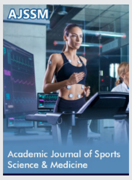

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Research Article

The Effects of Exercise Selection Versus Exercise Intensity & Load On Maximal Strength, Muscular Power, And Fatigue in Collegiate Track and Field Athletes

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Abstract

Refining implementation of resistance training variables is yet to be investigated.

Objective: The purpose of this study is to compare the effect of varying exercise intensity and load versus varying exercise selection on measures of muscular strength, power, and indices of fatigue.

Methods: Fourteen collegiate track and field athletes were randomly assigned to a 4-week exercise program consisting of weekly variation of exercise intensity (EI) or exercise selection (ES). Lower body strength using a linear position transducer in the back squat exercise, and maximal jump height using a contact switch mat were tested pre and post 4-week protocol. Fatigue was assessed through weekly differences in vertical jump height and subjective reports every session using a 7-criteria wellness questionnaire.

Results: There were no significant differences for either intervention from pre to post testing between groups ($p < 0.05$). ES group had scored better on ratings of power, sleep quality, and overall well-being. EI group had scored better on ratings of fatigue, pain/stiffness, general muscle strain, and stress. ES group had greater attainments of a calculated smallest worthwhile change, but also experienced greater ratings of fatigue.

Conclusion: Varying exercise selection, and varying exercise intensity and load are both acceptable measures in exercise programming if implemented correctly.

Keywords: Resistance Training; Periodization; Monitoring; Track and Field; Fatigue

Introduction

The integration of resistance training into exercise regimens has become a prevalent practice among both athletic and general populations. Extensive research has demonstrated that resistance training can enhance muscle cross-sectional area, boost muscular strength and power, mitigate the risk of injury, and ultimately enhance athletic performance [1,2]. Despite the benefits of resistance training, existing literature reveals inconsistencies regarding the most effective methods of implementation for optimizing performance gains, while concurrently addressing fatigue management and reducing the likelihood of injury.

For resistance training to be effectively implemented, programs must systematically introduce programming variables in order elicit physiological adaptation that is conducive to increases in performance [1,2]. A popular method of organizing exercise program variation is periodization, with the most common variables of exercise programing tending to be exercise intensity and exercise volume [1,2]. The relationship of resistance training exercise intensity and volume has been extensively investigated and research has given insight to the effect varying intensity has on the adaptive process. Low intensity (<67% 1RM), high volume resistance exercise (>12 repetitions) demonstrates increases in endurance-like properties [1,3,2]. When using higher intensity (>85% 1RM), lower volume resistance exercises (<6 repetitions) the adaptive process is shifted towards favoring improvements in muscular strength [4-7]. Even moderate resistance exercise intensity between 67-85% 1RM with moderate volume (6-12 repetitions) has been shown to elicit muscular changes specific to muscular hypertrophy and improvements in muscle cross-sectional area [8-12]. In resistance training, exercise intensity and volume can be manipulated to the desired adaptation and if properly implemented, can aid in improving sports performance. A third variable of exercise programming that is utilized almost as frequently is exercise selection [2].

The role of exercise selection in exercise programming is a crucial variable that is supported by evidence for its significance in the adaptive process, akin to exercise intensity and load [2]. The concept of exercise specificity, initially introduced by DeLorme in 1945, underscored the importance of exercise selection in tailoring exercise prescriptions to target specific training adaptations [13]. This notion evolved into the SAID principle, which stands for specific adaptations to imposed demands, highlighting the impact of exercise selection or mode on training adaptation [14]. Recent research on exercise selection has predominantly focused on exploring various variations of similar exercises and their effects on parameters such as muscular physiological changes and kinematic variables [15]. Studies have also delved into comparing the impact of different exercise variations on key properties like muscular strength, power, and endurance, as previously mentioned [16,15,2].

The efficacy of exercise intensity, volume, and exercise selection as key programming variables is well-supported by existing research [2,17,14,2]. However, the relative effectiveness and impact of these variables on fatigue and performance remains a topic of ongoing debate. By examining exercise selection and exercise intensity as independent variables in comparison to each other, researchers may be able to provide valuable insights for developing guidelines on when and how to introduce or manipulate these variables within a training cycle. Furthermore, the ability of practitioners to strategically manage fatigue through informed decision-making regarding exercise manipulation and intensity/volume adjustments can enhance progression and reduce the risk of injury. Therefore, the primary objective of this study is to investigate and compare the effects of varying exercise selection with those of varying exercise intensity and volume on anaerobic performance measures and fatigue levels in college track and field athletes.

Methods

Experimental Approach to the Problem

In a random-matched pairs experimental design, collegiate track and field athletes were assigned to either an Exercise Selection variation group (ES) or an Exercise Intensity and Load variation group (EI). Groups were pre- and post-tested to determine the effect each intervention had on the following measures: changes maximal strength in the back squat exercise, maximal power and fatigue using counter movement vertical jump, and ratings of overall wellness and fatigue. A 4-week exercise protocol consisting of weekly variations of exercise intensity, with exercise selection being held constant (EI group) was compared to weekly variations of exercise selection with exercise intensity being held constant (ES group).

Subjects

Fourteen active roster male and female collegiate track and field athletes from a National Collegiate Athletic Association (NCAA) division 2 conference were tested during the 2018-2019 spring season as part of their in-season training program (Table 1).

Table 1: Demographics of the 14 subjects who completed the study. Values are presented as mean ± SD. EI = Exercise Intensity Variation, ES = Exercise Selection Variation

Subject Characteristics. *			
Group	Age (y)	Height (cm)	Mass (kg)
EI	20.4 (± 1.6)	180.7 (± 5.9)	83.2 (± 16.5)
ES	20.8 (± 0.9)	177.5 (± 5.1)	83.2 (± 17.7)

All subjects participating in this study were anaerobically trained based on their primary track and field event, i.e. throwing, sprinting, or jumping. Prior to the start of the experiment subjects had given their informed consent, and the Institutional Review Board (IRB) of East Stroudsburg University of Pennsylvania had approved of this study and its protocols. All subjects were familiarized with the testing procedures and the exercise program used in this study before the exercise sessions had begun. Inclusion criteria within this study had consisted of 100% participation in exercise sessions, previous exposure to linear periodization, and free from musculoskeletal injury at the time of the experiment. Subjects were randomly assigned to either ES or EI experimental groups, and groups were balanced according to sex and primary track and field event.

Procedures

Familiarization to testing protocol, exercise technique, and administration of pre-testing had occurred during the first week of the experimental design. During familiarization, subjects were instructed on testing procedures of maximal strength in the back squat exercise using a linear position transducer (GymAware; Kinetic Performance Technologies, Canberra, Australia), vertical jump assessment using a contact switch mat (JustJump, Probotics, Huntsville, AL), and a 7-criteria wellness questionnaire of overall wellness and fatigue was administered prior to any physical activity each day of testing. The 7-criteria wellness questionnaire was used to gauge a subjective measure of fatigue and was like those done by researchers previously [18,19]. Upon arriving at the facility during the first week of the experiment, subjects had demographic data recorded consisting of age (yr), mass (kg), height (m), and gender. The subjects had then completed the wellness questionnaire answering 7 criteria related questions to assess overall fatigue, wellness, and power by rating each respective feeling on a scale of 1 to 5. Prior to physical testing, each subject had then undergone a standardized dynamic warm-up that would remain consistent throughout the entire duration of the experiment. For vertical jump testing, 3 vertical jump trials were recorded, allowing adequate rest between trials. Maximal strength was then assessed in the back squat exercise using a GymAware unit and following procedures outlined in previous research [20,21]. To calculate an estimated 1-RM for the back squat with the resistance and velocities obtained from the GymAware, a two-point regression analysis was performed.

During the 4-week exercise protocol and following the first week of familiarization and pre-testing, subjects were required to arrive at the facility at the same time every day. Exercise sessions took place on the same 2 days of the week, separated by 48 hours between sessions. Subjects in the EI group had weekly variation in the intensity and load of the back squat exercise. The loading scheme and rest periods had remained consistent with National Strength and Conditioning Association (NSCA) guidelines of muscular strength with less than 6 repetitions and greater than 85% exercise intensity [1]. Subjects in the ES group had weekly variation in exercise selection, consisting of variations of the back squat exercise. Intensity and working repetitions of ES group was equated to the average intensity and average total sets and repetitions from the EI group. This was done to account for any discrepancies in total working repetition volume. The exercise intensity scheme had followed a 4-week program, consisting of 3 weeks of progressive intensity by 2.5% weekly, followed by a 4th week of decreased intensity. Exercise intensity and volume prescription starts at 85% progressing by 2.5% weekly to 90% on week three and dropping back to 85% on week 4 for the EI group. Sets and repetitions for EI had started at 3 sets of 5 repetitions on week 1, 3 sets of 4 repetitions on week 2, 3 sets of 2 repetitions on week 3, and ended at 3 sets of 5 repetitions on week 4. The average intensity and working repetitions were calculated as 3 sets of 4 repetitions at 86.8% for the ES group. Numbers were rounded to the nearest whole number for weight prescription for both the ES and EI groups. For exercise variations in the ES group, exercises were selected to best match relative difficulty of intensity prescription of the EI group. Week 1 consisted of a low pin back squat, week 2 consisted of a box squat, week 3 consisted of a quarter squat, and week 4 consisted of a 1 ¼ squat. During each session, upon subjects' arrival at the facility the 7-criteria questionnaire was completed followed by a standardized warm-up, and 3 vertical jump trials. Subjects then completed their workout for the day. All other exercises in the workout had remained identical between subjects and groups with the exception being the back squat exercise. Throughout the 4 weeks of the exercise protocol, subjects were still participating in respective team practices and strength and conditioning sessions. Team training session load during practice and all other strength and conditioning sessions outside of what was required for the study were kept constant between athletes in each individual event group.

Post-testing occurred one week after the 4-week exercise protocol was complete and procedures were repeated in similar conditions to pre-testing. Subjects had demographic data taken, completed the 7-criteria wellness questionnaire, standardized warm-up, followed by 3 vertical jump trials and maximal strength assessment in the back squat exercise. Each session throughout the experiment was supervised by multiple NSCA Certified Strength and Conditioning Specialist (CSCS) coaches to ensure proper warm-up, technique, and safety. To limit any extrinsic factors that could affect data, weekly food logs and weekly practice logs were completed during pre-testing, each week of the 4-week exercise protocol, and during post-testing. Data from pre-testing was then compared to data from post-testing and the results were analyzed.

Statistical Analysis

All statistical analysis was performed using SPSS (SPSS for Windows, version 11.0; SPSS, Inc., Chicago, IL). First, a normality test was utilized to test data distribution. Due to inter-group size differences, a Mann-Whitney U test was used to assess differences across the changes in back squat 1-RM and changes in vertical jump height. Statistical significance was accepted at $p \leq 0.05$. To determine practical worthwhile changes, a value of the smallest worthwhile change was calculated using 20% of standard deviation for both 1-RM and vertical jump height [22].

Results

During the 2018-2019 spring competitive season, a total of 16 male and female competitive division 2 track and field athletes were assessed for study eligibility. All 16 subjects were deemed eligible for the study based on inclusion criteria and were randomized to either EI or ES groups. Subjects were equated for gender and primary event group to balance the characteristics of both EI and ES groups. Throughout the study duration, 2 subjects were dropped from experimental data analysis due to unrelated injuries. Both subjects were randomly assigned to the ES group. A total of 14 subjects were used for experimental data analysis with EI group consisting of 8 subjects (n=8), and ES group consisting of 6 subjects (n=6). Subject characteristics can be found in (Table 1).

Comparing changes in 1-RM values for back-squat from pre to post as a measure of maximal lower body strength, a Mann-Whitney U test was used to account for a non-normal distribution of subjects across EI and ES groups. Comparing both groups, changes in pre-post 1-RM, a p-value of .573 was found proving not significant ($p > 0.05$). A calculation of the smallest worthwhile change was derived through 20% of the standard deviation to interpret individual subject improvement. Average change, relative change, smallest worthwhile change attainment, and results from Mann-Whitney U test for both groups for changes in back squat 1-RM can be found in (Table 2).

Table 2: 1-RM Back Squat pre- to post-testing results. Values are presented in mean ± SD. *EI = Exercise Intensity Variation, ES = Exercise Selection Variation, Attn. = Attainment.

1-RM Back Squat Characteristics.				
Group	**Mann-Whitney U**	**Average Change (lb)**	**Relative Change (lb/subject #)**	**Attn. Smallest Worthwhile Change**
EI	p - value of 0.573	7.76 (± 9.52)	0.96	n = 2
ES		6.79 (± 21.60)	1.13	n = 2

Looking at changes in vertical jump height as a measure of muscular power, a p-value of 1.0 was found, showing non-significant changes in vertical jump height when comparing the changes of both groups from pre- to post ($p > 0.05$). Average change, relative change, smallest worthwhile change attainment, and results from Mann-Whitney U test for both groups for changes in vertical jump height can be found in (Table 3). Weekly averages for both groups' vertical jumps can be found in (Table 4).

Table 3: Vertical Jump pre- to post-testing results. Values are presented as mean ± SD. *EI = Exercise Intensity Variation, ES = Exercise Selection Variation, Attn. = Attainment

Vertical Jump Characteristics. *				
Group	**Mann-Whitney U**	**Average Change (in)**	**Relative Change (in/# subjects)**	**Attn. Smallest Worthwhile Change**
EI	p - value of 1.0	1.18 (± 1.25)	0.62	n = 2
ES		0.14 (± 2.11)	0.1	n = 4

Table 4: Average weekly vertical jump (in) between both exercise intervention groups. * Avg. = Average, EI = Exercise Intensity Variation, ES = Exercise Selection Variation.

Average Weekly Vertical Jump (In).			
EI Group		**ES Group**	
Week	Avg. Vertical Jump (In)	Week	Avg. Vertical Jump (In)
Week 1	28.2	Week 1	26.7
Week 2	28.6	Week 2	27.6
Week 3	28.6	Week 3	26.6
Week 4	29.2	Week 4	27.6

When assessing results from the 7-criteria wellness questionnaire, subjects were asked to rate feelings of fatigue, muscle strain, pain/stiffness, power, sleep quality, level of stress, and level of overall well-being on a scale of 1 to 5. A numerical value of 5 indicated feeling "as bad as possible" while a numerical value of 1 indicated feeling "as good as possible". Comparing group responses, EI group had reported lower ratings in fatigue, pain/stiffness, general muscle strain, and stress. ES group had reported lower ratings in power, sleep quality, and overall well-being. A comparison of results from the 7-criteria wellness questionnaire can be found in (Table 5).

Table 5: Average ratings of fatigue."-" value indicates EI improvement, "+" value indicates ES improvement, EI = Exercise Intensity Variation, ES = Exercise Selection Variation.

Average Ratings of Fatigue	Inter-Group Rating Difference
Fatigue	-0.17
General Muscle Strain	-0.07
Pain / Stiffness	-0.16
Power	0.06
Sleep Quality	0.06
Stress	-0.22
Well-Being	0.34

Discussion

The aim of this study was to investigate and compare the effects of a 4-week program of exercise intensity variation to a 4-week program of exercise selection variation on muscular strength, muscular power, and ratings of fatigue and overall well-being. It was hypothesized that there would be no difference between either EI or ES group differences on strength, power, or fatigue. For changes in vertical jump and 1-RM back squat, there were no significant statistical differences within the data presented, supporting the hypothesis put forth. Consequently, looking at data involving ratings obtained from the questionnaire used, ES and EI groups had differed. The EI group had reported lower ratings in fatigue, pain/stiffness, general muscle strain, and stress but the ES group had reported lower ratings in power, sleep quality, and overall-wellbeing. These ratings of power and fatigue can then be matched with weekly averages of vertical jump found in table 4. In week 3 of the exercise protocol, it's interesting to note that even though the subjects of the ES group had reported lower scores in power and fatigue, they also experienced a decrement in vertical jump height. Contrary to what was found in previous research, less fatigue would indicate that a higher average vertical jump should have been present [23,24]. Looking solely at ratings of fatigue, ES group had also reported a higher fluctuation within the fatigue ratings. This leads to the idea that as a novel exercise stimulus was introduced in the manner of exercise variation, additional fatigue or perception of fatigue may also be accompanied.

EI group had performed better from pre- to post measures in both average change in vertical jump, as well as average change in back squat 1-RM. When the average vertical jump for each week is included in analysis, this finding differs. When every weekly trial was included rather than just the comparison of pre- to post, ES group had performed better on average for vertical jump height. This evidence supports the claim that ES group may experience greater levels of fatigue induced by exercise variation. If fatigue is greater within ES groups due to weekly changes in exercise selection, it could also be hypothesized that the accumulation of fatigue had caused decrements in post-testing results when looking at change in average vertical jump height. Another interesting finding is when outlying subjects are removed from informal data analysis. ES group had one subject that had performed worse than accepted normal values within both Whitney-Mann U tests. Removing this subject from data analysis showed inter-subject relative improvements between ES and EI groups were greater within the ES group. ES group had more subjects improve overall and had the same or more attainments of the calculated smallest worthwhile change value in the back squat 1-RM and the vertical jump measures despite ratings of fatigue.

The importance of exercise selection for specificity of sports performance, specific joint angle strength, and muscular hypertrophy has all been investigated in literature. Literature has also compared the training of beginner and experienced athletes, showing beginner athletes needing less variation for adaptation, versus experienced athletes training consisting of more frequent exercise variation [1,2]. In the current study, the training age of the subjects was not accounted for, but all subjects were previously exposed to resistance training for at least a year prior. Despite having experience with resistance training and linear periodized training programs, the training age could have been drastically different between subjects. This could have potentially influenced the responsiveness and fatigue to the individual stimulus across both groups. A second important factor to consider is the study duration. Most mesocycles consist of durations between 2-6 weeks, where the focus of the adaptation-response is held constant. The training age of the athlete can also influence this optimal duration. Haff, Zatsiorsky, and other researchers tend to agree that more advanced athletes require greater training variation and have smaller adaptation windows in comparison to beginner athletes [25]. This could suggest that 1 week per given variation, whether intensity or exercise oriented, is simply not enough to elicit an appropriate adaptive response. A subject pool containing advanced athletes could theoretically require a mesocycle closer to 2-3 weeks in duration, versus 5-6 weeks in mesocycle duration being more appropriate for novice subjects.

Despite the limitations of the current study, some trends were still notable. Albeit no statistical significance was found across either EI or ES groups in the change in back squat 1-RM or average vertical jump height, the subjective ratings of fatigue provided further insight. The ES group had shown a greater attainment of smallest worthwhile change despite higher ratings of fatigue. The EI group had reported lower ratings of fatigue, general muscle strain, and stress. These findings along with pre-post vertical jump indicate that varying exercise selection may contribute to increases in fatigue for this subject group but may still cause favorable adaptation. The discrepancies in the ratings of fatigue, compared to the weekly average vertical jump and attainment of smallest worthwhile change also indicate that while exercise selection variation does cause favorable adaptation, it may also cause undue fatigue. Future research should expand on implementing a classification of training age and proper mesocycle length to determine the effects both methods may have on performance outcomes.

Practical Applications

The manipulation of exercise intensity and load, as well as exercise selection, are widely recognized as effective programming variables that can benefit athletes when implemented correctly. However, caution should be exercised when introducing variations in exercise selection, particularly as major competitions approach, to avoid excessive fatigue. It may be more prudent to incorporate diverse exercise selection during the off-season and early pre-season training phases, transitioning towards sport-specific exercises as the competitive season progresses. Furthermore, for novice athletes, both methods of manipulating exercise intensity and exercise selection may lead to favorable adaptations. In contrast, experienced athletes with a higher training age may be able to manage unnecessary fatigue and experience favorable adaptive responses through the introduction of exercise variations.

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Conflict of Interest

The authors declare there are no external sources of funding or conflicts of interest, and this manuscript is not currently published or being considered for publication elsewhere.

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