiment. Therefore, appropriate to the findings of each experiment, these studies will be published as two separate research investigations.

EXPERIMENT 1:

EFFECT OF INTER-REPETITION REST PERIODS ON POWER PRODUCTION IN THE POWER CLEAN

ABSTRACT

Previous investigations have shown power contributes to athletic performance and is therefore a focus of many strength and conditioning training programs. The contribution of fatigue to increase power with training is unknown. Manipulations of inter-repetition rest (IRR) periods during power training could result in various levels of fatigue. The purpose of this study was to examine the effect of three different IRR periods in a multiple set protocol on power production in the power clean. Ten male, recreational weightlifters participated in this study (age = 23.6 ± 0.37 years; body mass = 80.36 ± 0.90 kilogram; height = 177 ± 0.52 centimeters; power clean 1 repetition max (RM)/body mass = 1.39 ± 0.01; mean ± standard error). Session 1 consisted of documentation and determination of a 1RM in the power clean. In a randomized order, sessions 2-4 involved subjects performing 3 sets x 6 repetitions (Rep) at 80% of 1RM with 0 (P0), 20 (P20), or 40 seconds (P40) of IRR with 3 minutes rest between sets. Power, force, and velocity were obtained during each protocol and peak values were analyzed. A protocol x set x repetition repeated measures one-way ANOVA with Bonferoni post-hoc was performed to determine significant differences ($p \leq 0.05$). Peak power significantly decreased by approximately 14.94% (Rep 1: 4563.98 ± 655.08 Watts (W), Rep 6: 3881.98 ± 502.08 W) during protocol P0 in comparison to a

decrease of 5.76% (Rep 1: 4303.22 ± 566.92 W, Rep 6: 4055.18 ± 581.90 W) during P20 and a decrease of 4.08% (Rep 1: 4549.13 ± 658.52 W, Rep 6: 4363.13 ± 476.01 W) during P40. Peak force significantly decreased by 7.15% (Rep 1: 2861.35 ± 246.76 Newtons (N), Rep 6: 2656.59 ± 225.21 N) during protocol P0 in comparison to a decrease of 2.88% (Rep 1: 2810.79 ± 326.94 N, Rep 6: 2729.78 ± 284.62 N) during protocol P20 and an increase of 0.04% (Rep 1: 2860.80 ± 322.88 N, Rep 6: 2862.12 ± 280.21 N) during P40. Peak velocity significantly decreased by 9.07% (Rep 1: 1.97 ± 0.15 meters/second (m/s), Rep 6: 1.79 ± 0.11 m/s) during protocol P0 in comparison to a decrease of 3.86% (Rep 1: 1.89 ± 0.13 m/s, Rep 6: 1.82 ± 0.12 m/s) during P20 and a decrease of 1.89% (Rep 1: 1.93 ± 0.17 m/s, Rep 6: 1.89 ± 0.14 m/s) during P40. These results demonstrate longer IRR periods allow for greater peak power, force, and velocity in the power clean during a multiple set exercise protocol. The addition of IRR periods may allow for a greater volume of training while minimizing fatigue during strength/power training.

INTRODUCTION

The ability to generate muscular power is considered the main determinate of performance in athletics. Power is the product of muscular force and velocity, which is defined by the force-velocity relationship. Maximal power has been shown to occur at percentages of maximal force and velocity. Training at the percentage that maximizes power has been shown to elicit the greatest training adaptations to muscular power. Muscular power decreases with fatigue; therefore, training methods that minimize fatigue for the development of muscular power are of interest.

Muscular strength, power, speed, nutrition, and sports skills are all determinants of success in competitive athletics (50). The ability to generate power is the main determinant of performance in sports requiring high forces over a short time period (2, 3, 33, 47, 48). Movements such as sprinting, jumping, throwing, change of direction, and striking are common to many sports. The ability to generate maximal power at impact, take-off, or release is determined by the instantaneous velocity at that time point. The instantaneous velocity is determined by the product of the muscular force generated and the time during which the forces were applied (48). Therefore, the ability to generate high levels of force over a short period of time (rate of force development) and the ability to produce high force outputs as muscle shortening velocity increases are of importance to individuals concerned with muscular power productions (48).

It has been established that power is the product of force and velocity. The force-velocity relationship demonstrates that the force on a muscle and the velocity with which it shortens display an inverse relationship (36). This relationship signifies that as the velocity of a concentric muscle action is increased, the ability of the muscle to generate force is decreased. Therefore, maximal muscular power exists at a compromised level of maximal force and velocity (54). Understanding the force-velocity relationship is important for establishing the load at which power output is maximized and for the development of muscular power.

Kaneko et al. (42) demonstrated that training at the load that maximizes power output increases power efficiently over a wide loading spectrum. This suggests that training at the optimal training load provides an effective stimulus for increasing maximal power and is important in the development of muscular power. The optimal load that maximizes power during resistance training has been shown to vary with exercise. It has been demonstrated that power is maximized at 30% maximum voluntary contraction (MVC) in single muscle fibers and single joint movements (9, 16, 20, 23, 58-60). For multiple-joint muscle actions, the optimal load has been shown to vary with exercise. For upper-body movements, such as the bench press and bench press throw the optimal load has been shown to be 40-50% 1RM (46), 30-45% 1RM (40) , 50-70% 1RM (18), 30% 1RM (7), 55% 1RM (4), and 30-45% 1RM (49). For lower body movements, optimal power has been shown to be 0% (7, 14, 15, 17, 19) and 55-59% 1RM (5) in the jump squat, 60-70% 1RM (39) and 40-65% 1RM (40) in the half squat, and 56-78% 1RM (57) in the leg press. The optimal load for the weightlifting movements, such as the clean and/or snatch, has been identified at 70-80% 1RM (14, 31, 43). Therefore, it is critical to understand how the optimal load changes with exercise selection during the development of muscular power.

Muscular power output is reduced with fatigue (21, 41), especially during high-intensity activities that require a high rate of muscle contraction (53). Reductions in power output result from a decline in both force and velocity (25, 26). Power, force, and velocity have been shown to decrease with each repetition during resistance exercise (38, 44). Izquierdo et al. (38) demonstrated significant decreases in repetition velocity at one-third (13%) and one-half (8%) of repetitions to failure in the bench press and squat exercises, respectively. Lawton et al. (44) demonstrated a near-linear decrease in power output during a six repetition maximum bench press exercise. Significant decreases in power output were found with each repetition (7.6 ± 9.3%, 17.9 ± 8.1%, 30.3 ± 9.4%, 41.9 ± 11.6%, and 52.9 ± 11.5%, respectively) (44). Duffey and Challis (24) also demonstrated significant decreases in mean and peak velocity during repetitions to failure in the bench press. Furthermore, significant bar path deviations were seen when compared to the first repetition (24). Drinkwater et al. (22) also found significant decreases in mean and peak power output during the bench press over multiple sets and repetitions. These studies demonstrate that kinetic and kinematic variables are decreased during a multiple repetition resistance exercise protocol.

It has been suggested that fatigue may reduce the effectiveness of power development through decreases in movement velocity and manipulations to exercise technique (52). Therefore, methods to minimize fatigue are of interest during the development of muscular power. One less common exercise method to minimize fatigue is the use of IRR periods. To date, only two studies have examined the effect of IRR on resistance exercise performance. Haff et al. (32) demonstrated a cluster set configuration to produce significantly higher barbell velocities than a traditional set at 90% and 120% of 1RM during the clean pull.

Additionally, the cluster set resulted in significantly higher barbell displacement when compared to the traditional set at 120% intensity (32). Lawton et al. (44) demonstrated greater power output per repetition in the bench press exercise with the use of IRR when compared to continuous repetitions. Furthermore, the IRR protocols significantly increased total power output by 21-25% when compared with the continuous set configuration (44). These studies give insight to the use of IRR for the maintenance of kinetic and kinematic variables during resistance exercise; however these studiesare limited in that they observed these changes during a single set protocol.

The effect of IRR rest on kinetic and kinematic variables during a multiple set exercise protocol is unknown. Therefore, the purpose of this investigation was to examine the effect of IRR on kinetic and kinematic variables in the power clean during a multiple set exercise protocol. It is hypothesized that IRR will allow for the maintenance of power and exercise technique over multiple sets and repetitions.

METHODOLOGY

Experimental Approach to the Problem

All subjects participated in 4 testing sessions over a period of 2 weeks with 72 hours given between sessions. Session 1 consisted of documentation and determination of a one repetition maximum (1RM) in the power clean. In a randomized order, during sessions 2-4, subjects performed 3 sets x 6 repetitions at 80% 1RM with 0 (P0), 20 (P20), or 40 seconds (P40) IRR with 3 minutes rest given between sets. Power, force, and velocity were collected during each protocol for each repetition and peak values were analyzed. Peak values of power, force, and velocity were compared between protocols.

Subjects

Ten male, recreational weightlifters participated in this study (age = 23.6 ± 0.37 years; body mass = 80.36 ± 0.90 kilograms; height = 177 ± 0.52 centimeters; power clean 1RM/body mass = 1.39 ± 0.01; mean ± standard error). The subjects had at least 4 years of weight training and 1 year of weightlifting experience. Subjects were required to display proper technique of the power clean exercise for participation in this study. All subjects read and signed an informed consent approved by the Institutional Review Board at Appalachian State University.

Preliminary Testing (Session 1)

All subjects reported to the Neuromuscular Laboratory for session 1 after refraining from strenuous exercise for a minimum of 48 hours. During preliminary testing, subjects were tested for height, weight, and a 1RM in the power clean exercise. Power clean 1RM testing was performed as described by Winchester et al. (61). Briefly, subjects underwent a series of warm-up sets and several maximal lifts until a 1RM was achieved. Proper technique of the power clean was assessed as discussed previously (6, 10, 11, 27, 29, 37, 61, 62).

Protocol Testing (Sessions 2-4)

In a randomized order, each subject completed 3 testing sessions over a period of 2 weeks. During sessions 2-4, subjects performed 3 sets of 6 repetitions at 80% 1RM with 0 seconds (P0), 20 seconds (P20), or 40 seconds (P40) of IRR. 80% 1RM has been shown to be the optimal load for peak and average power in the power clean exercise (13). Three minutes rest was given between sets. Testing sessions were separated by a minimum of 48 hours to allow for complete recovery.

Instrumentation

All kinetic and kinematic data was collected and analyzed as described by Cormie et al. (13). Briefly, testing was conducted with subjects standing on a force plate (AMTI, BP60011200; Watertown, MA) with two linear position transducers (2-LPT)(Celesco PT5A-15; Chatsworth, CA) attached to the right side of the barbell. Analog signals from the force plate and 2-LPT were collected at 1,000 Hz using a BNC-2010 interface box with an analog-to-digital card (National Instruments PCI-6014; Austin, TX). The voltage outputs from the force plate and 2-LPT were converted to force (N) and displacement (m), respectively. LabVIEW (National Instruments, Version 7.1) software was used during data collection and analysis. Vertical velocity was calculated throughout the movement using the displacement-time data for each sample. Power output was calculated by the integration of vertical velocity to force data at each corresponding time point. Cormie et al. (13) have demonstrated this method to accurately assess power output in multidimensional movements. Data was collected for each repetition and values of peak power, force, and velocity were calculated for each protocol.

Statistical Analysis

A 3 x 3 x 6 repeated measures (protocol x set x repetition) analysis of variance (ANOVA) was used to analyze peak values of power, force, and velocity for each repetition during each protocol. When significant values were determined, a Bonferoni post-hoc was used to determine statistical significance. All statistical analysis was performed using SPSS version 17.0 (SPSS Inc., Chicago, IL.).

RESULTS

The effect of IRR periods during a multiple set exercise protocol were examined during this investigation. The effect of IRR on power, force, and velocity for each protocol are presented in Figures 1-3. Mean percentages of the first repetition peak power were significantly lower for P0 when compared to P20 and P40 (P0: 92.49 ± 1.39%; P20: 97.43 ± 1.31%; P40: 98.18 ± 0.91%; mean ± standard error). Mean percentages of the first repetition peak force were significantly lower ($p \leq 0.05$) for P0 when compared to P20 and P40 (P0: 96.59 ± 0.72%; P20: 98.85 ± 0.68%; P40: 100.20 ± 0.83%; mean ± standard error). Mean percentages of the first repetition peak velocity were significantly lower ($p \leq 0.05$) for P0 when compared to P20 and P40 (P0: 94.28 ± 0.42%; P20: 98.14 ± 0.48%; P40: 99.08 ± 0.33%; mean ± standard error).

The effect of IRR on power, force, and velocity for repetitions 1 to 6 are presented in Figures 4-6. Peak power significantly decreased by approximately 14.94% (Rep 1: 4563.98 ± 655.08 Watts (W), Rep 6: 3881.98 ± 502.08 W) during protocol P0, in comparison to a decrease of 5.76% (Rep 1: 4303.22 ± 566.92 W, Rep 6: 4055.18 ± 581.90 W) during P20, and a decrease of 4.08% (Rep 1: 4549.13 ± 658.52 W, Rep 6: 4363.13 ± 476.01 W) during P40. Peak force significantly decreased by approximately 7.15% (Rep 1: 2861.35 ± 246.76 Newtons (N), Rep 6: 2656.59 ± 225.21 N) during protocol P0, in comparison to a decrease of 2.88% (Rep 1: 2810.79 ± 326.94 N, Rep 6: 2729.78 ± 284.62 N) during protocol P20, and an increase of 0.04% (Rep 1: 2860.80 ± 322.88 N, Rep 6: 2862.12 ± 280.21 N) during P40. Peak velocity significantly decreased by approximately 9.07% (Rep 1: 1.97 ± 0.15 meters/second (m/s), Rep 6: 1.79 ± 0.11 m/s) during protocol P0, in comparison to a decrease of 3.86% (Rep 1: 1.89 ± 0.13 m/s, Rep 6: 1.82 ± 0.12 m/s) during P20, and a decrease of 1.89% (Rep 1: 1.93 ± 0.17 m/s, Rep 6: 1.89 ± 0.14 m/s) during P40.

Table 1. Subject Characteristics. Ten male, recreational weightlifters (*n* = 10) participated in this study. Subjects had at least 4 years of weight training and 1 year of weightlifting experience and were required to display proper technique of the power clean exercise for participation in this study.

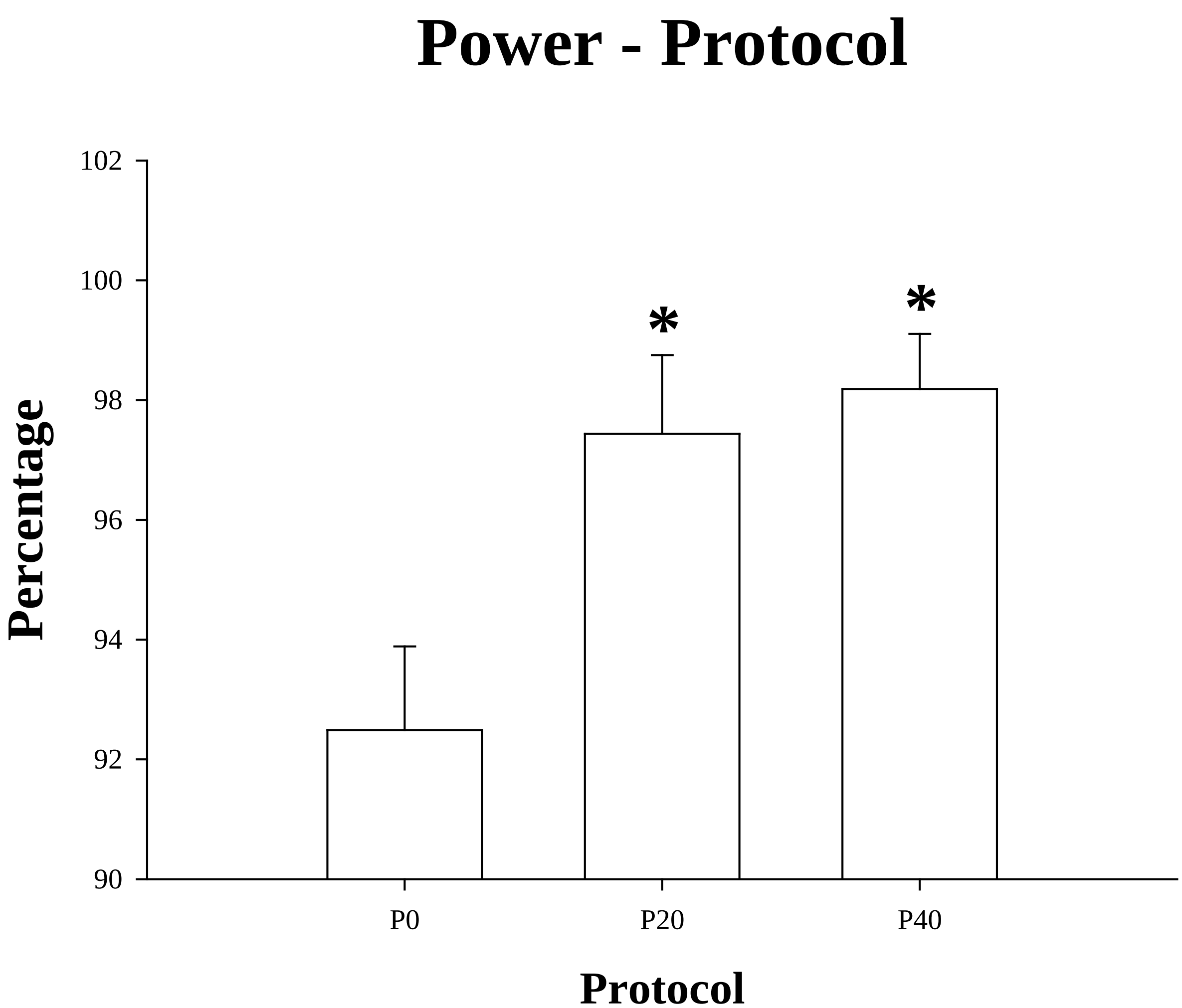
Subject Characteristics (*n* = 10)

Age	**23.6 ± 0.37 years**
Body Mass	**80.36 ± 0.90 kilograms**
Height	**177 ± 0.52 centimeters**
Power Clean 1 repetition max/body mass	**1.39 ± 0.01**

*** Mean ± Standard Error**

Figure 1. Mean power for each protocol. Power is represented as a percentage of the first repetition. P0 = 0 seconds IRR. P20 = 20 seconds IRR. P40 = 40 seconds IRR.

* Significant differences were found between P0 and both P20 and P40 ($p \leq 0.05$).



* significantly different from P0

Figure 2. Mean force for each protocol. Force is represented as a percentage of the first repetition. P0 = 0 seconds IRR. P20 = 20 seconds IRR. P40 = 40 seconds IRR.

* Significant differences were found between P0 and both P20 and P40 ($p \leq 0.05$).

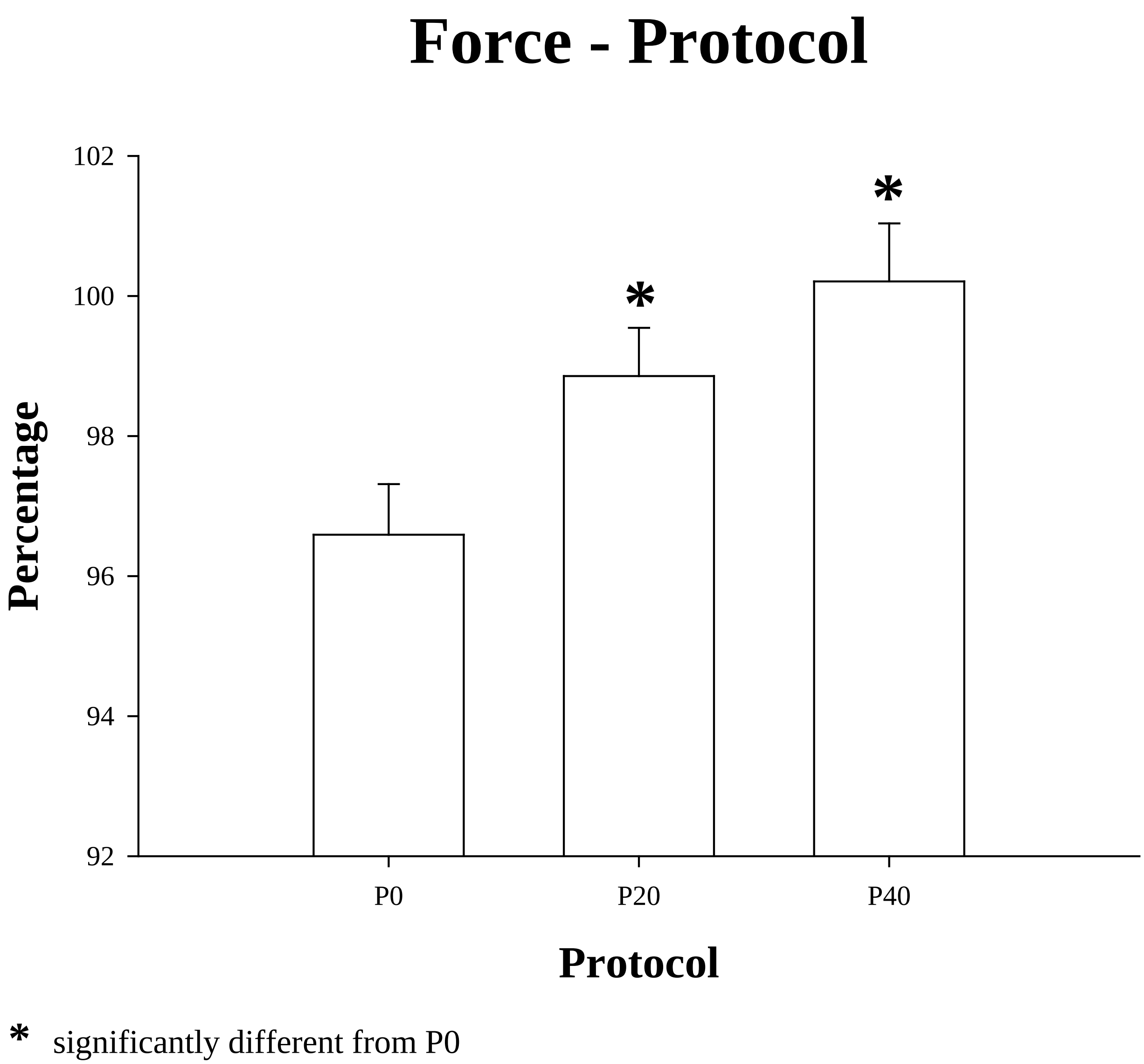


Figure 3. Mean velocity for each protocol. Velocity is represented as a percentage of the first repetition. P0 = 0 seconds IRR. P20 = 20 seconds IRR. P40 = 40 seconds IRR.

* Significant differences were found between P0 and both P20 and P40 ($p \leq 0.05$).

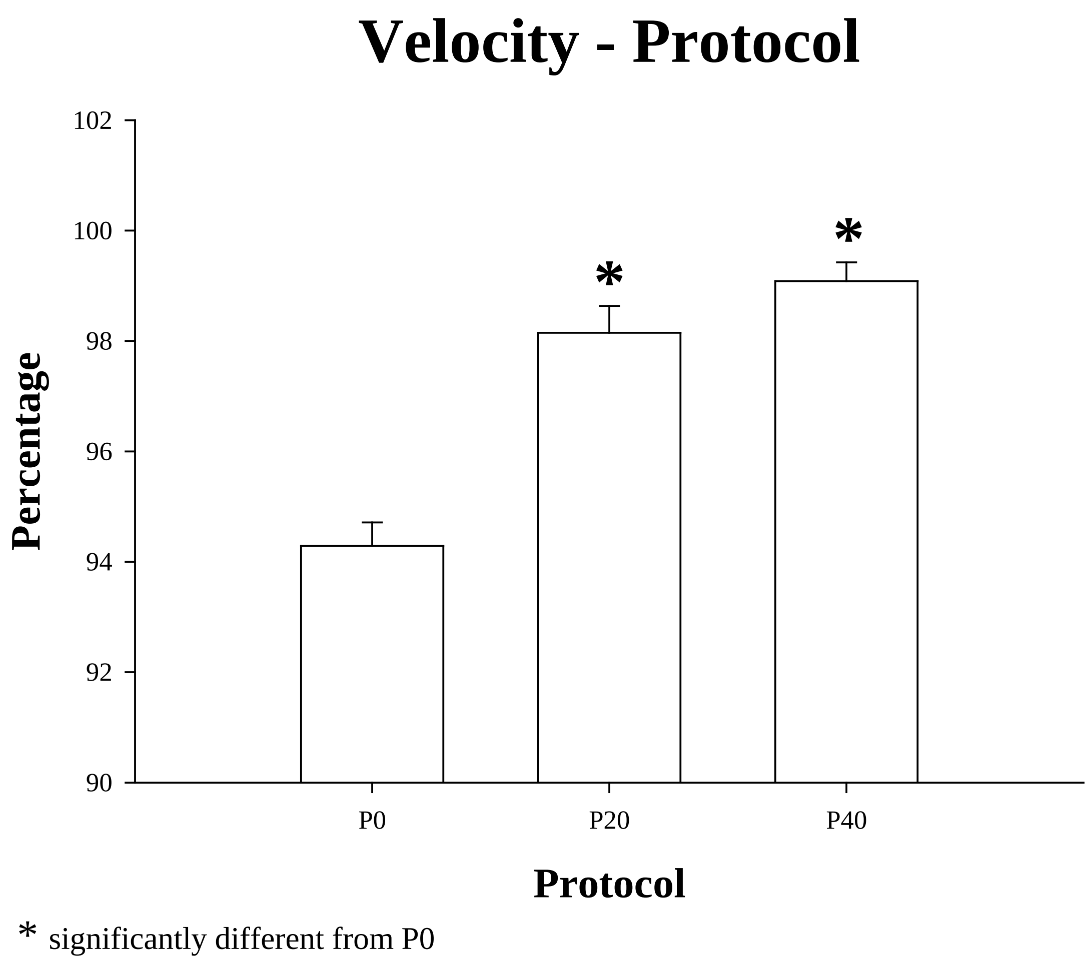
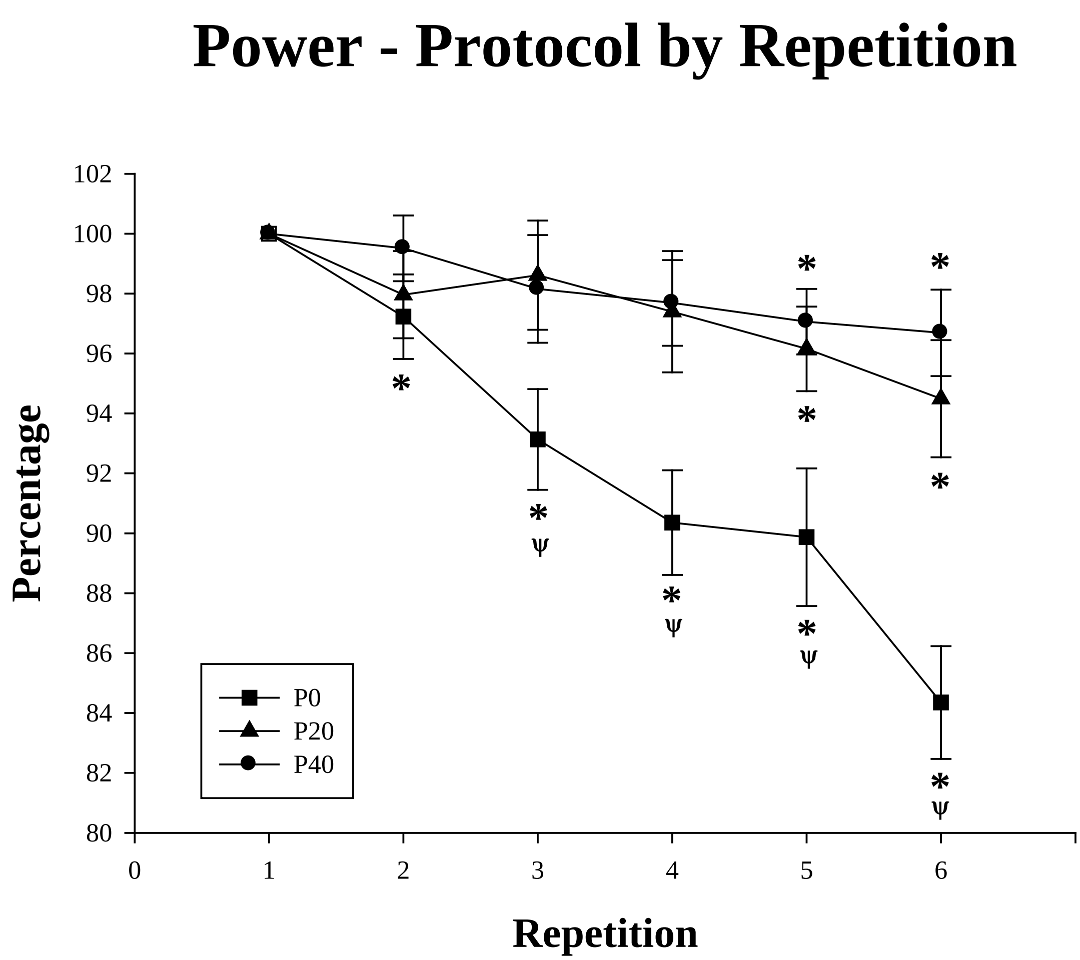
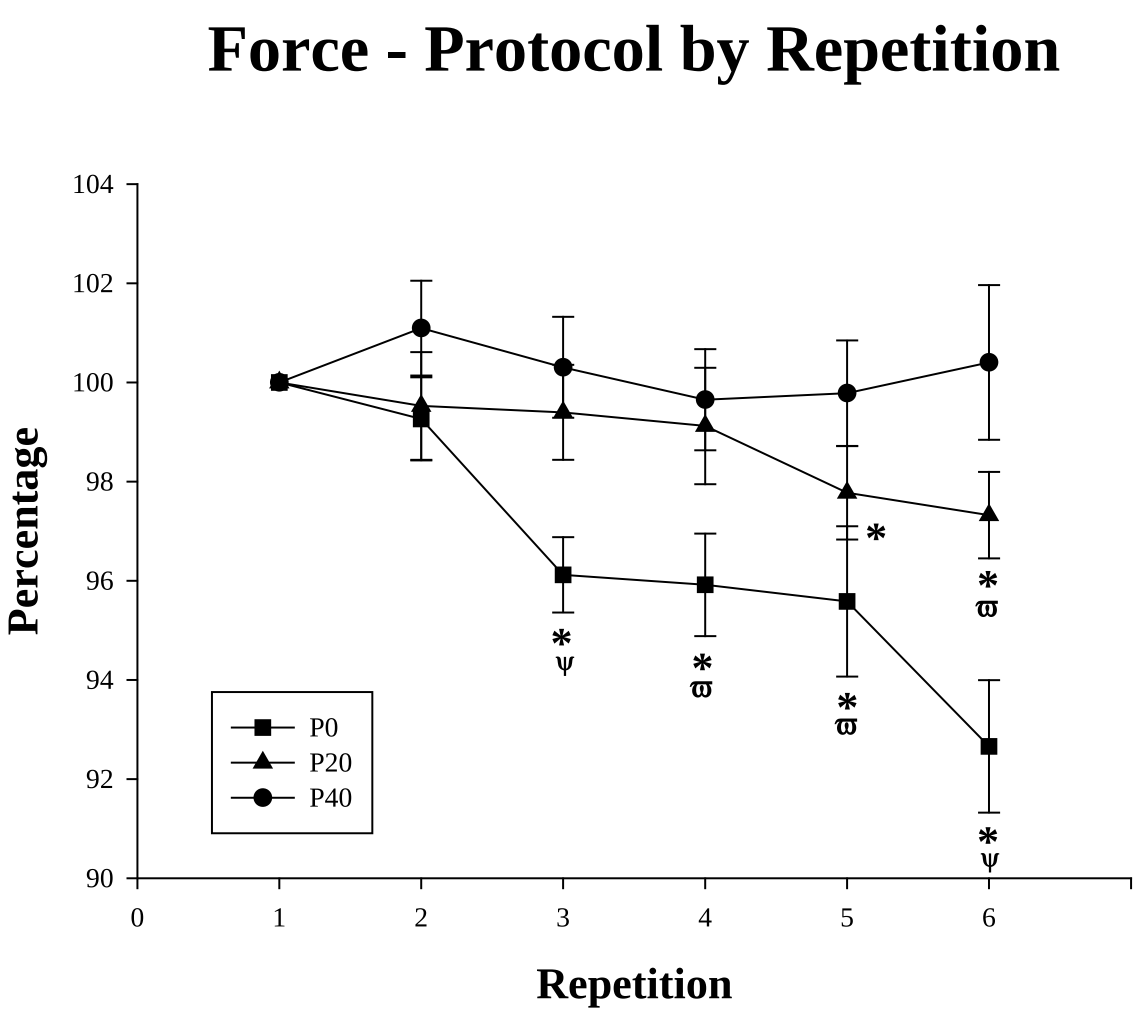


Figure 4. Peak power across repetitions for each protocol. Power is represented as a percentage of the first repetition. P0 = 0 seconds IRR. P20 = 20 seconds IRR. P40 = 40 seconds IRR. * Significant differences were found between repetitions 2-6 from repetition 1 in P0 ($p \leq 0.05$). * Significant differences were found between repetitions 5 and 6 from repetition 1 in P20 and P40 ($p \leq 0.05$). Ψ Peak power in P0 was significantly different from P20 and P40 during repetitions 3-6 ($p \leq 0.05$).



* significantly different from 1st repetition
ψ significantly different from P20 and P40

Figure 5. Peak force across repetitions for each protocol. Force is represented as a percentage of the first repetition. P0 = 0 seconds IRR. P20 = 20 seconds IRR. P40 = 40 seconds IRR. * Significant differences were found between repetitions 3-6 from repetition 1 in P0 ($p \leq 0.05$). * Significant differences were found between repetitions 5 and 6 from repetition 1 in P20 ($p \leq 0.05$). Ψ Peak force in P0 was significantly different from P20 during repetitions 3 and 6. ω Peak force in P0 was significantly different from P40 during repetitions 3-6 ($p \leq 0.05$).

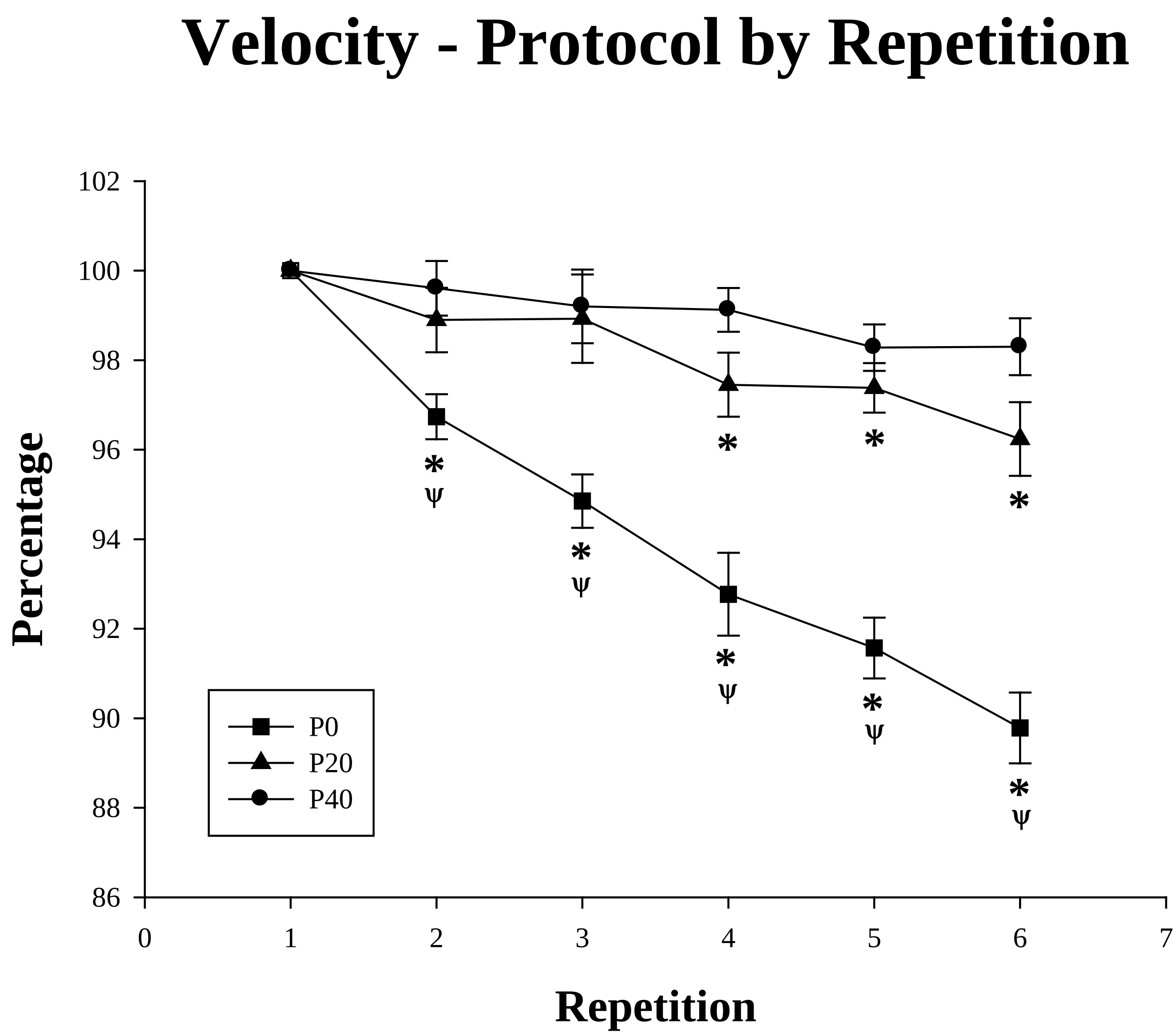


* significantly different from 1st repetition

ψ significantly different from P20 and P40

ϖ significantly different from P40

Figure 6. Peak velocity across repetitions for each protocol. Velocity is represented as a percentage of the first repetition. P0 = 0 seconds IRR. P20 = 20 seconds IRR. P40 = 40 seconds IRR. * Significant differences were found between repetitions 2-6 from repetition 1 in P0 ($p \leq 0.05$). * Significant differences were found between repetitions 4-6 from repetition 1 in P20 ($p \leq 0.05$). Ψ Peak velocity in P0 was significantly different from P20 and P40 during repetitions 2-6 ($p \leq 0.05$).



* significantly different from 1st repetition
ψ significantly different from P20 and P40

DISCUSSION

It has been demonstrated that training at the intensity that maximizes power output is important for the development of muscular power (42). Kaneko et al. (42) demonstrated that 12 weeks of training at the load that optimizes power output (30%) increased muscular power to a greater extent than 100%, 60%, and 0% of isometric strength. Therefore, training methodologies that maximize power output may provide the greatest training stimulus and adaptation for the development of muscular power. The current investigation examined the effect of three different IRR periods in a multiple set protocol on power production in the power clean.

This study demonstrated longer IRR results in maintenance of peak power, force, and velocity in the power clean during a multiple set exercise protocol. This is in agreement with previous research by Lawton et al. (44) and Haff et al. (32) demonstrating the effect of IRR periods on exercise performance. Lawton et al. (44) demonstrated significant decreases in power output during 6 continuous repetitions in the bench press exercise. Whereas the IRR protocols (single, doubles, triples) significantly increased total power output by 21-25% compared to the continuous set configuration (44). During the current investigation, P0 displayed significant decreases in power, force, and velocity (14.94%, 7.15%, and 9.07, respectively) over 6 repetitions. Haff et al. (32) demonstrated higher barbell velocities with the use of a cluster set when compared to a continuous set configuration. Similarly, this study found significant differences between continuous and IRR protocols with regard to power, force, and velocity over multiple repetitions. Peak power in P0 was significantly different from P20 and P40 during repetitions 3-6. Peak force in P0 was significantly different from P20 during repetitions 3 and 6 and P40 during repetitions 3-6. Peak velocity in P0 was significantly different from P20 and P40 during repetitions 2-6. Collectively, these studies indicate that IRR protocols are an effective exercise method to maintain power, force, and velocity over multiple repetitions when compared to a continuous set configuration.

Interestingly, this study found significant differences in power, force, and velocity as early as the second repetition during the continuous set configuration. Izquierdo et al. (38) found significant decreases in repetition velocity at repetitions 3, 4, 5, and 7 (75%, 70%, 65%, and 60% of 1RM, respectively) in the bench press and at repetitions 5, 9, 11, and 15 (75%, 70%, 65%, and 60% of 1RM, respectively) in the squat during continuous repetitions to failure. The authors suggested that to maintain maximal velocity, the repetition velocity should not decrease more than 13% and 8% of the first repetition in the bench press and squat, respectively. The results from this study demonstrated that power decreased by only ~4-6% during the IRR protocols. This indicates that these guidelines can be achieved through the use of IRR over a multiple set and repetition exercise protocol in the power clean.

It is believed that IRR allows for greater power output due to partial recovery of energy substrates and reversal of fatigue (30, 32, 44). Bogdanis et al. (8) has demonstrated that phosphocreatine (PCr) resynthesis is important for the recovery of power during repeated bouts of sprint exercise. Significant correlations (r = 0.71–0.86) were found between the resynthesis of PCr and the percentage of restoration of peak power output, peak pedal speed, and mean power during the initial 6 seconds of exercise after 1.5 and 3 minutes recovery (8).

Furthermore, Harris et al. (35) demonstrated that PCr synthesis half-time was calculated to be 21-22 seconds, and occlusion of the circulation to a fatigued skeletal muscle inhibits PCr resynthesis. Therefore, it is speculated that IRR of at least 20 seconds may allow for partial PCr resynthesis and maintenance of power, force, and velocity. This notion is supported by Pereira et al. (51) who demonstrated that rest interval lengths of 14 to 17 seconds were sufficient to maintain jumping performance during 30 maximal volleyball spikes. Whereas, a rest interval length of 8 seconds resulted in increased blood lactate concentrations and decreased countermovement jump performance (51). To date, no study has examined PCr resynthesis during an IRR protocol; therefore, future research is needed to identify the exact mechanisms relating the maintenance of power production during IRR protocols.

Conclusions

Kaneko et al. (42) demonstrated that the development of muscular power is greatest when training at the intensity at which power is maximized (42). Our data demonstrates that 20 - 40 seconds IRR can be useful to maintain power, force, and velocity during a multiple set protocol. Therefore, it could be speculated that this training methodology would induce a greater training stimulus when compared to a continuous set configuration. This may be advantageous for individuals seeking a greater training response with regards to the development of muscular power. Since there were no significant differences between P20 and P40, it can be speculated that there is no additional benefit to resting longer than 20 seconds.

Practical Application

The addition of IRR may allow for greater training stimulus while minimizing fatigue during a strength/power phase. There were no significant differences between P20 and P40; therefore, the addition of 20 seconds IRR may be more practical for strength coaches under time constraints with their athletes. Future research should examine the longitudinal effects of IRR in a periodized strength training program for the development of muscular power.

EXPERIMENT 2:

EFFECT OF INTER-REPETITION REST PERIODS ON POWER CLEAN TECHNIQUE

ABSTRACT

Horizontal bar path has been frequently studied in the weightlifting movements for single repetition maximum attempts. It is unclear how bar path is affected over multiple repetitions in the power clean. The inclusion of inter-repetition rest (IRR) periods may allow for improved lifting mechanics when compared to a traditional set configuration. The purpose of this investigation was to examine the effect of IRR on power clean bar paths during a multiple set protocol. Ten male, recreational weightlifters participated in this study (age = 23.6 ± 0.37 years; body mass = 80.36 ± 0.90 kilograms; height = 177 ± 0.52 centimeters; 1 repetition maximum (RM) = 111.98 ± 0.69; 1RM/body mass = 1.39 ± 0.01; mean ± standard error). Session 1 consisted of documentation and determination of 1RM in the power clean exercise. Sessions 2 and 3 included performing one of the following exercise protocols in a randomized order. Protocols consisted of 3 sets of 6 repetitions at 80% 1RM with either 0 (P0) or 20 seconds (P20) inter-repetition rest. Three minutes rest was given between each set. Average curves for vertical and horizontal bar displacement were generated and used for analysis of bar path. Significant differences were found in horizontal displacement between repetition 1 and 6 for the first and second set of P0. During the first set of P0, the catch position in repetition 6 is in a significantly more forward position as compared to repetition 1. In addition, during the second set of P0 the first pull is

significantly more forward during repetition 6 as compared to repetition 1. During the third set of P0, position values approached significance during the first and second pull phases of the lift. In contrast, when examining the bar path in P20 no significant differences from repetition 1 to 6 were found. The results of this study demonstrate that subjects were able to display a more appropriate bar path within a multiple set and repetition protocol with the addition of a 20 second IRR period. It may be advantageous to include IRR periods to reinforce proper movement mechanics, especially in sports that require a high level of mechanical proficiency.

INTRODUCTION

Muscular strength, power, speed, nutrition, and sports skills are all determinants of success in competitive athletics (50). Although strength and power are highly correlated to sporting success, the ability to apply forces in the appropriate manner is also of great importance. It is believed that the ability to demonstrate appropriate technique is dependent on the level of fatigue. Therefore, the ability to maintain exercise technique over multiple repetitions is of interest to athletes.

It is generally accepted that fatigue induces detrimental effects of exercise performance through manipulations to motor control and technique. Halil et al. (34) found postural balance to be impaired following fatiguing exercise in collegiate volleyball players. Gabbett (28) demonstrated reductions in tackling technique under fatigue. In addition, individuals with the best tackling technique during a non-fatigue state demonstrated the greatest decrements in technique under fatigue. Apriantono et al. (1) found reduced leg swing speed and poorer ball contact during instep kicks under fatigued conditions in soccer players. Stone and Oliver (55) also demonstrated decreased kicking performance during fatigue in soccer players. Research suggests that depression of muscular force and ineffective inter-muscular coordination play a role in decreased kicking performance (1).

Researchers believe that fatigue may induce manipulations to lifting technique (52), however few studies have examined these effects. Chen (12) found lifting strategies to be altered following arm fatigue. The altered lifting mechanics resulted in higher spinal disc (L5/S1) compression forces which may put individuals at a greater risk for injuries under fatigued conditions (12). Madigan and Pidcoe (45) demonstrated decreased vertical ground impact forces and increased maximum joint flexion during landing with fatigue. The results indicate that fatigue induces changes to landing strategies leading to decreased performance. With regard to resistance exercise, Duffey and Challis (24) examined the effects of fatigue on bench press kinematics and found lifters to keep the barbell more directly over the shoulder in later repetitions as compared to the initial repetitions. The authors also found increases in measures of bar path straightness, the length of the path the bar traveled, and the maximal deviation from a straight line, as the subjects progressed through the trial. It has been suggested that if the kinematics of a lift at the end of a set are different from the desired movement pattern, it may not be beneficial to train to muscular fatigue (24). Collectively, these studies suggest that fatigue induces changes to exercise technique which can have negative effects on exercise performance and increase the risks of injury.

Numerous studies have analyzed bar path in the weightlifting movements during single repetitions (6, 10, 11, 27, 37). Stone et al. (56) established descriptive barbell kinematic variables that can be used to assess bar path in the weightlifting movements. These variables have been used to quantify exercise technique in both the power clean and the power snatch (61, 62). Throughout the literature it is recognized that appropriate bar path technique displays a horizontal displacement pattern of towards the lifter, away from the lifter, and back towards the lifter (56, 61, 62). Despite the acknowledgment of proper bar path during single repetitions, it is unknown how bar path is affected over multiple repetitions in the weightlifting movements.

With the understanding of the effects of fatigue on exercise technique, it is apparent why methods to minimize fatigue are of interest during training and for the development of exercise technique. Recently, IRR has become of interest for the attenuation of fatigue during resistance exercise. Haff et al. (32) demonstrated a cluster set to produce significantly higher barbell velocities (90% and 120% of 1RM) and displacement (120% of 1RM) when compared to a continuous set configuration in the clean pull. Lawton et al. (44) found greater mean power output across 6 repetitions in the bench press exercise with the use of IRR when compared to continuous repetitions. These studies demonstrate the importance of IRR on the attenuation of fatigue; however, neither study examined the effect of IRR on exercise technique. The effects of IRR on bar path are unknown.

Therefore, the purpose of this investigation was to examine the effect of IRR on bar path in the power clean during a multiple set protocol. It was hypothesized that IRR would allow for the maintenance of bar path over multiple sets and repetitions.

METHODOLOGY

Experimental Approach to the Problem

All subjects participated in 4 testing sessions over a period of 2 weeks with 72 hours given between sessions. Session 1 consisted of documentation and determination of a 1RM in the power clean. In a randomized order, during sessions 2-4 subjects performed 3 sets x 6 repetitions at 80% 1RM with 0, 20, or 40 seconds IRR with 3 minutes rest between sets. Vertical and horizontal displacements were collected during each protocol for each repetition. Average vertical and horizontal displacement curves were generated for analysis. Horizontal displacement was compared between repetition 1 and repetition 6 during the same set of each protocol.

Subjects

Ten male, recreational weightlifters participated in this study (age = 23.6 ± 0.37 years; body mass = 80.36 ± 0.90 kilograms; height = 177 ± 0.52 centimeters; power clean 1RM/body mass = 1.39 ± 0.01; mean ± standard error). The subjects had at least 4 years of weight training and 1 year of weightlifting experience. Subjects were required to display proper technique of the power clean exercise for participation in this study. All subjects read and signed an informed consent approved by the Institutional Review Board at Appalachian State University.

Preliminary Testing (Session 1)

All subjects reported to the Neuromuscular Laboratory for session 1 after refraining from strenuous exercise for a minimum of 48 hours. During preliminary testing, subjects were tested for height, weight, and a 1RM in the power clean exercise. Power clean 1RM testing was performed as described by Winchester et al. (61). Briefly, subjects underwent a series of warm-up sets and several maximal lifts until a 1RM was achieved. Proper technique of the power clean was assessed as discussed previously (6, 10, 11, 27, 29, 37, 61, 62).

Protocol Testing (Sessions 2-4)

In a randomized order, each subject completed 3 testing sessions over a period of 2 weeks. During sessions 2-4, subjects performed 3 sets of 6 repetitions at 80% 1RM with 0 seconds (P0), 20 seconds (P20), or 40 seconds (P40) of IRR. 80% 1RM has been shown to be the optimal load for peak and average power in the power clean exercise (13). Three minutes rest was given between sets. Testing sessions were separated by a minimum of 48 hours to allow for complete recovery.

Instrumentation

All kinetic and kinematic data was collected and analyzed as described by Cormie et al. (13). Briefly, testing was conducted with subjects standing on a force plate (AMTI, BP60011200; Watertown, MA) with two linear position transducers (2-LPT)(Celesco PT5A-15; Chatsworth, CA) attached to the right side of the barbell. Analog signals from the force plate and 2-LPT were collected at 1,000 Hz using a BNC-2010 interface box with an analog-to-digital card (National Instruments PCI-6014; Austin, TX). The voltage outputs from the force plate and 2-LPT were converted to force (N) and displacement (m), respectively. LabVIEW (National Instruments, Version 7.1) software was used during data collection and analysis. Vertical and horizontal displacements were recorded for each repetition of each protocol. Vertical and horizontal displacement average curves were generated for repetition 1 and repetition 6 of each set for each protocol. Horizontal displacement was used in analysis.

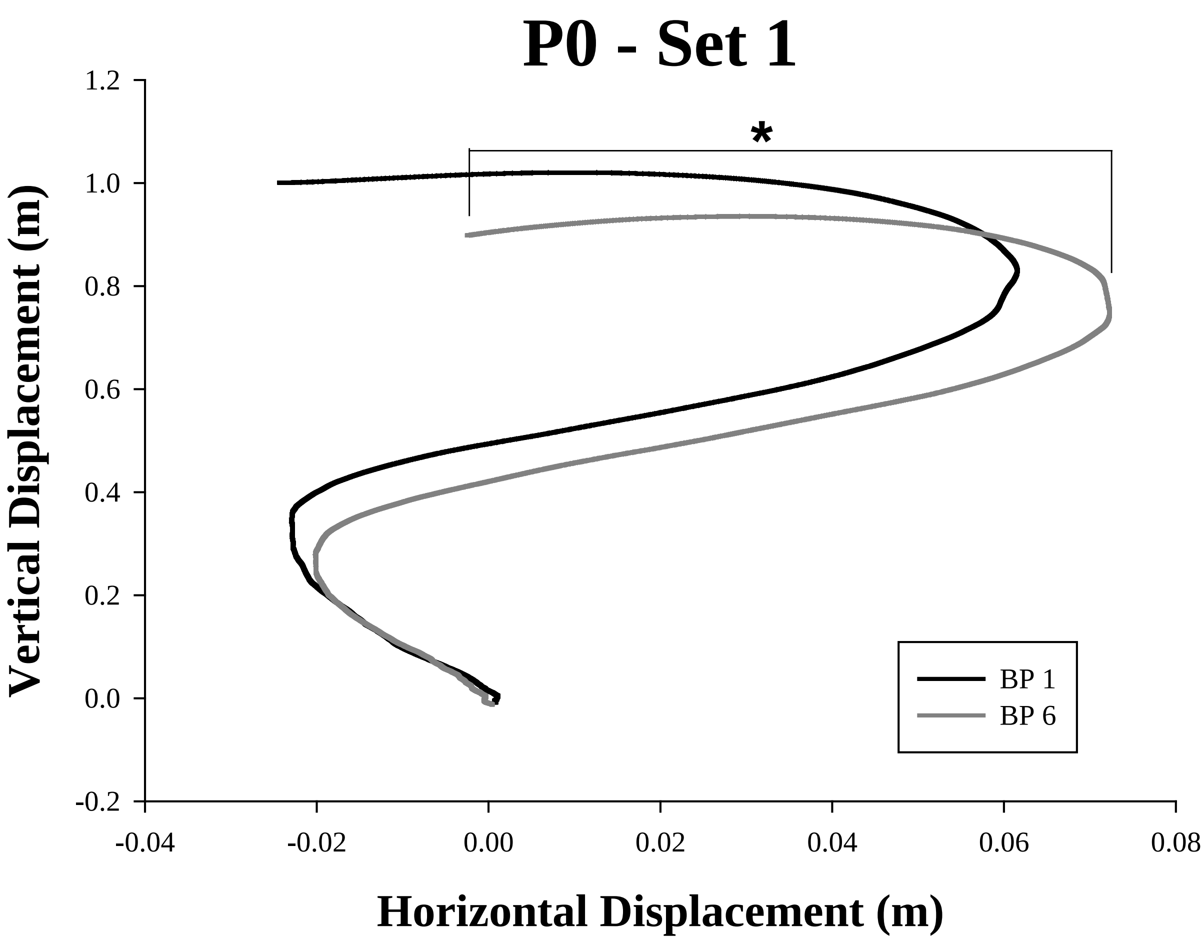
Statistical Analysis

A students *t*-test was used to compare horizontal displacement between repetition 1 and repetition 6 of the same set of every protocol. Significance was set at $p \leq 0.05$ and all statistical analysis was performed using SPSS version 17.0 (SPSS Inc., Chicago, IL.).

RESULTS

The effects of IRR on bar path are presented in Figures 13-21. Significant differences in horizontal displacement were found between repetition 1 and repetition 6 for the first and second set of P0. During the first set of P0, the catch position in repetition 6 was in a significantly more forward position compared to repetition 1. In addition, during the second set of P0, the first pull was significantly more forward during repetition 6 compared to repetition 1. During the third set of P0, position values approached significance during the first and second pull phases of the lift. No significant differences were found between repetition 1 and repetition 6 in all sets of P20. During the second set of P40, significant differences in horizontal displacement were found between repetition 1 and repetition 6. The second pull and loop was significantly more forward during repetition 6 compared to repetition 1. In set 3 of P40, significant differences in horizontal displacement were found between repetition 1 and repetition 6 during the first pull, transition, and beginning of the second pull.

Figure 7. Bar Path for Set 1 of P0. P0 = 0 seconds IRR. BP 1 = bar path of repetition 1. BP 6 = bar path of repetition 6. * Significant differences in horizontal displacement were found between repetition 1 and repetition 6 for the first set of P0 ($p \leq 0.05$). The catch position in repetition 6 was in a significantly more forward position compared to repetition 1.



* significantly different horizontal displacement

Figure 8. Bar Path for Set 2 of P0. P0 = 0 seconds IRR. BP 1 = bar path of repetition 1. BP 6 = bar path of repetition 6. * Significant differences in horizontal displacement were found between repetition 1 and repetition 6 ($p \leq 0.05$). The first and second pull were significantly more forward during repetition 6 compared to repetition 1.

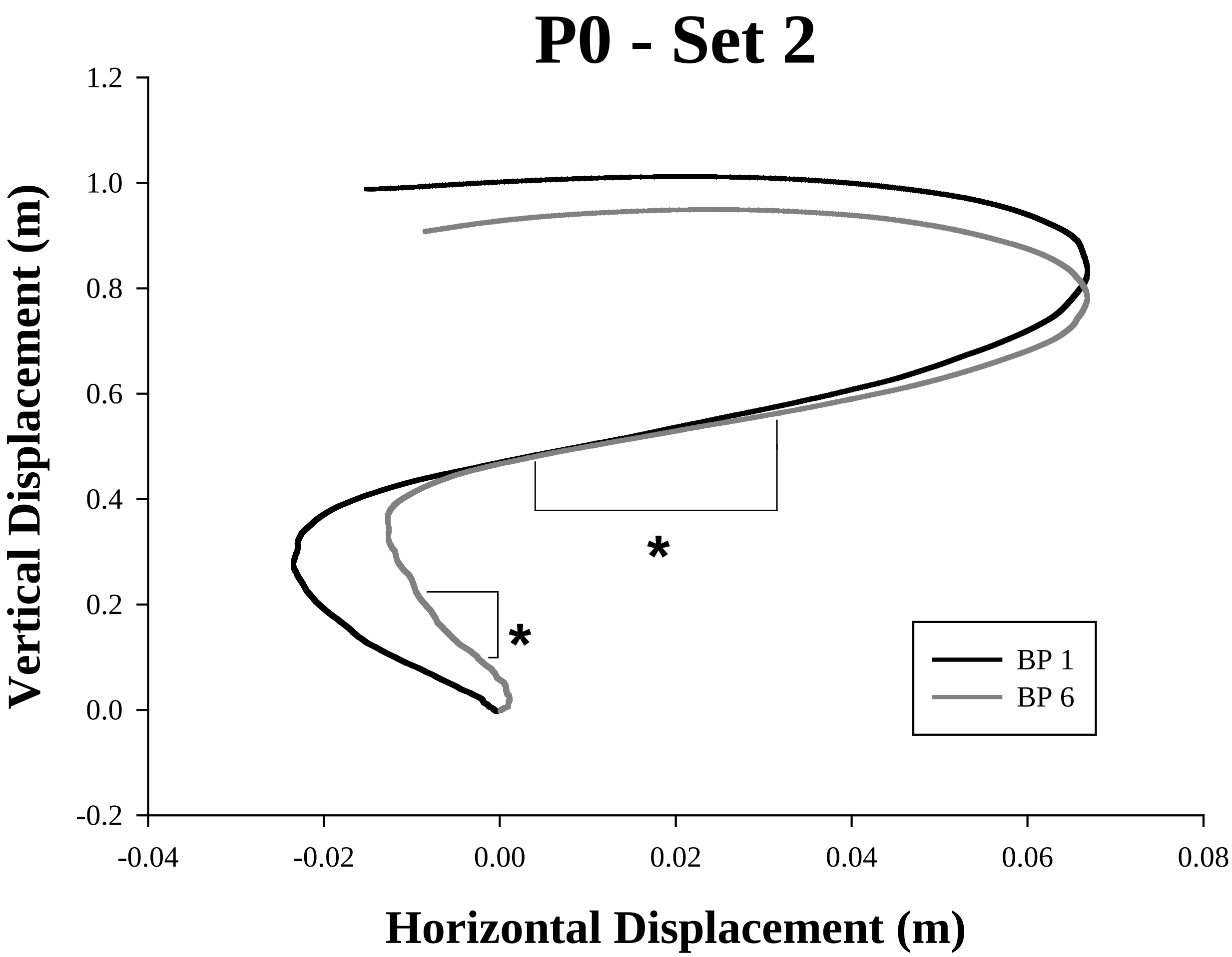


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Figure 9. Bar Path for Set 3 of P0. P0 = 0 seconds IRR. BP 1 = bar path of repetition 1. BP 6 = bar path of repetition 6. No significant differences in horizontal displacement were found between repetition 1 and repetition 6.

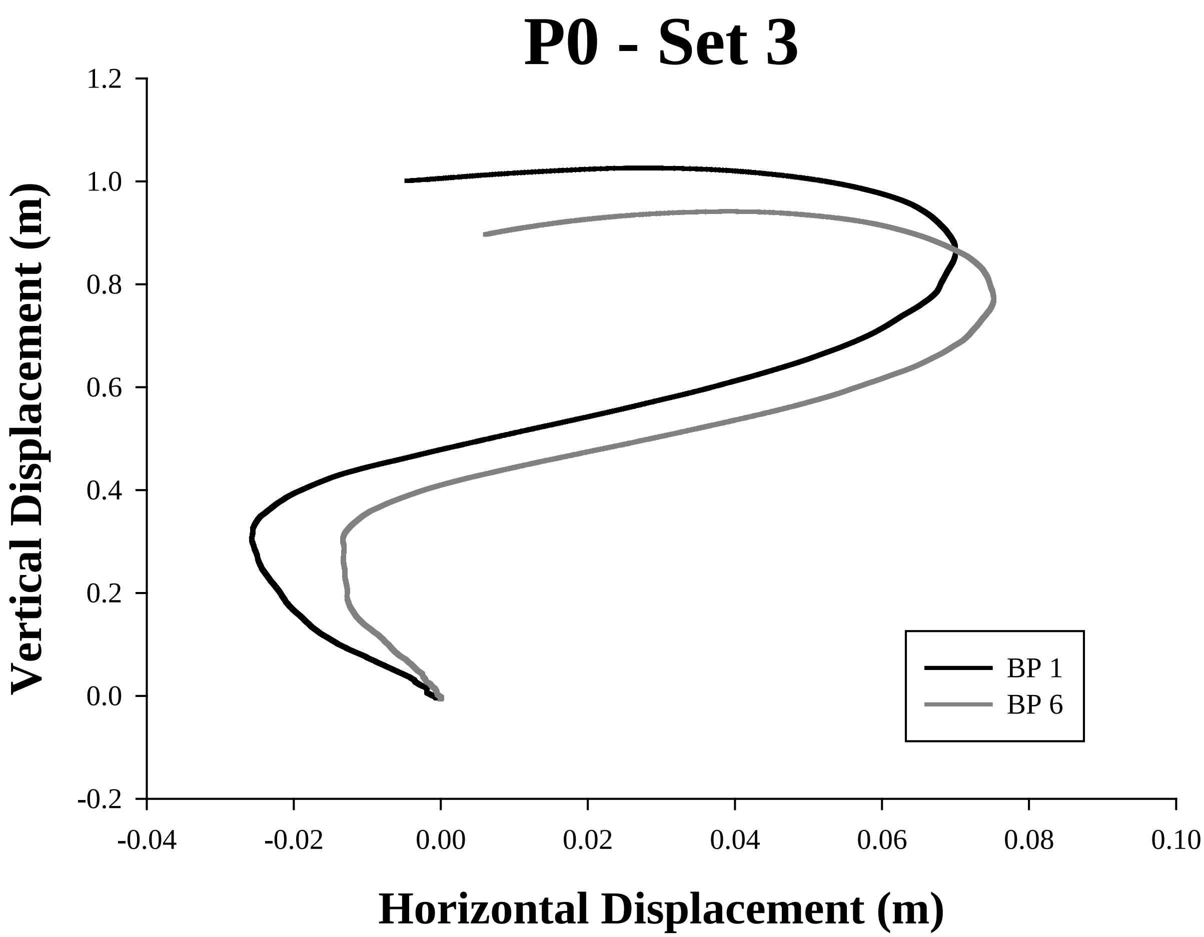


Figure 10. Bar Path for Set 1 of P20. P20 = 20 seconds IRR. BP 1 = bar path of repetition 1. BP 6 = bar path of repetition 6. No significant differences in horizontal displacement were found between repetition 1 and repetition 6.

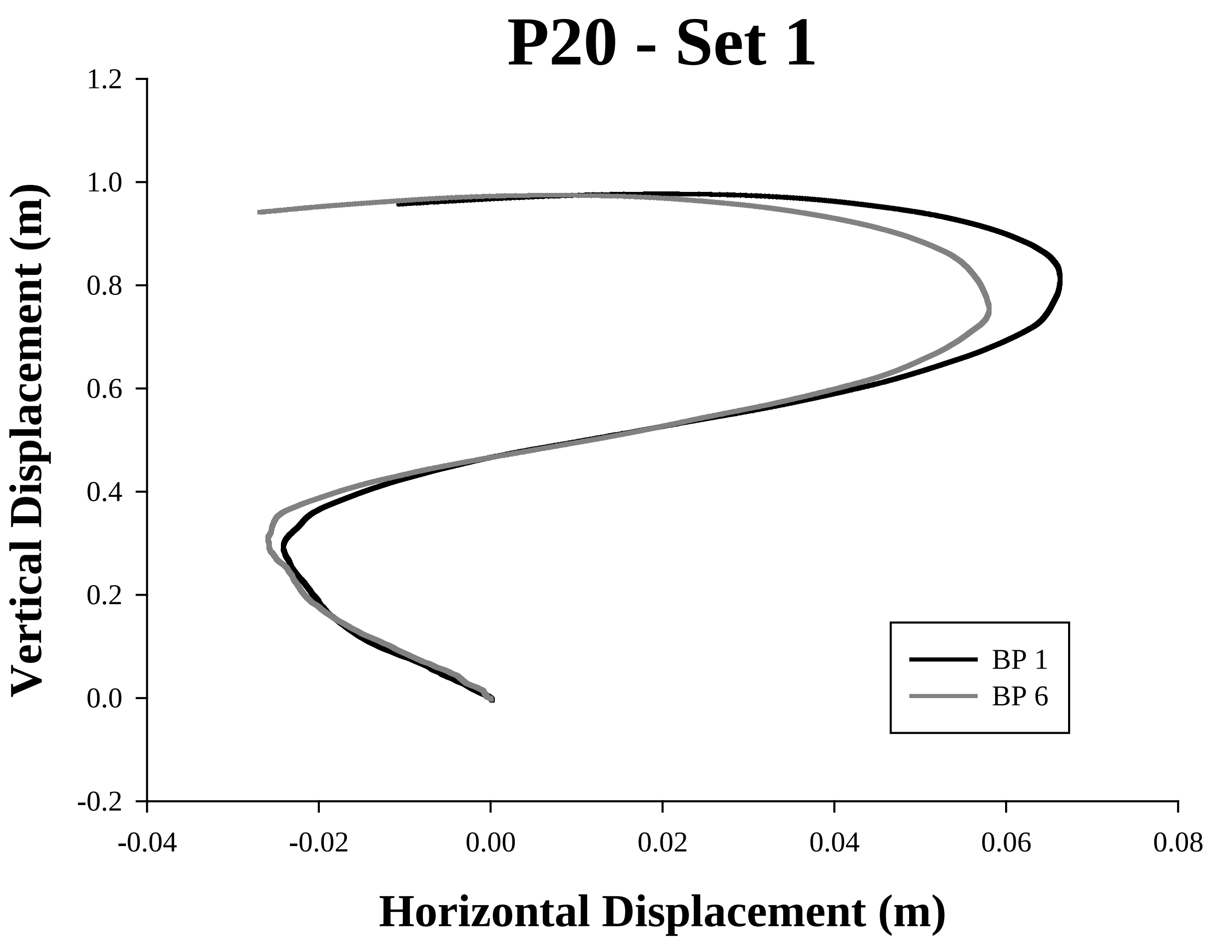


Figure 11. Bar Path for Set 2 of P20. P20 = 20 seconds IRR. BP 1 = bar path of repetition 1. BP 6 = bar path of repetition 6. No significant differences in horizontal displacement were found between repetition 1 and repetition 6.

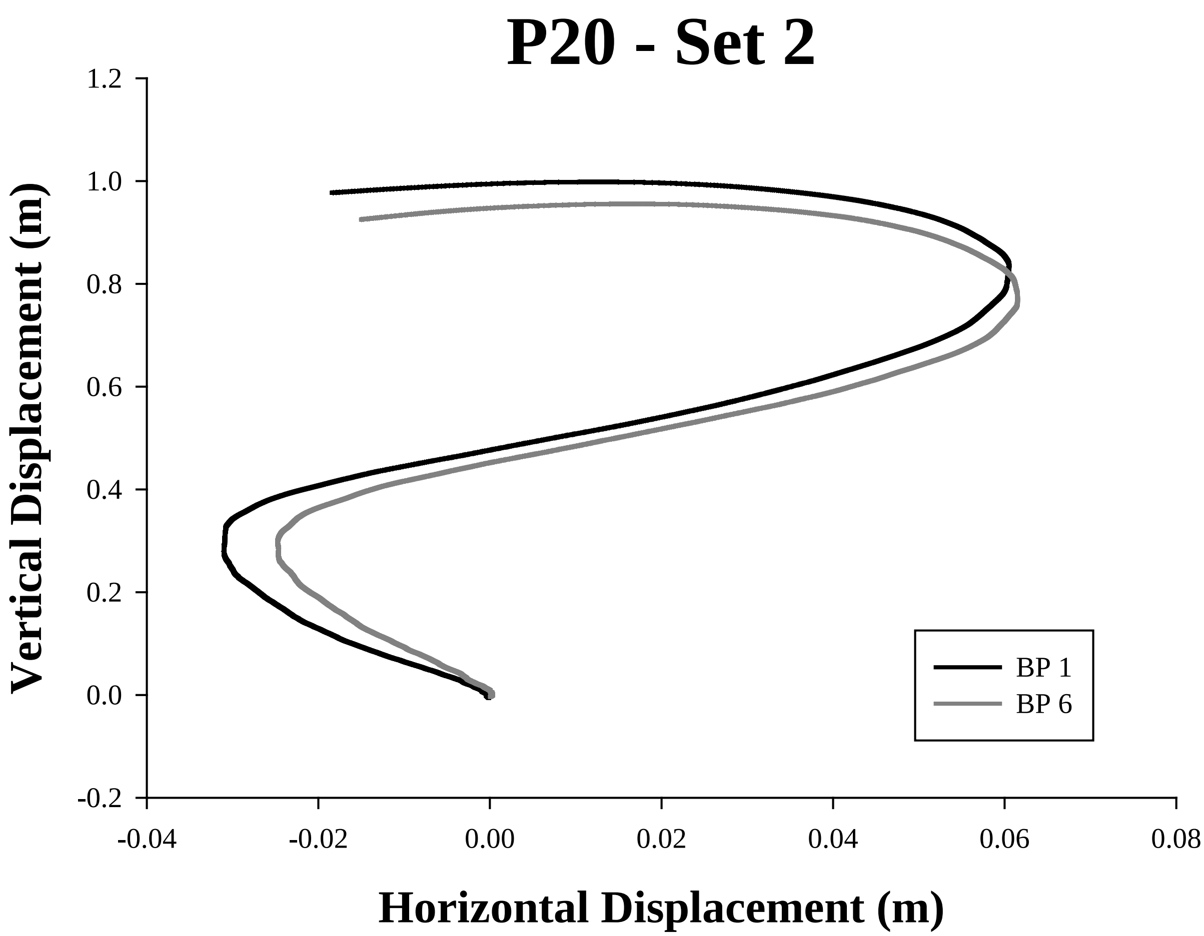


Figure 12. Bar Path for Set 3 of P20. P20 = 20 seconds IRR. BP 1 = bar path of repetition 1. BP 6 = bar path of repetition 6. No significant differences in horizontal displacement were found between repetition 1 and repetition 6.

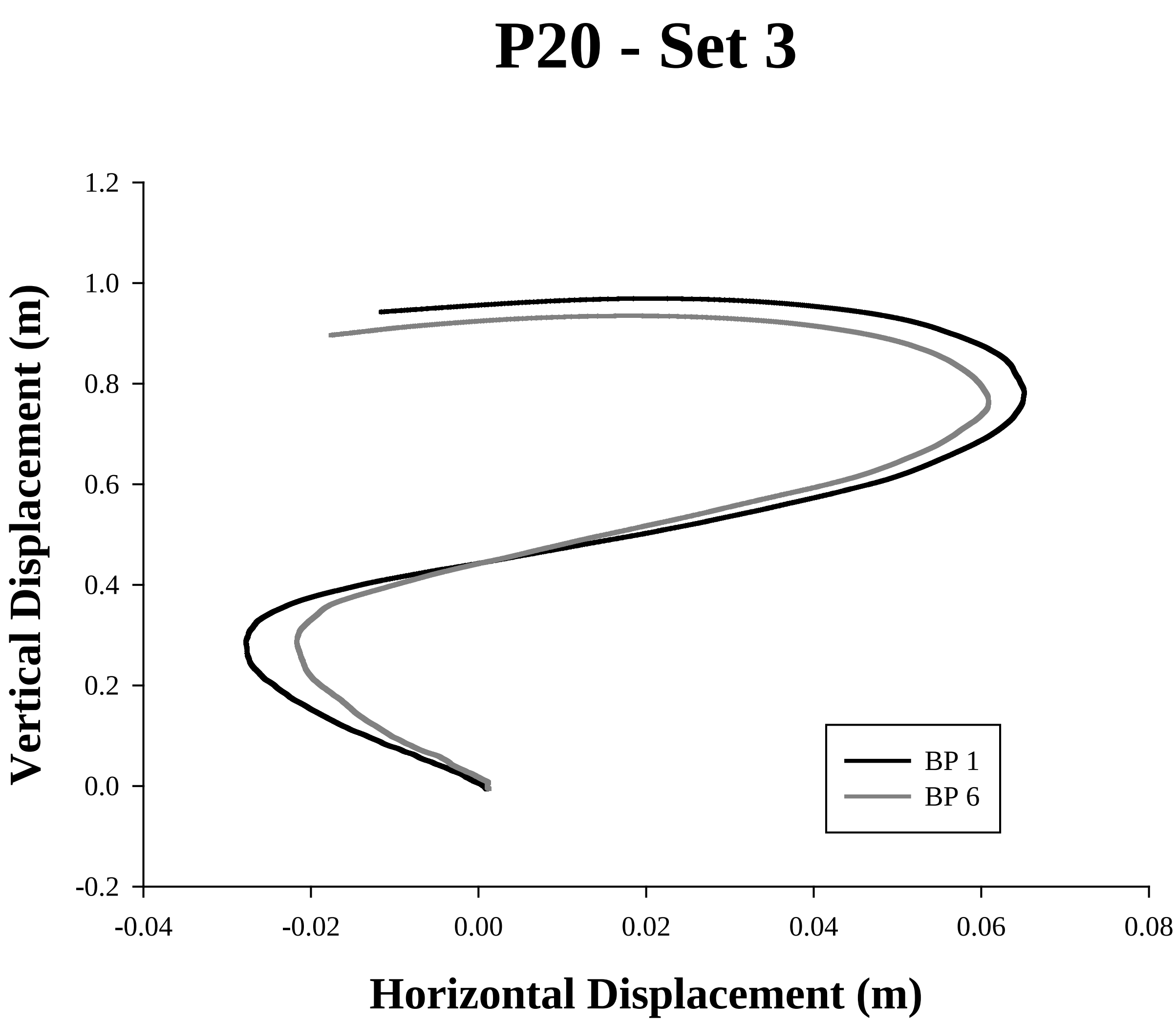


Figure 13. Bar Path for Set 1 of P40. P40 = 40 seconds IRR. BP 1 = bar path of repetition 1. BP 6 = bar path of repetition 6. No significant differences in horizontal displacement were found between repetition 1 and repetition 6.

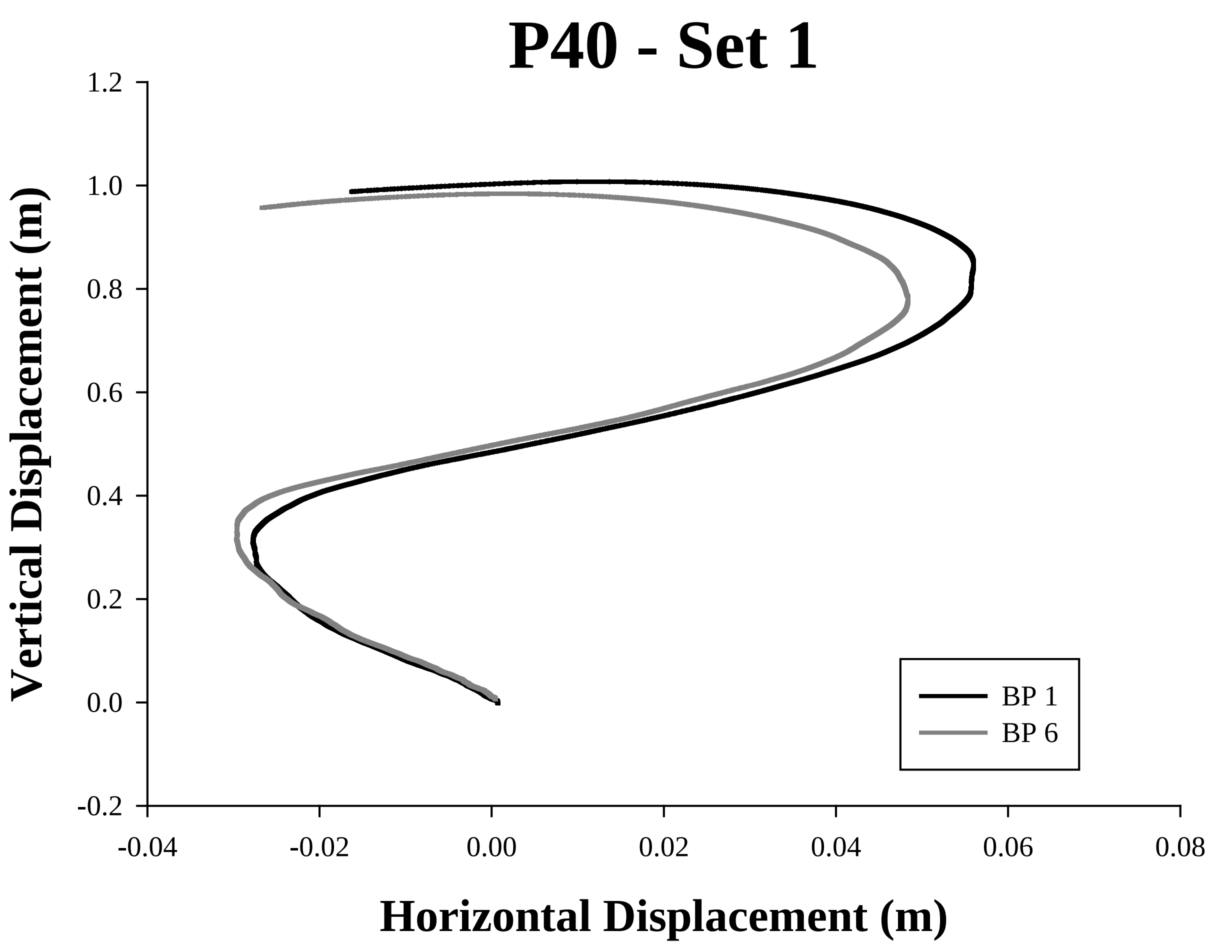
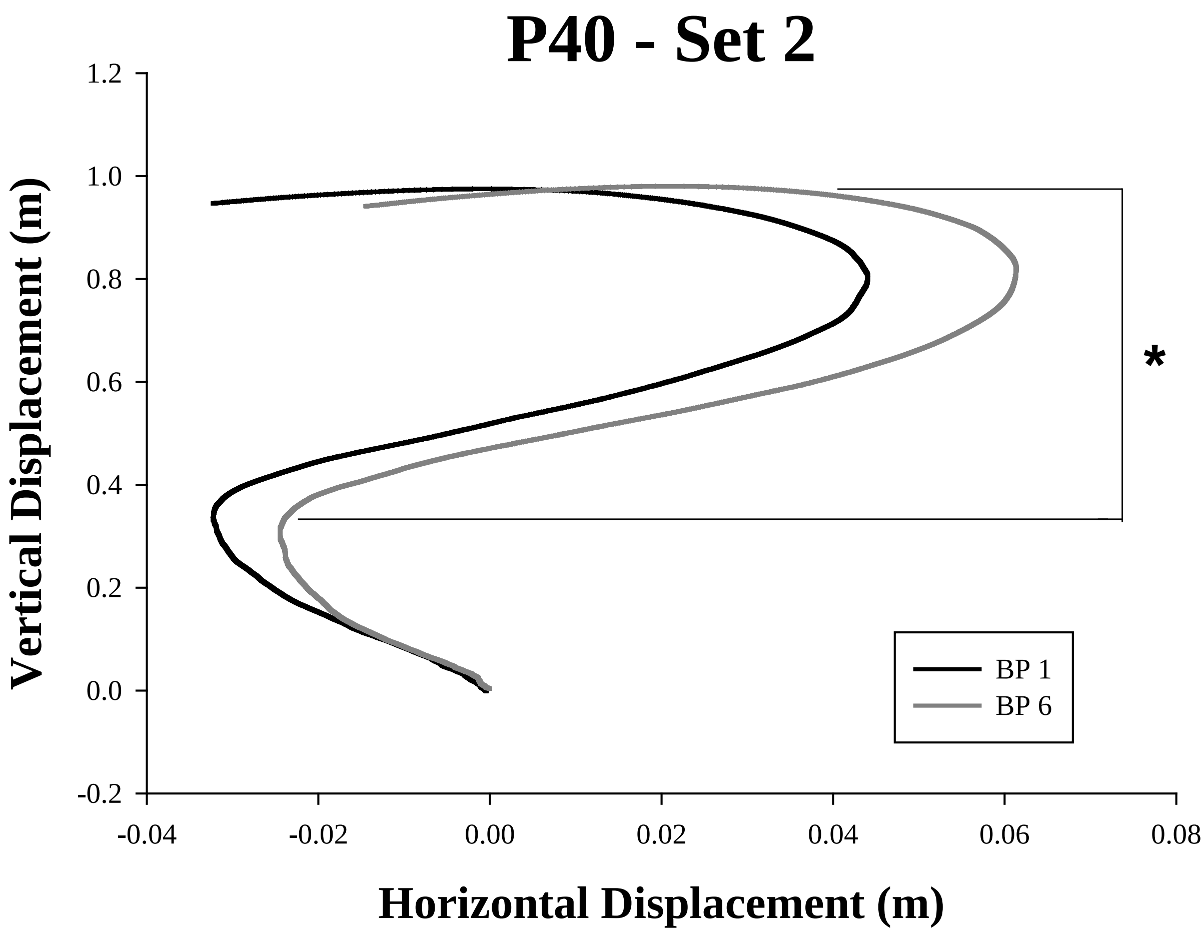
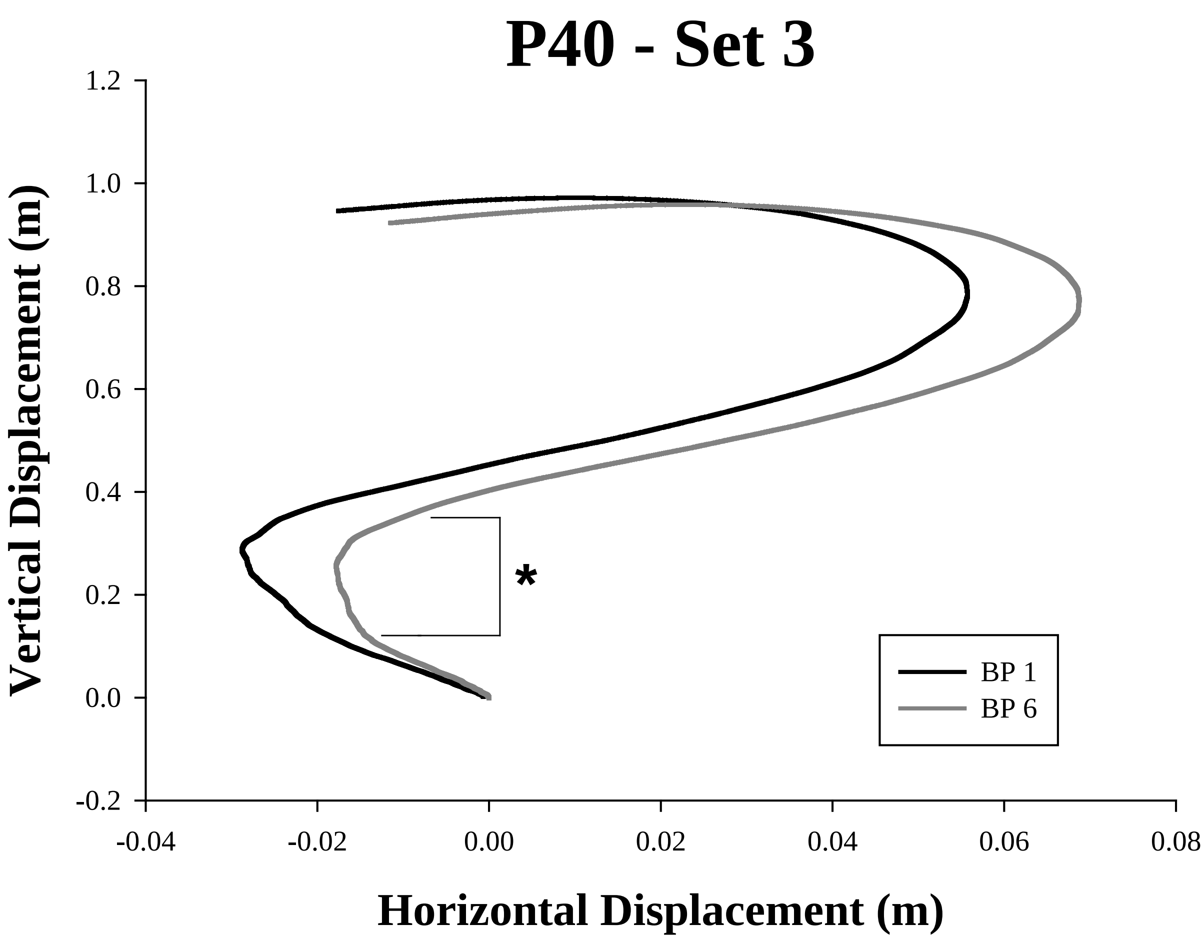


Figure 14. Bar Path Set 2 of P40. P40 = 40 seconds IRR. BP 1 = bar path of repetition 1. BP 6 = bar path of repetition 6. * Significant differences in horizontal displacement were found between repetition 1 and repetition 6 ($p \leq 0.05$). The second pull and loop were significantly more forward during repetition 6 compared to repetition 1.



* significantly different horizontal displacement

Figure 15. Bar Path for Set 3 of P40. P40 = 40 seconds IRR. BP 1 = bar path of repetition 1. BP 6 = bar path of repetition 6. * Significant differences in horizontal displacement were found between repetition 1 and repetition 6 ($p \leq 0.05$). The first pull, transition, and beginning of the second pull were significantly more forward during repetition 6 compared to repetition 1.



* significantly different horizontal displacement

DISCUSSION

It is generally accepted that fatigue decreases the quality of performance through manipulations to exercise technique, which may also reduce the effectiveness of muscular power development (52). Two studies have examined the effect of IRR and found attenuation of fatigue when compared to a continuous set configuration. However, neither study examined the effect of IRR on bar path. The current investigation is the first to: 1) analyze bar path in the power clean exercise over multiple repetitions and 2) to examine the effects on inter-repetition rest on bar path variability.

The results demonstrate that during all protocols, subjects were able to display appropriate bar path despite the level of fatigue achieved. This is seen by the horizontal displacement patterns for the barbell of towards the lifter, away from the lifter, and back towards the lifter in all exercise protocols (56, 61, 62). However, performing multiple continuous repetitions in the power clean led to variations in bar path. Stone et al. (56) identified several factors that contributed to successful versus unsuccessful lifting technique in the weightlifting movements. Two key factors are: 1) the amount of looping should not be excessive and 2) a net rearward barbell displacement of $\leq$ 20 cm (56). Therefore, the more forward positions seen in the first pull, second pull, and catch of P0 indicate poorer lifting technique. During the first set of P0, the degree of looping increased, which resulted in a more forward catch position. Additionally, during the second set of P0, the lifters were in a more forward position during the first and second pulls. These changes in bar path are most likely due to the increased fatigue associated with no rest between repetitions. These findings are in agreeance with previous literature concerning changes to exercise technique during fatigue.

Duffey and Challis (24) examined the effects of submaximal, continuous repetitions to failure on bench press kinematics. The authors found: 1) movement patterns differed between a single maximal repetition and multiple submaximal repetitions and 2) bar kinematics changed during the submaximal, continuous repetitions to failure (24). It has been suggested that as fatigue increases, a lifter may adopt a more efficient technique; however, Duffey and Challis (24) found both measures of bar path straightness to increase with fatigue. Similarly, Madigan and Pidcoe (45) demonstrated a decrease in vertical ground impact forces and an increase in maximum joint flexion during landing with fatigue. Collectively, these two studies indicate that lifters adopt a less efficient lifting strategy which results in performance decrements. Therefore, methods to maintain appropriate lifting technique and performance are of interest to athletics.

It has been suggested that the addition of IRR may not only allow the replenishment of energy substrates, but also an increase in the quality of repetitions (30). Haff et al. (32) demonstrated that lifters were able to maintain barbell velocity and displacement over multiple repetitions in the clean pull; however, bar path was not examined. The current study demonstrates that the addition of 20 seconds IRR lead to maintenance of bar path over multiple repetitions. As seen in Figures 16-18, during each set of P20 bar paths were nearly identical for repetitions 1 and 6. The maintenance of bar path may be speculated to be due to decreased levels of fatigue.

It is thought that fatigue may reduce the effectiveness of power development through manipulations to exercise technique (52); however, few studies have examined the effect of exercise technique on variables such as power, force, or velocity. Winchester et al. (62) found that as exercise technique in the power snatch improved, there were also increases in peak power and peak force. The current investigation demonstrated decreases in exercise technique with a continuous set configuration and the maintenance of bar path with the use of IRR. With respect to the research by Winchester et al. (62), it can be speculated that as bar path variations increased, there may have been decreases in peak power and force. Conversely, the maintenance of bar path may have been associated with maintenance of peak power and force across repetitions. Therefore, reductions in proper exercise technique during multiple repetitions may provide an inferior stimulus for the development of muscular power. Collectively, this demonstrates the importance of maintaining proper exercise technique throughout a set with regard to muscular power.

Conclusions

It has been suggested that if the kinematics of a lift at the end of a set are different from the desired movement pattern, it may not be beneficial to train to muscular fatigue (24). The results from this investigation demonstrate that a continuous set configuration resulted in variations to bar path; whereas, IRR periods of 20 seconds resulted in the maintenance of bar path. The use of IRR may be a practical methodology to increase the effectiveness of power training through the maintenance of exercise technique. Future research should examine the longitudinal effects of IRR in a periodized strength-training program.

Practical Application

These findings have applications in the development of athletes of all levels. First, in the beginning phases of technique development it may be advantageous to include IRR to reinforce proper movement mechanics. Second, in sports that require a high level of mechanical proficiency, such as weightlifting, it could be recommended that brief IRR be implemented during multiple repetition efforts. Future research should examine the effect of IRR on exercise technique and muscle recruitment patterns.

CONCLUSION

The results from these investigations provide insight to the effects of IRR on exercise performance during a multiple set and repetition protocol in the power clean. Kaneko et al. (42) demonstrated that the development of muscular power is greatest when training at the intensity at which power is maximized (42). The results from this study demonstrate that 20 to 40 seconds IRR can maintain power, force, and velocity during a multiple set protocol. Therefore, it could be speculated that this training methodology would induce a greater training stimulus when compared to a continuous set configuration. This may be advantageous for individuals seeking a greater training response with regard to the development of muscular power.

Furthermore, it has been suggested that if the kinematics of a lift at the end of a set are different from the desired movement patter, it may not be beneficial to train to muscular fatigue (24). The results from this investigation demonstrate that a continuous set configuration resulted in variations to bar path; whereas, IRR periods of 20 seconds resulted in the maintenance of bar path. Therefore, the use of IRR may be a practical methodology to maintain bar path during multiple repetitions in the power clean exercise.

Collectively, this study demonstrated that continuous repetitions in the power clean resulted in significant decreases to power, force, and velocity, which coincided with increases in bar path variations. Conversely, IRR lead to maintenance of power, force, and velocity while minimizing variations in bar path. The differences seen in the exercise protocols may be explained by the different levels of fatigue achieved during exercise; however, this study did not directly measure markers associated with fatigue. Future research should examine this limitation. It can only be concluded that changes in bar path manifested changes to power, force, and velocity. Therefore, it seems reasonable that to increase the effectiveness of power training, one should be concerned with the maintenance of power, force, and velocity while maintaining exercise technique.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD DOCUMENTS

APPALACHIAN STATE UNIVERSITY
Official Use Only _____-____

REQUEST FOR REVIEW OF HUMAN PARTICIPANTS RESEARCH

Please complete and send the form electronically to irb@appstate.edu. The first page with signatures must be submitted to IRB, Research & Graduate Studies, John E. Thomas Building.

1. Date: 07/19/10__

2. Project Title: Effect of Inter-Set and Inter-Repetition Rest Period Length on Kinetic and Kinematic Variables in the Power Clean.

3. Principal Investigator(s): Justin Hardee

4. Phone: ______850-449-0088__________ Email: hardeej@appstate.edu__________________

5. Academic Department/Unit: ________Health, Leisure, and Exercise Science____________________

6. ASU Status: Faculty/Staff_________ Graduate Student ___X____ Undergraduate Student_____ Other

7. If student, name of faculty mentor: _____Dr. N. Travis Triplett, Dr. Jeffrey M. McBride_____________

8. Faculty mentor's e-mail address: _______tripttnt@appstate.edu________________________________
Phone: ________7148_______________________________________

9. This is: Honors or Master's Thesis __x___ Capstone or Project of Learning _____ Dissertation
Faculty Research _____ Other ___ ___________________

10. Project Support: ____X______ Non-Sponsored

___________ Sponsored: Sponsor_________ Proposal # ____________
Pending ___ Funded _________

11. Plan to publish or present off-campus: Yes __X____ No____________

12. Projected data collection dates: 8/01/10____ to 02/01/11___

13. Does this research involve any out-of-country travel? Yes _____ No__X______

Proposals cannot be considered until the researchers have completed the online CITI Training (http://www.citiprogram.org/default.asp?language=english) required for human subject research.

I have read Appalachian State University's Policy and Procedures on Human Subjects Research and agree to abide them. I also agree to report any significant and relevant changes in procedures and instruments as they relate to participants to the Chairperson of the Institutional Review Board.

__________________ PI	___________ Date	__________________ Co-investigator	___________ Date
__________________ If PI is student, Faculty Mentor	___________ Date	__________________ Co-investigator	___________ Date

APPALACHIAN STATE UNIVERSITY

Informed Consent for Participants in Research Projects Involving Human Subjects

Institutional Review Board
Studv #: 11-0020

Title of Project: Effect of Inter-Set and Inter-Repetition Rest Periods on Kinetic and Kinematic Variables in the Power Clean.

Investigator(s): Justin Hardee, Dr. N. Travis Triplett, Dr. Jeffrey M. McBride

I. Purpose of this Research/Project:

The primary purpose of this study is to identify how power output and perceived exertion is affected during various inter-set and inter-repetition rest interval lengths the power clean exercise. This resistance exercise is commonly used for athlete training and is also used in the competitive sport of Olympic Weightlifting. A repetition is one completed movement pattern of the lift and a set is a series of repetitions in sequence.

II. Procedures:

All testing will take place in the Neuromuscular Lab at the Convocation Center one individual at a time. You will be asked to participate in four testing sessions over a two week period with each session separated by at least 48 hours. During the first session demographic and anthropometric information (age, height, weight) will be obtained, and you will become oriented to the testing procedures. You will then be tested for your one repetition maximum (1RM), which is a measure of your strength, in the power clean exercise. You will also be familiarized to a perceived exertion scale called the CR-10 scale. During the second, third, and fourth testing session, you will perform one lifting protocol per session. The lifting protocol will include three sets of six repetitions at 80% of your 1RM with either 0, 20, or 40 seconds rest between repetitions. After completion of each set you will be asked to rate your perceived exertion using the CR-10 scale. Three minutes rest will be given between each set. All power cleans will be performed on force plate with two linear position transducers attached to the barbell. A force plate measure how much force you exert during you lift and the linear position transducers tell us how the barbell is moving during the lift. During all testing laboratory assistants, which will be certified strength and conditioning specialists and certified in CPR and first aid, will ensure proper lifting technique and ensure safety.

III. Risks:

There are minimal risks to you during the testing conducted in this study. There may be some discomfort and/or soreness in your muscles due to the nature of resistance exercise. There is also a small risk of musculoskeletal injury. All procedures for the testing are outlined in the standards for Strength and Conditioning as supported by the National Strength and Conditioning Association. To provide the utmost safety for you, the primary investigator is a Certified Strength and Conditioning Specialist (CSCS) through the National Strength and Conditioning Association and certified in CPR/AED and First Aid through the American Red Cross. No monies have been set aside for medical care resulting from injuries occurring while participating.

IV. Benefits:

You will be given your individual results which may assist you in developing your own resistance exercise program for improvement in muscle power. In addition, you will be assisting in an important contribution to expanding the current body of knowledge in this area of research.

V. Extent of Anonymity and Confidentiality:

Your identity will not be disclosed in any published documents or shared with anyone but the experimenters. All information collected will be kept confidential and disguised so that no personal identification can be made and all experimental data will be identified by number only. Confidentiality of all subjects will be maintained by keeping subject files under lock and key. Individual data will not be reported in results of final publication. Data will be analyzed and be reported in manuscript format and submitted to a peer-reviewed journal for publication. Data will be stored for a period of five years. Papers will be shredded and data files deleted at this time.

VI. Compensation:

You will be compensated twenty-five dollars for completion of the entire study. However, no funds for any injury or illness resulting from participation in this study have been allotted. In the event of physical injury resulting from the research procedures, immediate first-aid is provided free of charge.

Current University policy requires the collection of Social Security numbers (or Appalachian Banner ID numbers) if study compensation is more than $20 for a single study or $599 for participation in multiple studies in a calendar year. Since the compensation for this study is more than $20, you will need to provide your address and Social Security number (or Appalachian Banner ID number) when you complete the form for payment.

VII. Freedom to Withdraw:

I understand that participation is voluntary and this consent may be withdrawn at any time without prejudice, penalty, or loss of benefits to which I am entitled. I have been given the right to ask questions and have had any questions asked answered to my satisfaction. I may terminate my participation in the study at anytime and for any reason.

VIII. Approval of Research

This research project has been approved, as required, by the Institutional Review Board of Appalachian State University and ______________________________________ (if others, i.e., school or school system, hospital, daycare center, multi-institutional project etc.).

____8/23/2010 ____________ ________7/29/2011____________

IRB Approval Date Approval Expiration Date

IX. Subject's Responsibilities

I voluntarily agree to participate in this study. I have the following responsibilities:

- Complete four 1.5-hour testing sessions involving maximum lifting.

VITA

Justin Perry Hardee was born in Pensacola, Florida, on December 14, 1985. Following graduation at Gulf Breeze High School, he attended Pensacola Junior College to obtain an Associate of Arts and the University of West Florida to obtain a Bachelor of Science in Exercise Science.

In August 2009, Justin accepted a research and teaching assistantship in the Biochemistry and Human Performance Laboratories at Appalachian State University and began study toward a Master of Science in Exercise Science. The M.S. was awarded May 2011. Following graduation Mr. Hardee will commence work toward his Ph.D in Applied Physiology at the University of South Carolina in Columbia, South Carolina.