Journal of Strength and Conditioning Research Publish Ahead of Print
DOI: 10.1519/JSC.0000000000002272

Title: Auto-regulated exercise selection training regimen produces small increases in lean body mass and maximal strength adaptations in highly trained individuals.

Jacob T. Rauch[1], Carlos Ugrinowitsch[2], Christopher I Barakat[1], Michael R Alvarez[1], David L Brummert[1], Daniel W Aube[1], Andrew S Barsuhn[1], Daniel Hayes[1], Valmor Tricoli [2], Eduardo O. De Souza[1]

[1]Human Performance Laboratory, Health Sciences and Human Performance Department, University of Tampa, Tampa Florida, United States of America;
[2] School of Physical Education and Sport, University of São Paulo, São Paulo, Brazil

Corresponding author:

Jacob Rauch, MS(c), CSCS

401 W. Kennedy Boulevard, Tampa Florida

Phone: (813)-257-3149

E-mail: Jacob.rauch@spartans.ut.edu

Auto-regulated exercise selection training regimen

ABSTRACT:

The purpose of this investigation was to compare the effects of auto-regulatory exercise selection (AES) vs. fixed exercise selection (FES) on muscular adaptations in strength-trained individuals. Seventeen males (Mean ± SD; age = 24 ± 5.45 years; height = 180.3 ± 7.54cm, lean body mass [LBM] 66.44 ± 6.59kg; squat and bench press 1RM: body mass ratio 1.87, 1.38 respectively) were randomly assigned into either AES or FES. Both groups trained three times a week for 9 weeks. AES self-selected the exercises for each session, whereas FES was required to perform exercises in a fixed order. LBM was assessed via DEXA and maximum strength via 1RM testing, pre and post training intervention. Total volume load was significantly higher for AES than for FES (AES: 573,288kg ± 67,505, FES: 464,600 ± 95,595, p=0.0240). For LBM, there was a significant main time effect (p=0.009). However, confidence interval analysis (95%CI_{diff}) suggested that only AES significantly increased LBM (AES: 2.47%, ES: 0.35, 95% CI_{diff} [0.030kg: 3.197kg], FES: 1.37 %, ES: 0.21, 95% CI_{diff} [-0.500kg: 2.475kg]). There was a significant main time effect for maximum strength (p≤0.0001). However, 95% CI_{diff} suggested that only AES significantly improved Bench-press 1RM (AES: 6.48%, ES: 0.50, 95% CIdiff [0.312kg: 11.42kg; FES: 5.14%, ES: 0.43 95%CIdiff [-0.311kg: 11.42kg]. On the other hand for back squat 1RM similar responses were observed between groups, (AES: 9.55%, ES: 0.76 95% CIdiff [0.04kg: 28.37kg], FES: 11.54%, ES: 0.80, 95%CIdiff [1.8kg: 28.5kg]. Our findings, suggest AES may provide a small advantage in LBM and upper body maximal strength in strength-trained individuals.

Keywords: periodization, muscular hypertrophy, exercise selection, readiness, volume load

INTRODUCTION

It has been suggested that taking into account an individual's response to exercise may optimize the adaptive process in a given training cycle (2, 3, 9, 10, 19). This concept has been referred to as auto-regulatory periodization, which is a form of periodization that adjusts the training load to the athlete's readiness for exercise on a day-to-day or week-to-week basis (9). Previous research on auto-regulatory schemes has suggested superior strength-induced adaptations compared to traditional models in which training loads are pre-defined (9, 10). For instance, Mann et al. (2010) demonstrated greater maximal strength and strength endurance adaptations in division I college football players following 6 weeks of auto-regulatory progressive resistance exercise (APRE) compared to traditional linear periodization. Furthermore, McNamara & Stearne (2010) compared the effects of flexible non-linear periodization (FNLP) and non-linear periodization (NLP) on maximal strength in untrained individuals and revealed that while there were no differences between groups on the bench press or standing long jump assessments the flexible group demonstrated greater strength improvements on the leg press exercise.

It is important to note that most of the research available on the effects of autoregulation has addressed primarily quantitative resistance training variables (e.g., volume, intensity, rest interval) and the subsequent effects on muscular strength. However, practitioners vary not only quantitative training variables, but also qualitative variables such as exercise selection throughout training programs. To the best of our knowledge, there is a paucity of data comparing lean body mass and strength gains when using an auto-regulatory approach to exercise selection versus pre-determined exercise selection.

Furthermore, varying exercise selection may affect total volume load. In fact, it has been demonstrated that greater volume loads may result in greater increases in muscular hypertrophy and strength (11, 13, 16). However, it has yet to be determined how auto-regulating exercise selection will affect this volume load and subsequent training adaptations. Therefore, the purpose of our study was to investigate the effects of auto-regulatory exercise selection compared to fixed exercise selection on total lean body mass and maximal strength in strength-trained individuals. We hypothesized that several years of strength training experience will allow individuals to select exercises they feel most prepared to perform, which may optimize lean mass accretion and strength-induced adaptations.

METHODS

Experimental Approach to the Problem

This was a parallel group repeated measures design, which investigated the effects of auto-regulated exercise selection (AES) and fixed exercise selection (FES) on total lean body mass and strength adaptations in strength-trained males. Both groups trained three times a week for nine weeks. Training intensity (load) and number of sets performed were equated between groups. AES subjects were allowed to select which exercises they wanted to perform on a daily basis, whereas FES were given predetermined exercises. To increase ecological validity, volume load (i.e. sets x repetitions x kg) was monitored, but not balanced between groups, to determine if training–induced adaptations (i.e. muscle mass and strength) would result in different volume loads. To ensure proper nutrition throughout the experimental period, subjects received pre-workout supplementation and post-workout whey protein powder (25g). One serving of whey protein powder (25g) was also provided on non-training days, in an attempt to optimize muscle protein synthesis throughout the entire experimental period. Subjects were trained to track their dietary intakes during weeks 1, 2, 5, and 9. Total calories and macronutrients were calculated for these time points. Perceptual measures of recovery (i.e. perceived recovery scale - PRS) and exertion (i.e. rate of perceived exertion - RPE) were obtained before and after each training session, respectively, to monitor possible differences in internal load between groups. Total lean body mass and maximal strength (1RM) were assessed at week 0 and 10 on the back squat and bench press exercises.

SUBJECTS

Thirty-two strength-trained males volunteered for this study. Inclusion criteria consisted of being able to squat and bench 1.75 and 1.3 times their body mass, respectively. After pre-testing, 14 subjects withdrew due to either not meeting the predetermined strength requirements (n=6) or personal reasons (n=8). Therefore, 17 strength trained males (Mean ± SD; age = 24 ± 5.45 years; height = 180.3 ± 7.54cm; total body mass= 83.08 ± 8.70kg, lean body mass= 66.44 ± 6.59kg; squat and bench press 1RM: body mass ratio 1.87 and 1.38, respectively) completed the experimental protocol. Subjects were excluded from participation if they were currently taking any medications, anti-inflammatory drugs, or performance enhancers. No medical disorders, diseases, or musculoskeletal injuries were reported amongst subjects. Lastly, subjects were required to have continuously trained for at least three years before the commencement of the experimental protocol (mean 5.6 ± 3.29 years). Subjects were classified into quartiles according to total lean body mass. Then subjects from each quartile were randomly assigned to either AES or FES. All subjects read and signed an informed consent approved by the Institutional Review Board.

PROCEDURES

Familiarization

All subjects completed two familiarization sessions interspersed by a minimum of 48hrs prior to the commencement of the study. During the familiarization sessions, subjects performed a general warm-up consisting of five minutes of walking at 5.5 km/h on a treadmill (Tuff Tread, White Phoenix, LLC., Willis TX). After warming-up, subjects were given a thorough explanation of the squat and bench press 1RM testing protocols as described elsewhere (17). In brief, for the squat exercise body and foot placement were determined with measuring tape fixed on the bar and floor. In addition, an adjustable seat was placed behind the subject to keep the bar displacement and knee flexion angle (~ 100 °) constant on each repetition. Subjects positioning were recorded during the familiarization sessions and replicated on testing sessions. For the bench press exercise, subjects were required to maintain five points of contact (head, shoulder blades, lower back, left and right foot) at all times while lowering the bar with control touching the sternum and fully extending the arms for a rep to be considered successful. Individuals were considered familiarized with the 1RM tests, when the coefficient of variation between familiarization sessions was <5% on both strength tests (17).

Supplementation

Each participant was provided with one serving of pre-workout 30 minutes prior to exercise (Dymatize M.Pact , Dymatize Nutrition, Dallas, USA), and protein supplementation containing 25g protein (2.77g LEU) and 4g carbohydrates (Elite Whey Protein, Dymatize Nutrition, Dallas TX) immediately after each training session. To continuously optimize protein synthesis and recovery after training days, subjects were also provided with one serving of whey protein for every non-training day. To ensure compliance to protein intake on non-training days subjects were required to bring back the empty protein bags on the following training day.

Nutrition Monitoring (Dietary Intake)

Dietary intake was assessed through a self-reported food diary, (MyFitnessPal - http://www.myfitnesspal.com). Subjects tracked dietary intake during weeks 1, 2, 5, and 9. Subjects' body mass was reassessed at weeks 5 and 9 to accurately quantify their nutritional intake relative to body mass. Subjects were instructed to maintain their normal dietary habits and advised on how to properly record all food and their corresponding portion sizes throughout the duration of the study. If any subject's protein intake fell below 1.5g/kg, they were given additional nutritional guidance from a certified sports nutritionist.

Perceptual measures

PRS was assessed prior to beginning the general warm-up. Subjects were required to sit down and determine their perceived recovery (i.e. 0-10 scale) on that given day. Zero and ten indicate very poorly recovered/extremely tired, and very well recovered/highly energetic, respectively (7). RPE assessments were performed five minutes after each training session. Subjects were again required to sit down and point to a number on a 1-10 scale that best indicated their perceived level of effort for that given workout. All assessments were performed in isolation from other subjects to ensure accuracy (14). Perceptual measures of the three weekly sessions were averaged for further analysis.

Body Composition Assessments

A Lunar Prodigy Dual energy X-ray absorptiometry (DEXA) apparatus (Hologic, Bedford, MA, USA) was used to measure body composition. Total Lean body mass (LBM) and fat mass (FM) were determined with the subject lying in a supine position with knees extended and instructed not to move for the entire duration of the scan. Subjects were required to fast for 10 hours prior to the exam and refrain from exercising for 48 hours prior to the assessment. Body composition measures were acquired at weeks 0 and 9. The coefficient of variation (CV) was determined prior the study using five different subjects with similar characteristics to the current participants. DEXA scans were performed on three different days interspersed by 48hours at the same time of the day. The CV for body composition was 1.5%.

Muscular Strength Assessments

Maximal strength was assessed on the 1RM back squat and 1RM bench press exercises.

The same researcher conducted all of the tests. Strength testing loads were progressively increased until failure was reached. In brief, participants performed a general warm-up and a specific warm-up consisting of two sets. During the first set, participants performed 10 repetitions with 50% of the predicted 1RM. In the second set, they performed five repetitions with 75% of the predicted 1RM. After the second warm-up set, participants rested for 3-minutes. Then, each participant had up to five attempts to achieve the 1RM load. A rest period of 3-5 minutes was allotted between 1RM attempts. Strong verbal encouragement was given throughout the 1RM test. In order to subjects 1RM test be considered for further analysis the coefficient variation (CV) between assessments had to have been less that 5%. If a subject demonstrated a CV >5% a third testing session was provided. Maximal strength was assessed at week 0 and 48 hours after the last training session.

Strength Training Regimen

Subjects underwent a 9-week (3d/wk) hypertrophy-oriented full body-training regimen. Each workout consisted of six different exercises. A 90-120 second rest interval was allowed between sets while two minutes were respected between exercises. A daily undulating periodization model was implemented for both groups as follows: Day 1: 6-8RM, Day 2: 12-14RM and Day 3: 18-20RM. The training regimen was divided into three mesocycles, the number of sets progressed in each mesocycle; Mesocycle 1: four sets per exercise, Mesocycle 2: five sets per exercise, and Mesocycle 3: six sets per compound exercise and five sets per accessory exercise. The only difference between conditions was the exercises performed. The FES group was handed a workout sheet with seven predetermined exercises, whereas the AES group was handed a workout sheet in which they had to select one exercise per muscle group. Four certified strength and conditioning specialist were present for every training session, providing verbal encouragement and ensuring the proper amount of sets and repetitions were being performed.

Exercise options for the lower body included barbell back squat, plate loaded leg press, and knee extensions. Exercise options for the upper body included barbell bench press, incline dumbbell chest press, cable pec fly, bodyweight pull-ups, bent over barbell row, and straight-arm cable pull down. Exercise options for the accessory muscles included military press, dumbbell lateral raises, cable face-pulls, dumbbell bicep curls, preacher curls, cable bicep curls, triceps cable press down, dumbbell skull crushers, and overhead dumbbell triceps extensions. In the AES condition there was no limit on how many times a subject could select a given exercise per week. In the FES condition each subject completed each exercise once per week (Table 1).

INSERT TABLE 1 HERE

STATISTICAL ANALYSIS

After normality (i.e. Shapiro Wilk) and variance assurance (i.e. Levene), a two sample t-test was used to detect differences between groups at pre-training. The overall volume load between groups was also compared using a two-sample t-test. Volume load of each mesocycle for the AES and FES groups was compared using a mixed model with the group (AES and FES) and mesocycle (1st meso, 2nd meso, and 3rd meso) as fixed factors, and subjects as a random factor. In addition, a mixed model was performed for the remaining dependent variables, assuming group (AES and FES) and time (pre and post) as fixed factors, and subjects as a random factor (SAS 9.4, SAS Institute Inc., Cary, NC, USA). Whenever a significant F-value was obtained, a post-hoc test with a Tukey's adjustment was performed for multiple comparison purposes (18).

In regards to exercise selection, the number of times each exercise was chosen was analyzed through an unpaired T test (i.e. when data passed to normality test) or through nonparametric test (e.g. Mann-Whitney) when normality was rejected. In addition, we presented the mean difference ($Mean_{diff}$), upper and lower limits values of 95% confidence intervals of within-group comparisons (CI_{diff}). Confidence intervals that did not cross zero were considered as significant. Finally, within group effect sizes (ES) were calculated as follows: mean post minus mean pre divided by the pooled standard deviation (SD) of pretest-values. The significance level was previously set at $p < 0.05$. Results are expressed as mean ± SD.

RESULTS

Macronutrients and calorie intake

There were no significant differences in macronutrients and calorie intake within and between groups throughout the training period ($p>0.05$) (Table 2).

INSERT TABLE 2 HERE

Exercise selection

FES performed each exercise nine times throughout the duration of the study. AES selected various exercises in similar fashion compared to FES these include; squat (8.44±1.21 vs. 9.0±0.0, p=0.65), DB incline press (7.11±1.23 vs. 9.0±0.0, p=0.14), Cable fly (8.55±1.29 vs. 9.0±0.0, p=0.73), Bent over BB row (8.11±3.56 vs.9.0±0.0, p=0.66), DB military press (11.78± 7.07 vs. 9.0±0.0, p=0.37), DB lateral raise (10.25±3.10 vs. 9.0±0.0, p=0.24), DB skull crusher (7.55±3.67 vs. 9.0±0.0, p=0.25), DB incline curl (9.55± 2.24 vs. 9.0±0.0, p= 0.07) E-Z bar preacher curl (7.66 ± 5.31 vs. 9.0±0.0, p=0.46), and DB bicep curl (8.66 ± 1.78 vs. 9.0±0.0, p=0.85). There was a trend towards significance in which the AES group selected a greater frequency for the BB bench-press (11.63±1.32 vs. 9.0±0.0, p=0.06). In addition, there were significant differences in the number of times in which several exercises were selected. For example, AES chose the Leg-press (14.11±1.90 vs. 9.0±0.0, p=0.01), Straight arm lat pull down (12.44±5.50 vs. 9.0±0.0, p=0.002) and Cable press down (17.33±5.5 vs. 9.0±0.0, p=0.0003) more frequently when compared to FES . On the other hand, AES chose the following exercises on fewer occasions when compared to FES; leg extension (4.33±1.21 vs. 9.0±0.0, p=0.001), pull-up (6.5±1.30 vs. 9.0±0.0, p=0.0002), cable face pull (6.42±2.22 vs. 9.0±0.0, p=0.0035), and overhead cable triceps extension (1.88±2.47 vs. 9.0±0.0, p=0.0001).

Volume load

Overall volume load was significantly higher ($p=0.0240$) for AES than for FES (AES: 573,288kg ± 67,505, FES: 464,600 ± 95,595), (Figure 1A). In addition, when volume load was analyzed per mesocycle, there was a trend towards a group by time interaction ($p=0.075$) indicating the two groups responded differently over time. AES 2^{nd} vs. 1^{st}- Mean$_{diff}$ 66,915kg, CI$_{diff}$ [15,377kg : 118,453kg], 47.6%, ES: 4.01, $p=0.009$, FES : Mean$_{diff}$ 3.722kg, CI$_{diff}$ [-54,717kg : 62,160kg], 2.33%, ES: 1.40, $p=0.98$). AES- 3^{rd} vs. 1^{st} Mean$_{diff}$: 84,772kg, CI$_{diff}$ [33,234kg : 136,310kg] , 60.3%, ES: 5.08, $p=0.001$; FES : Mean$_{diff}$ 18,093kg, CI$_{diff}$ [40,346kg : 76,532kg], 11.3%, ES: 0.26, $p=0.72$), (Figure 1B).

INSERT FIGURE 1 HERE

Perceptual measures

No significant between-group differences were detected at pre-testing for PRS and RPE ($p\geq0.05$). For PRS, there was a trend towards a main time effect ($p=0.051$), (AES: Mean$_{diff}$ 0.131 AU, CI$_{diff}$ [-0.450AU : 0.713AU], 1.65 %, ES: 0.24, $p=0.84$; FES: Mean$_{diff}$ 0.56AU, CI$_{diff}$ [-0.01AU : 1.150AU], 7.99%, ES: 0.07, $p=0.056$), (Figure 2A). For RPE, there was a significant main time effect ($p=0.0004$) (AES: Mean$_{diff}$ 0.110AU, CI$_{diff}$ [-0.543AU : 0.765AU], 6.0 %, ES: 0.86 $p=0.16$; FES: Mean$_{diff}$ 1.040AU, CI$_{diff}$ [0.384AU : 1.694AU], 13.9%, ES: 0.98 $p\leq0.001$), (Figure 2B).

INSERT FIGURE 2 HERE

Body composition

No significant differences between groups were detected at pre-testing for FM and LBM ($p \geq 0.05$).

For FM, there was a significant group effect ($p=0.04$) in which FES group was leaner than AES group. For LBM, there was a significant main effect for time ($p=0.009$). However, confidence interval analysis suggested that only AES significantly increased LBM (AES: Meandiff 1.609kg, CIdiff [0.030kg : 3.197kg], 2.47 %, ES: 0.35, $p=0.045$; FES: Meandiff 0.988kg, CIdiff [-0.500kg : 2.475kg], 1.37 %, ES: 0.21, $p=0.238$). The individual values for total LBM are presented in Table X.

INSERT TABLE 3 HERE

Maximal strength

For back squat 1RM, there was a significant main effect for time ($p \leq 0.0001$), (AES: Meandiff 14.2kg , CIdiff [0.04kg - 28.37kg], 9.55%, ES: 0.75, $p=0.04$; FES: Meandiff 15.15kg, CIdiff [1.8kg - 28.5kg], 11.54%, ES: 0.80, $p=0.02$), (Figure 3A). For, bench-press 1RM, there was a significant main effect for time ($p \leq 0.003$). Confidence interval analysis suggested that only AES demonstrated a significant improvement in Bench-press 1RM (AES: Meandiff 6.53kg , CIdiff [0.312kg - 12.76kg], 6.48%, ES: 0.50, $p=0.03$; FES: 95% CI diff: : 5.55kg, -0.311kg to 11.42kg, 5.14%, ES: 0.43, $p=0.06$), (Figure 3B).

INSERT FIGURE 3 HERE

DISCUSSION

The purpose of this study was to examine the effects of auto-regulatory exercise selection compared to fixed exercise selection on total lean body mass and strength adaptations in strength-trained individuals. We hypothesized that trained individuals would auto-regulate exercise selection based off of their recovery and readiness for exercise further optimizing strength training-induced adaptations. We partially confirmed our initial hypothesis as our findings suggest that AES regimen produced a small advantage in total lean body mass and upper body maximum strength adaptations compared to FES.

Research has shown that there is a dose response relationship between volume load and increases in muscle mass and strength (6, 15). In the present study, volume load was monitored but not equated. After nine weeks of training, AES trained with significantly greater volume loads compared to FES (AES: 573,288kg ± 67,505, FES: 464,600 ± 95,595). This may be further explained by the fact that the AES group selected compound exercises more frequently than the FES group. For example, AES selected the leg-press exercise 14.1 times compared to the set 9.0 in FES throughout the experimental period. Furthermore, AES selected the Bench-press exercise 11.6 times compared to the set 9.0 in FES group. Therefore, our data suggest that strength trained individuals self-selected compound exercises more frequently compared to isolation or accessory exercises which may have allowed them to more effectively increase volume load. Additionally, a dose response relationship between volume loads and perceptual measures of internal load has previously been identified (RPE) (8). Lodo et al. (2012) demonstrated that increases in training volume load resulted in an increase in session RPE. In our investigation, both groups responded similarly in measures of internal load despite AES training with 20% more volume load (i.e. ~100.00kg). Thereby, through allowing trained-individuals to select exercises in which they feel the most comfortable and prepared to perform this may enhance their ability to tolerate greater volume loads.

Furthermore, there was a significant time effect in which both groups increased lean body mass (i.e. 1.28kg). Our results confirm previous findings that demonstrated lean body mass gains following resistance training protocols in combination with protein supplementation to be 0.98kg in trained individuals (1). Even though some subjects lost lean body mass in the FES group (Table 1), this was not sufficient to reach a significant group by time interaction. However, the Meandiff and CIdiff analysis suggested that only AES significantly increased lean body mass (e.g., AES: 2.47%- Meandiff 1.609kg, CIdiff [0.030kg : 3.197kg], ES: 0.35; FES: 1.37%- Meandiff 0.988kg, CIdiff [-0.500kg : 2.475kg], 1.37 %, ES: 0.21). Additionally, research has demonstrated a continuum of trainable adaptations that is directly associated with the training status of the individual (5, 12), indicating that untrained individuals may be more responsive to training whereas trained individuals may need to add more variation and/or progression to see further adaptations. In this regard, the small changes in lean tissue reported in our study may be considered important for trained individuals. Moreover, as there is limited data on lean body mass regimens in strength-trained populations, our data may suggest that for this population to see small additional gains in lean body mass, significant increases in volume load may be necessary (> 100,00kg additional volume load) to prompt adaptations. In fact, Schoenfeld et al.

(2017) mentioned in a recent meta-analysis that while 10 sets per muscle group is superior for muscle growth when compared to 1-5 and 5-9 sets per week, there is limited data that has analyzed the effects of greater volume loads (i.e., > 12 sets per week). In our investigation our subjects progressed from 12-16 weekly sets per muscle group. On average between the groups this amount of volume resulted in increases of lean body mass by roughly ~1.92%.

As the training protocol in the current study was designed to maximize muscle mass and not muscular strength, significant maximal strength increases were not expected. However, our maximal strength assessments revealed that both groups increased Back Squat and Bench Press 1RM values similarly. In addition, CI_{diff} suggested that AES produced a small benefit in strength gains on the bench press exercise over FES (AES: 0.312kg to 12.76kg and FES: -0.311 to 11.42kg, respectively). It has been demonstrated that strength gains are specific to the movement that is practiced most frequently (4). Thus, the increased frequency of the bench press exercise in the AES group may have led to improved bench press adaptations. On the other hand, as both groups performed the back squat exercises in a similar frequency (8.44 vs 9.0 sessions), similar responses to strength gains on the back squat were observed.

The previous literature addressing auto-regulatory schemes has primarily investigated different methods of auto-regulating intensity. While the magnitude of strength response between auto regulating intensity on trained individuals is agreement with our current study (i.e. 6.5kg and 15.6kg on the bench press and back squat exercise respectively) (2) . Comparisons between these studies should be taken with a degree of caution as different methods of auto-regulation were applied.

In conclusion, our findings suggest AES may provide a small advantage in lean mass accretion and upper body strength in strength-trained males. Our results also support the use of compound exercises in a resistance training protocol in trained individuals, as they aid in increasing overall training volume. Furthermore, allowing strength-trained individuals to select the exercises they feel most prepared to perform on a given day may allow them to tolerate greater volume loads without additional increases in measures of internal load. While the previous auto regulatory studies have each manipulated different training variables, those studies demonstrate that providing individuals some degree of freedom to decide either intensity, repetition range and now exercise selection may allow them to optimize the adaptive process to strength training. Although the exact mechanisms are not completely understood, it is likely that this is due to increased adherence and effort to a give training regimen as well as providing them with an optimal load on each given day based off of their recovery and readiness for exercise(2).

Limitations

This study has several inherent limitations. First off, as volume load was not equated between groups both training regimens demonstrated varying training stimulus, which may have affected the response to training. Secondly, the study duration (9 weeks) limits our ability to determine the long-term effects of AES on lean body mass and strength adaptations. Future research should investigate this topic over a longer duration of time. Thirdly, strength endurance assessments were not conducted which may have been a more specific measurement as training intensity did not near 1RM loads throughout the intervention. Additionally, future investigations on the topic may wish to provide more than three exercise options per muscle group as this may have limited the true self-regulation of exercise selection. Lastly and perhaps the most important, the absence of muscle hypertrophic assessment (i.e. muscle cross-sectional) limits our understanding of how an auto-regulatory protocol varying exercise selection can modulate muscle hypertrophy compared with a pre-determined exercise selection routine.

Practical Application

Strength and conditioning professionals may wish to implement auto regulating exercise selection into their training protocols, as this may improve one's ability to tolerate greater training loads. When dealing with trained populations small improvements in performance are important, what may not appear, as statistically significant may still be practically relevant. As each individual responds differently to training and there are various factors that affects one's readiness for exercise on a daily basis, any training model that factors in an individuals response to exercise may improve fatigue management and maximize training adaptations.

REFERENCES

1. Cermak NM, Res PT, de Groot LC, Saris WH, and van Loon LJ. Protein supplementation augments the adaptive response of skeletal muscle to resistance-type exercise training: a meta-analysis. *Am J Clin Nutr* 96: 1454-1464, 2012.

2. Colquhoun RJ, Gai CM, Walters J, Brannon AR, Kilpatrick MW, D'Agostino DP, and Campbell WI. Comparison of Powerlifting Performance in Trained Men Using Traditional and Flexible Daily Undulating Periodization. *J Strength Cond Res* 31: 283-291, 2017.

3. Fabien Pereira da Silva JV-A, Leonardo Lopes de Souza, Juliano spineti dos Santos, Tiago Figueiredo, Gabriel Andrade Paz, Jeffrey W. Willardson, Humberto Mirando. Effects of Daily and Flexible Non-Linear Periodization on Maximal and Submaximal Strength, Vertical Jump and Speed Performance of Brazil- ian Army Skydivers. *Int J Sports Exerc Med* 2: 1-6, 2016.

4. Fahey TD and Chico C. Adaptation to exercise: Progressive resistance exercise. *Sportsci org, last update: April*, 1998.

5. Kraemer WJ, Adams K, Cafarelli E, Dudley GA, Dooly C, Feigenbaum MS, Fleck SJ, Franklin B, Fry AC, Hoffman JR, Newton RU, Potteiger J, Stone MH, Ratamess NA, Triplett-McBride T, and American College of Sports M. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 34: 364-380, 2002.

6. Krieger JW. Single vs. multiple sets of resistance exercise for muscle hypertrophy: a meta-analysis. *J Strength Cond Res* 24: 1150-1159, 2010.

7. Laurent CM, Green JM, Bishop PA, Sjokvist J, Schumacker RE, Richardson MT, and Curtner-Smith M. A practical approach to monitoring recovery: development of a perceived recovery status scale. *J Strength Cond Res* 25: 620-628, 2011.

8. Lodo L, Moreira A, Zavanela PM, Newton MJ, McGuigan MR, and Aoki MS. Is there a relationship between the total volume of load lifted in bench press exercise and the rating of perceived exertion? *J Sports Med Phys Fitness* 52: 483-488, 2012.

9. Mann JB, Thyfault JP, Ivey PA, and Sayers SP. The effect of autoregulatory progressive resistance exercise vs. linear periodization on strength improvement in college athletes. *J Strength Cond Res* 24: 1718-1723, 2010.

10. McNamara JM and Stearne DJ. Flexible nonlinear periodization in a beginner college weight training class. *J Strength Cond Res* 24: 2012-2017, 2010.

11. Peterson MD, Pistilli E, Haff GG, Hoffman EP, and Gordon PM. Progression of volume load and muscular adaptation during resistance exercise. *European journal of applied physiology* 111: 1063-1071, 2011.

12. Peterson MD, Rhea MR, and Alvar BA. Maximizing strength development in athletes: a meta-analysis to determine the dose-response relationship. *J Strength Cond Res* 18: 377-382, 2004.

13. Radaelli R, Fleck SJ, Leite T, Leite RD, Pinto RS, Fernandes L, and Simão R. Dose-response of 1, 3, and 5 sets of resistance exercise on strength, local muscular endurance, and hypertrophy. *The Journal of Strength & Conditioning Research* 29: 1349-1358, 2015.

14. Row BS, Knutzen KM, and Skogsberg NJ. Regulating explosive resistance training intensity using the rating of perceived exertion. *J Strength Cond Res* 26: 664-671, 2012.

15. Schoenfeld BJ, Ogborn D, and Krieger JW. Dose-response relationship between weekly resistance training volume and increases in muscle mass: A systematic review and meta-analysis. *J Sports Sci* 35: 1073-1082, 2017.

16. Sooneste H, Tanimoto M, Kakigi R, Saga N, and Katamoto S. Effects of training volume on strength and hypertrophy in young men. *The Journal of Strength & Conditioning Research* 27: 8-13, 2013.

17. Souza EO, Ugrinowitsch C, Tricoli V, Roschel H, Lowery RP, Aihara AY, Leão AR, and Wilson JM. Early adaptations to six weeks of non-periodized and periodized strength training regimens in recreational males. *Journal of sports science & medicine* 13: 604, 2014.

18. Ugrinowitsch C, Fellingham GW, and Ricard MD. Limitations of ordinary least squares models in analyzing repeated measures data. *Med Sci Sports Exerc* 36: 2144-2148, 2004.

19. Zourdos MC, Klemp A, Dolan C, Quiles JM, Schau KA, Jo E, Helms E, Esgro B, Duncan S, Garcia Merino S, and Blanco R. Novel Resistance Training-Specific Rating of Perceived Exertion Scale Measuring Repetitions in Reserve. *J Strength Cond Res* 30: 267-275, 2016.

Acknowledgements

The researchers would like to thank Dymatize Nutrition for supplying both the Pre workout and protein powder. In addition, there are no conflict of interests involved in this manuscript. Lastly the results of the present study do not constitute endorsement by the authors or the NSCA.

Figure Legends

Figure 1.)

#- Indicates p≤ 0.05 for between-group comparisons

* - Indicates p≤ 0.05 for within-group comparisons

Figure 2.)

* - Indicates p≤ 0.05 for main effect of time

Figure 3.)

* - Indicates p≤ 0.05 for main effect of time

Table 1. Periodization schemes for the fixed exercise selection group (FES) on the three weekly training sessions.

Table 2. Total caloric intake and macronutrients distribution throughout the 9-wk training period for the auto-regulatory exercise selection (AES) and fixed exercise selection (FES) groups

Table 3. Individual lean body mass values

Table 1. Periodization schemes for the fixed exercise selection group (FES) on the three weekly training sessions.

FES			
Muscle Group	Day 1 (6-8RM)	Day 2 (12-14RM)	Day 3 (18-20RM)
Legs	Squat	Leg press	Leg Extension
Chest	Barbell Bench Press	Dumbbell Incline Press	Cable Fly
Back	Bent Barbell Row	Pullup	Straight arm Lat Pulldown
Shoulders	DB Military Press	Dumbbell Lateral Raises	Cable Face Pulls
Biceps	Dumbbell Bicep Curls	E-Z Bar Preacher Curls	Dumbbell Incline Curls
Triceps	Cable Press down	Dumbbell Incline Skull crusher	Cable Overhead Triceps Extension

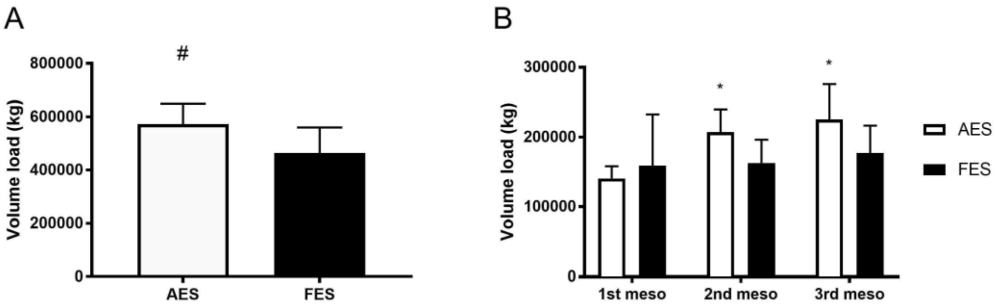
Table 2. Total caloric intake and macronutrient distribution throughout the 9-wk period for the auto-regulatory exercise selection (AES) and fixed exercise selection (FES) groups.

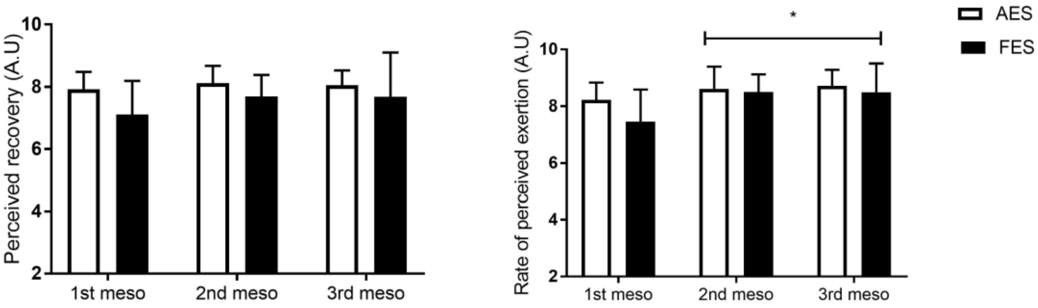
		AES		
Weeks	**Total calories (kcal)**	**Fat/g/kg (g)**	**CHO/g/kg (g)**	**PRO/g/kg (g)**
Wk-1	2430.8±373.3	1.04±0.22	3.00±0.77	1.86±0.49
Wk-2	2352.8±381.3	0.92±0.18	2.95±0.91	1.98±0.47
Wk-5	2446.8±426.4	1.00+0.27	2.85+0.76	2.06+0.39
Wk-9	2610.7±791.8	1.10±0.43	3.23+1.26	1.99+0.30
		FES		
Wk-1	2345.1±295.3	1.04±0.13	2.83±0.67	1.74±0.35
Wk-2	2300.2±346.6	1.05±0.13	2.68±0.74	1.72±0.35
Wk-5	2258.1±526.8	0.99±0.21	2.58±0.99	1.75±0.36
Wk-9	2331.5±469.5	1.01±0.18	2.65±0.94	1.81±0.37

CHO- Carbohydrate, PRO- Protein

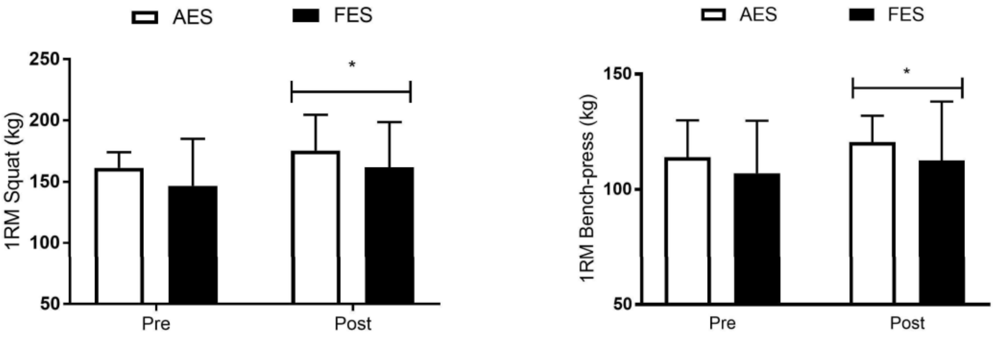
Table 3. Individual lean body mass values

AES				FES			
Participant	**LBM (kg) Pre**	**LBM (kg) Post**	**Ä (kg)**	**Participant**	**LBM (kg) Pre**	**LBM (kg) Post**	**Ä (kg)**
1	65.19	66.22	1.03	9	77.18	80.34	3.16
2	70.65	72.24	1.59	10	77.37	81.39	4.02
3	66.25	67.98	1.73	11	76.61	75.11	-1.5
4	69.04	69.30	0.26	12	67.49	67.10	-0.39
5	67.45	67.36	-0.09	13	61.89	61.57	-0.32
6	63.67	67.59	3.92	14	73.35	75.73	2.38
7	62.59	62.74	0.15	15	59.24	58.54	-0.70
8	63.41	67.69	4.28	16	56.80	57.88	1.08
	-	-	-	17	53.64	54.80	1.16
Mean	**66.03**	**67.64**	**1.60**		**67.06**	**68.05**	**0.98**
SD	**2.67**	**2.50**	**1.56**		**8.9**	**9.71**	**1.78**


A
#
800000
600000
400000
200000
0
Volume load (kg)
AES
FES
B
300000
200000
100000
0
Volume load (kg)
*
*
1st meso
2nd meso
3rd meso
AES
FES



Perceived recovery (A.U)
10
8
6
4
2
1st meso
2nd meso
3rd meso
Rate of perceived exertion (A.U)
*
AES
FES


AES
FES
1RM Squat (kg)
250
200
150
100
50
*
Pre
Post
AES
FES
1RM Bench-press (kg)
150
100
50
*
Pre
Post