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Original Research

Muscle Daily Undulating Periodization for Strength and Body Composition: The Proposal of a New Model

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ABSTRACT

International Journal of Exercise Science 15(4): 206-220, 2022. The traditional linear periodization model is designed for modifications to be performed over several weeks, whereas alterations in the undulating model are applied on a more frequent basis. The study investigated a novel periodization scheme, the muscle daily undulating periodization model (mDUP). Thirty-seven men were randomly assigned into 2 groups: (a) a group that performed 12 weeks of daily undulating periodization with fix overload (DUP-F) resistance training ($n = 19$) and (b) a group that performed 12-weeks of muscle daily undulating periodization with variation overload (mDUP) ($n = 18$). Body composition and strength assessments (muscular endurance and one repetition maximum [1 RM] for barbell bench press, 45º leg press, lat pull down, and standing arm curl) were completed before and after the program. Two-way MANOVA with repeated measures was used to compare groups with significance set at p<0.05. There were no differences between periodization programs for anthropometric variables ($p > 0.05$, $\eta 2p = 0.04$), but improvement was noted over time ($p < 0.001$, $\eta 2p = 0.60$). No differences were observed between periodization programs for strength ($p > 0.05$, $\eta 2p = 0.056$), but strength increased over time ($p < 0.001$, $\eta 2p = 0.95$). Similarly, no muscular endurance differences were seen between periodization programs ($p > 0.05$, $\eta 2p = 0.15$), but measures increased over time ($p < 0.001$, $\eta 2p = 0.60$). When it comes to body composition, muscle strength, and muscle endurance, the present study provides evidence that both periodization models displayed similar results, with more evident improvements in strength. Thus, it seems pertinent to consider this new periodization model plausible for RT practitioners in order to achieve new adaptations.

KEY WORDS: Resistance training, muscle force, performance, training, programming

INTRODUCTION

Periodization consists of planned variations in both the acute and chronic variables of a training program (4). Fleck (11) defines resistance training (RT) periodization as altering program variables in regular interval periods, with the intention of inducing optimal gains of strength, power, motor performance and/or muscle hypertrophy.

In this sense, an interesting RT model is undulating periodization (or nonlinear) that promotes a variation in intensity and volume within a maximal period of 7-10 days (28). Thus, the modification of training parameters is more frequent, being completed in shorter periods. This RT periodization model is relatively recent, considering that the first report of undulating periodization was proposed by Poliquin in 1988 (23). While the traditional linear periodization model is designed for modifications to be performed over several weeks, alterations in the undulating model are applied in a one-week basis (weekly undulating periodization), or every training session (daily undulating periodization) (30).

More recently, the premiere method of resistance training has been reported to be a flexible, nonlinear (FNL) workout program (17). This training system follows many of the same concepts, goals, and strategies of traditional strength periodization and undulating periodization. The major point of this variation is to adjust the training loads to the physiological and psychological state of the practitioner, guarantying an improved evolution. To the best of our knowledge, only two studies compared different undulating periodization models. McNamara & Stearne (19) found that FNL resulted in superior performance in the leg press exercise versus nonlinear periodization, while no differences were found for the chest press and standing long jump in beginning weight training students. Another study evaluated recreationally trained college subjects who completed nine weeks of linear, weekly or daily undulating models and no difference in strength gains was found among periodizations (17).

The present study was designed to propose and compare a new periodization model, never investigated before, the muscle daily undulating periodization model (mDUP). The main characteristic of this proposal is that a muscle group could be trained at light, moderate or high intensities on the same week, for example, exercises for the chest with 4-6 repetitions maximum (RM) on Monday and exercises for biceps with 12-15 RM, then on Thursday biceps exercises would start the session with 4-6 RM and chest exercises would be trained with 12-15 RM (25). In theory, this would allow this muscle group to be trained at a maximal effort without more than 3-4 days to be stimulated again with a lighter load.

This is particularly important, considering that exercise order has an effect on muscle strength gains, even in trained individuals (2). Moreover, previous studies have indicated that training induced neuromuscular adaptations for exercises performed at the end of a RT session are reduced versus exercises performed at the beginning of a RT session (8). Thus, the objective was to compare the effects of daily undulating periodization (DUP) with fixed overload (DUP-F) versus muscle daily undulating variable overload (mDUP) on strength, muscle endurance, and body composition of trained subjects following 12 weeks of training. The hypothesis is that both periodizations would result in similar increase of muscle strength and endurance, with limited results on body composition due the trained status of the subjects.

METHODS

Participants

Thirty-seven men aged 18-25 were recruited and randomly assigned into 2 groups: (a) a group that performed 12 weeks of daily undulating periodization with fix overload (DUP-F) resistance training (n = 19) and (b) a group that performed 12-weeks of muscle daily undulating periodization with variation overload (mDUP) (n = 18). The inclusion criteria were a minimum of strength training for at least 1-year and not currently using ergogenic supplements. According to the American College of Sports Medicine (1), the individuals were considered "trained." Training experience and habitual physical activity were determined by the use of a questionnaire and interview. During the 12-months prior to the study, all subjects had strength trained at least 4 times per week using 3 sets of 8-10 repetitions using an 8-10 RM resistance for the exercise performed. If the subjects missed 2 training sessions, they were removed from the study. The training period for all subjects started in the beginning of August when university classes began. All participants signed an informed consent document approved by the local University Research Ethics Committee for Human Use (Protocol No. 114/2006). The present research procedures were in accordance with guidelines for use of human subjects set forth by the ACSM (1) and the International Journal of Exercise Science ethical policies (21).

Protocol

In the present study, both periodization programs were based in previous studies from Rhea et al. (29, 30). The exercises proposed for both groups were the same, performed four times a week. Two days per week session A training was performed (Monday and Thursday) and two days per week session B training was performed (Tuesday and Friday) (table 1). The training load was different according to the repetition zone for each group (DUP-F versus mDUP) (table 2). The dependent variables were strength and body composition, and the independent variables were the periodization models (DUP-F and mDUP). Tests for body composition and maximum strength were performed pre-training (T1), after 8 weeks of training (T2), and after 12 weeks of training (T3) (Figure 1).

Table 1. Training program design.

Training A (sessions 1 and 3)	Training B (sessions 2 and 4)
Bench press	Front lat pull down
Incline bench dumbbell press	Single arm dumbbell row
Flat bench dumbbell fly	Reverse cable crossover
Standing arm curl	Triceps barbell extension
Alternating dumbbell arm curl	Triceps pushdown
Barbell wrist curl	Back squat
Shoulder press	45º leg press
Barbell Shoulder row	Leg curl
Lateral raise	Standing calf raise

Note: Four weekly sessions, 2 days per week training session A was performed (Monday and Thursday) and 2 days per week session B training was performed (Tuesday and Friday).

Table 2. Weekly training load by zone repetitions.

DUP-F (n = 19)	
Weeks 1,5,9	
Days 1 and 2	3 sets of 8 RM
Days 3 and 4	3 sets of 12 RM
Weeks 2,6,10	
Days 1 and 2	3 sets of 6 RM
Days 3 and 4	3 sets of 10 RM
Weeks 3,7,11	
Days 1 and 2	3 sets of 4 RM
Days 3 and 4	3 sets of 8 RM
Weeks 4,8,12	
Days 1 and 2	3 sets of 14 RM
Days 3 and 4	3 sets of 14 RM
mDUP (n = 18)	
Weeks 1,5,9	
Days 1 and 2	3 sets of 8RM –12 RM
Days 3 and 4	3 sets of 12RM –8RM
Weeks 2,6,10	
Days 1 and 2	3 sets of 6RM –10RM
Days 3 and 4	3 sets of 10RM –6RM
Weeks 3,7,11	
Days 1 and 2	3 sets of 4RM –8RM
Days 3 and 4	3 sets of 8RM –4RM
Weeks 4,8,12	
Days 1 and 2	3 sets of 14RM
Days 3 and 4	3 sets of 14RM

Note: Undulating Periodization with Fixed overload (DUP-F); Muscle Daily Undulating Periodization with Variable overload (mDUP); Maximum Repetitions (RM).

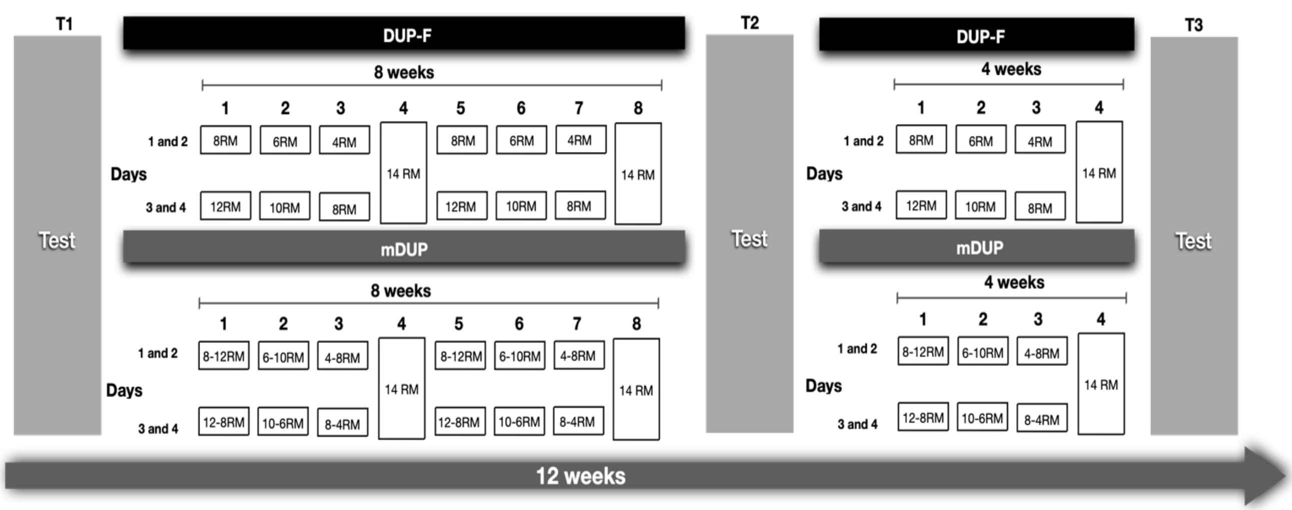

Figure 1. Experimental Design. Undulating Periodization with Fixed overload (DUP-F); Muscle Daily Undulating Periodization with Variable overload (mDUP); Baseline tests (T1); Tests after 8weeks training periodization (T2); Tests after 12weeks training periodization (T3); Maximum Repetition (RM).

Body composition was determined using skinfold thickness with a Lange skinfold caliper (Beta Technology, Santa Cruz, CA, USA). The Jackson and Pollock (15) equation for men (18 to 61 years old) was used to estimate body density. In this equation, the sum of the chest, abdominal, and thigh skinfolds is used. The same investigators performed all tests. Body fat percentage was estimated by the Siri (32) equation. Body fat percentage was used to estimate fat mass (kilogram) and fat-free mass (kilogram).

One Repetition Maximum (1 RM) tests for barbell bench press, 45º leg press, lat pull down (Cybex International, Medway, MA, USA), and standing arm curl were used to determine maximal strength. The 1 RM tests were performed on the same day with a minimum 10-min rest interval between tests in the following order: bench press, arm curl, 45º leg press, and lat pull down. After a general warm-up (10 min low-intensity treadmill running), subjects performed 8 repetitions with an estimated 50% 1 RM of the exercise being tested using each subject's previous training experience, and after 1-min rest, 3 repetitions with an estimated 70% of 1 RM were performed. After 3-min, subsequent trials were performed for 1 repetition with progressively heavier weights until the 1 RM was determined within 3 attempts, using 3- to 5-min rest periods between trials (18). The range of motion and exercise technique were standardized according to the descriptions of Brown and Weir (5). To assure pretraining 1 RM were stable prior to beginning training, the pretraining 1 RM were determined on 3 separate days with 48 hours between trials. A high interclass correlation was found between the second and the third 1 RM trials (bench press ICC = 0.99; 45º leg press ICC = 0.98; arm curl ICC = 0.97; lat pull down ICC = 0.99). The greatest 1 RM determined from the last 2 trials was used as the baseline measure. Student's t-tests showed no significant differences between the (DUP-F and mDUP) groups ($p \leq 0.05$), for pretraining maximal strength values in any of the 4 exercises tested.

The muscular endurance test was conducted 48 h after maximal strength testing. The test was accomplished by execution of repetitions to exhaustion. After a short period of light aerobic warm-up (10 min low-intensity treadmill running), participants performed as many repetitions as possible without stopping or pausing between repetitions with a fixed cadence and 80% of 1 RM [adapted from Prestes et al., (24)], in the same exercises performed: bench press, arm curl, 45º leg press, and lat pull down. As in the 1 RM test, to ensure the reliability of the baseline measure, this procedure was repeated on a separate day, and the highest number of repetitions was recorded, with high interclass correlation for both trials (bench press ICC = 0.95; 45º leg press ICC = 0.96; arm curl ICC = 0.96; lat pull down ICC = 0.97).

Statistical Analysis

Statistical analyses were performed using SPSS software (Version 22; SPSS, Inc, Chicago, IL, USA) and data are presented as mean ± SD. Normal distribution of variables were analyzed by the Shapiro-Wilk test. Two-way MANOVA with repeated measures was used to compare exercise groups on the dependent variables. The assumption of multivariate outliers was not violated (Mihanalobis distance). In addition, if M-box test was significant, Pillai's trace criterion was used for more robust departures from assumptions (33). Group (DUP-F and mDUP) served as a between-subjects factor, while Time (T1, T2, and T3) served as a within-subject factor, and the statistical significance was set at $p < 0.05$. If assumptions of sphericity were violated, the

Greenhouse-Geisser adjustment was used. The Bonferroni adjustment was used for multiple pairwise comparisons.

Eta partial squared ($\eta 2p$) was calculated as a measure of effect size (the proportion of variance in the dependent variable explained for by variation in the independent variable), considering 0.01, 0.06, and 0.14, as small, moderate, and large, respectively. The magnitude of the changes between groups was assessed using Cohen's d effect size and presented with the 90% confidence interval (90% CI) (figure 2). Threshold values for 0.2 (small), 0.6 (moderate), and 0.8 (large) were considered. The effect size across time points was calculated as recommended by Rhea (27). Participants enrolled in the present study were considered recreationally trained, therefore, effect size magnitudes were considered as < 0.35 (trivial), 0.35-0.80 (small), 0.80-1.50 (moderate), and > 1.50 (large).

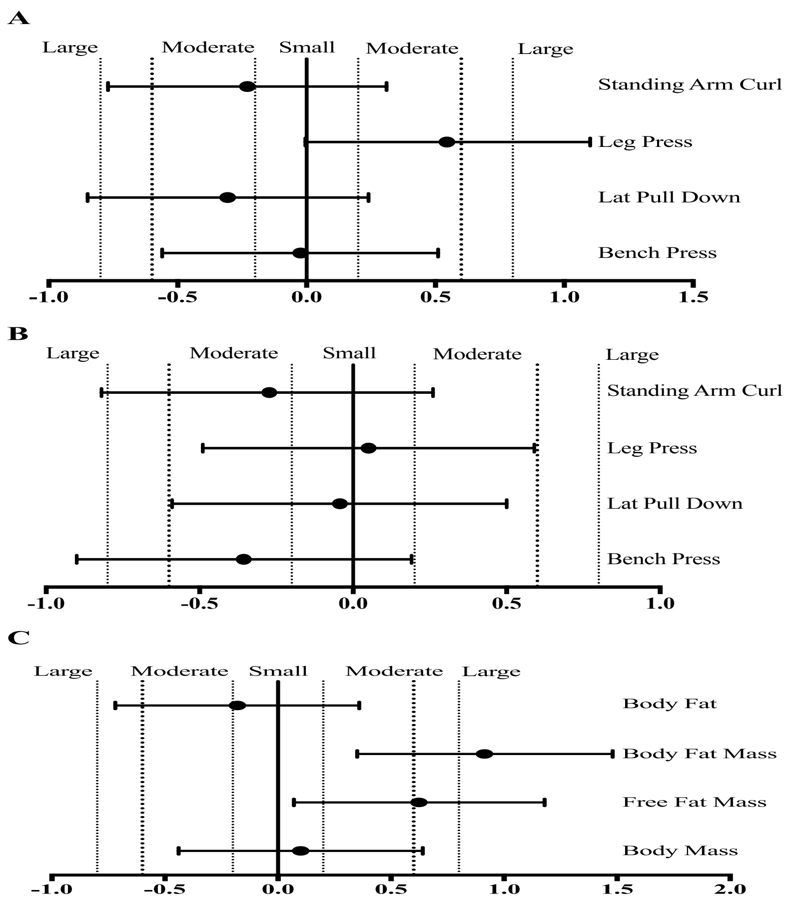

Figure 2. Effect size (± 90% CI) of the difference between the two periodization programs at T3 (DUP-F vs. DUP-V) of each dependent variable.

RESULTS

MANOVA revealed no significant effect between periodization programs (Pillai´s Trace = 0.056, $F(4,31) = 0.460$, $p > 0.05$, $\eta 2p = 0.056$), but instead showed a significant effect for time (Pillai´s

Trace = 0.949, $F(8,27) = 62.69$, $p < 0.001$, $\eta 2p = 0.95$). No interaction effect (Time x Group) was observed [Pillai´s Trace = 0.372, $F(8,27) = 2.00$, $p = 0.085$, $\eta 2p = 0.37$].

Univariate analysis indicated differences of time for bench press ($F(1.32,44.96) = 93.89$, $p < 0.001$, $\eta 2p = 0.73$), lat pulldown ($F(1.56,53.18) = 192.46$, $p < 0.001$, $\eta 2p = 0.85$), leg press ($F(1.20,40.78) = 118.93$, $p < 0.001$, $\eta 2p = 0.78$), and arm curl ($F(1.94,66.24) = 109.25$, $p < 0.001$, $\eta 2p = 0.76$). The univariate Time x Group interaction was significant only for arm curl ($F(1.94,66.24) = 109.25$, $p < 0.001$, $\eta 2p = 0.76$). No significant differences were observed between groups at any time point.

Pairwise comparisons with Bonferroni adjustment, showed that all strength measurements were greater at T3 in comparison to T1 in both groups (Table 3).Muscular Endurance: For muscular endurance, the MANOVA indicated no significant effect between periodization programs (Pillai´s Trace = 0.153, $F(4,32) = 1.44$, $p = 0.24$, $\eta 2p = 0.15$), and no interaction effect (Time x Group) [Pillai´s Trace = 0.115, $F(8,28) = 0.45$, $p = 0.87$, $\eta 2p = 0.11$]. Otherwise, there was a significant effect for time (Pillai´s Trace = 0.596, $F(8,28) = 5.15$, $p = 0.001$, $\eta 2p = 0.60$).

Univariate analysis revealed significant differences of time for bench press [$F(2,70) = 3.62$, $p = 0.032$, $\eta 2p = 0.09$], and leg press [$F(2, 70) = 11.18$, $p < 0.01$, $\eta 2p = 0.24$]. There was a trend effect for time in arm curl tests [$F(2, 70) = 2.88$, $p = 0.062$, $\eta 2p = 0.07$] (table 4). Significant differences were observed between groups for arm curl [$F(1,35) = 4.82$, $p = 0.035$, $\eta 2p = 0.12$]. Table 4 shows that participants in the DUP-F experienced a grater increase in arm curl muscular endurance at T2 than mDUP (9.4% vs. 2.3%, respectively).

The MANOVA for anthropometric variables revealed no significant main effect for periodization programs (Wilk's Lambda= 0.952, $F(3,33) = 0.55$, $p > 0.05$, $\eta 2p = 0.04$). On the other hand, there was a significant effect for time (Wilk's Lambda = 0.404, $F(8,28) = 5.15$, $p < 0.001$, $\eta 2p = 0.60$), and a multivariate Time x Group interaction [Wilk's Lambda= 0.647, $F(6,30) = 2.73$, $p < 0.05$, $\eta 2p = 0.35$].

Univariate analysis revealed significant differences of time for free fat mass [$F(2, 70) = 31.13$, $p < 0.001$, $\eta 2p = 0.47$], body fat mass [$F(1.17, 41.15) = 5.57$, $p < 0.01$, $\eta 2p = 0.14$], and body fat [$F(2, 70) = 46.32$, $p < 0.001$, $\eta 2p = 0.57$]. There was no significant time main effect for body mass. Pairwise comparisons indicated significant differences across T1 and T3 in both periodization programs for free fat mass, fat mass, and body fat (Table 5).

Table 3. Strength.

Groups	T1	T2	T3	Change T1-T2 (%)	Change T1-T3 (%)	Change T2-T3 (%)	ES T1-T2 (magnitude)	ES T1-T3 (magnitude)	ES T2-T3 (magnitude)
Bench Press (kg)									
DUP-V	85.5 ± 18.07	93.2 ± 20.17	99.8 ± 24.24┼*	9.0	16.7	7.1	0.43 (small)	0.79 (moderate)	0.33 (trivial)
DUP-F	80.1 ± 26.41	88.2 ± 28.98	92.8 ± 29.90┼*	10.1	17.7	6.5	0.47 (small)	0.48 (small)	0.16 (trivial)
Lat Pull Down (kg)									
DUP-V	70.8 ± 14.16	76.2 ± 13.46	81.4 ± 14.34┼*	7.6	15	6.8	0.38 (small)	0.75 (moderate)	0.39 (small)
DUP-F	69.4 ± 15.51	76.7 ± 15.52	81.7 ± 16.35┼*	10.5	17.7	6.5	0.47 (small)	0.79 (moderate)	0.32 (small)
45° Leg Press (kg)									
DUP-V	203.9 ± 51.69	249.4 ± 69.06	278 ± 72.49┼*	22.3	36.4	11.5	0.88 (moderate)	1.44 (large)	0.41 (small)
DUP-F	215.5 ± 49.61	245 ± 49.97	271.1 ± 47.01┼*	14	26.1	10.7	0.60 (moderate)	1.13 (large)	0.52 (moderate)
Standing Arm Curl (kg)									
DUP-V	38.8 ± 9.58	39.9 ± 10.27	44.5 ± 9.47┼*	2.8	14.7	11.5	0.11 (trivial)	0.59 (moderate)	0.45 (small)
DUP-F	35.7 ± 6.56	38.7 ± 6.71	41.6 ± 6.08┼*	8.4	16.5	7.5	0.46 (small)	0.90 (moderate)	0.43 (small)

Note: Undulating Periodization with Fixed overload (DUP-F); Undulating Periodization with Variable overload (DUP-V); Baseline tests (T1); Tests after 8weeks training periodization (T2); Tests after 12weeks training periodization (T3). * Significant difference in comparison to T1 ($p < 0.05$). ┼ Significant difference in comparison to T2 ($p < 0.05$).

Table 4. Muscular endurance.

Groups	T1	T2	T3	Change T1-T2 (%)	Change T1-T3 (%)	Change T2-T3 (%)	ES T1-T2 (magnitude)	ES T1-T3 (magnitude)	ES T2-T3 (magnitude)
Bench Press (kg)									
DUP-V	515.7 ± 163.83	558.8 ± 166.98	507.5 ± 106.96	8.4	-1.6	-9.2	0.26 (small)	-0.05 (trivial)	-0.31 (small)
DUP-F	453.8 ± 219.60	492.7 ± 198.69	470.5 ± 169.43	8.6	3.7	-0.5	0.18 (trivial)	0.08 (trivial)	-0.11 (trivial)
Lat Pull Down (kg)									
DUP-V	448.9 ± 134.33	443.1 ± 124.18	438.9 ± 116.84	-1.3	-2.2	-1	-0.04 (trivial)	-0.07 (trivial)	-0.03 (trivial)
DUP-F	436.6 ± 169.79	428.9 ± 148.07	427.9 ± 149.58	-1.8	-2	-0.2	-0.05 (trivial)	-0.05 (trivial)	-0.01 (trivial)
45° Leg Press (kg)									
DUP-V	2176.7 ± 1101.7	2696.1 ± 1434.97*	2444.4 ± 1030.76	23.7	12.3	-9.3	0.47 (small)	0.24 (trivial)	-0.18 (trivial)
DUP-F	2063.1 ± 805.57	2411.6 ± 899.27*	2389.5 ± 843.38	16.9	15.8	-0.9	0.43 (small)	0.41 (small)	-0.02 (trivial)
Standing Arm Curl (kg)									
DUP-V	270.4 ± 77.74	301.0 ± 85.54	276.5 ± 72.45	11.4	2.3	-8.1	0.40 (small)	0.08 (trivial)	-0.29 (trivial)
DUP-F	228.5 ± 54.06	243.4 ± 51.68 #	250.0 ± 55.62	6.5	9.4	2.7	0.28 (small)	0.40 (small)	0.13 (trivial)

Note: * Significant difference in comparison to T1 ($p < 0.05$). # Significant difference between group at the same time point ($p < 0.05$).

Table 5. Anthropometric variables.

Groups	T1	T2	T3	Change T1-T2 (%)	Change T1-T3 (%)	Change T2-T3 (%)	ES T1-T2 (magnitude)	ES T1-T3 (magnitude)	ES T2-T3 (magnitude)
Body Mass (kg)									
DUP-V	76.4 ± 4.32	75.5 ± 4.93	76.7 ± 4.19	-1.2	0.39	1.62	0.21 (trivial)	0.07 (trivial)	0.25 (trivial)
DUP-F	77.7 ± 6.13	78 ± 5.61	77.9 ± 5.80	0.36	0.21	-0.15	0.05 (trivial)	0.03 (trivial)	0.02 (trivial)
Free Fat Mass (kg)									
DUP-V	65.1 ± 2.73	65.9 ± 2.87*	66.7 ± 2.94┼*	1.21	2.35	1.12	0.29 (trivial)	0.56 (small)	0.26 (trivial)
DUP-F	65.8 ± 3.87	66.2 ± 3.57	66.7 ± 3.74┼*	0.65	1.31	0.65	0.11 (trivial)	0.22 (trivial)	0.12 (trivial)
Body Fat mass (kg)									
DUP-V	11.2 ± 3.17	9.54 ± 2.87*	10.0 ± 2.88┼*	-15.2	-10.93	5.0	0.54 (small)	0.39 (small)	0.13 (trivial)
DUP-F	11.9 ± 3.55	11.8 ± 3.4	11.2 ± 3.38┼*	-1.8	-5.88	-4.76	0.04 (trivial)	0.20 (trivial)	0.16 (trivial)
Body Fat (%)									
DUP-V	14.1 ± 2.86	13.7 ± 2.84*	13.3 ± 2.70┼*	-2.83	-5.80	-3.05	0.14 (trivial)	0.29 (trivial)	0.15 (trivial)
DUP-F	15.3 ± 3.68	15.1 ± 3.63	14.3 ± 3.69┼*	-1.31	-6.21	-4.97	0.05 (trivial)	0.26 (trivial)	0.21 (trivial)

Note: Undulating Periodization with Fixed overload (DUP-F); Undulating Periodization with Variable overload (DUP-V); Baseline tests (T1) Tests after 8 weeks training periodization (T2); Tests after 12 weeks training periodization (T3). * Significant difference in comparison to T1 ($p < 0.05$). ┼ Significant difference in comparison to T2 ($p < 0.05$).

DISCUSSION

The main objective of present study was to propose and compare a novel periodization model, the muscle daily undulating periodization model, which has never been investigated before. The main characteristic of this proposal is that a muscle group could be trained at light, moderate or high intensities in the same week. When it comes to muscle strength, muscle endurance, and body composition, the present study provides evidence that both periodization models displayed similar results, with more evident improvements in strength.

The superiority of periodized RT to increase maximal strength regardless of training volume or training status over non-periodized RT has been demonstrated in two meta-analyzes (27)(35). In this sense, it seems pertinent to adopt periodization models when the purpose of a training program is to increase muscle strength in healthy trained adult men.

According to review published by Evans (9), both linear and undulatory models are effective for increasing muscle strength, with the exception that the undulatory model may provide a greater benefit. The possible reason for this superiority focuses in periodization structure, which incorporates more frequent variations in load (23; 29). However, caution is needed due to study designs employed and results not necessarily being attributed to the nature of periodized training (9).

Similarly, in a study conducted by Miranda et al. (20) in resistance-trained men, linear periodization (LP) and DUP responses were tested for 12-weeks. Both interventions showed significant increases in muscle strength, but DUP promoted superior effect size gains in maximal and submaximal muscle strength. On the other hand, other authors have not identified significant differences between these periodization systems (3, 6, 14, 26).

Considering the results achieved in our study, the application of mDUP and DUP-F were effective in increasing muscle strength, bearing in mind the effect sizes achieved. Because periodization is designed to be a long-term approach to training (22, 11, 34), there may be different effects between mDUP and DUP-F after an intervention period longer than 12-weeks. In turn, in this study an increased muscle endurance was observed in both groups. However, arm-curl exercise showed a better response after 8-weeks of training for those volunteers who performed mDUP. In contrast, this difference did not remain after 12-weeks.

To the best of our knowledge, only three studies evaluating muscle endurance while employing DUP were found (29; 30, 7). In the first study (29) no differences were observed between DUP and LP, but both provided improvements. In turn, according to Rhea et al. (30) and De Lima et al. (7), DUP has superiority over LP when muscular endurance is considered, however, in both, the training program was high volume in relation to the repetition target zone. In this context, besides specificity involved in a training program aimed at improving muscular endurance, a possible cause for this superiority is that DUP exerts greater stress on the neuromuscular system, providing greater adaptations and resulting in increased muscle endurance. In addition, Rhea et al. (29, 30) and Prestes et al. (24, 26) noted the main methodological problem of comparisons between periodization models, which involves both intensity and volume not being equated in most studies.

It is important to highlight that in our study the training volume and intensity were not equal between periodization models, due to structural organization that involves the training model proposed by mDUP, which uses target zones to reach the intensity. This condition allows a variation in total training volume, thus making the equalization between the periodizations unfeasible. Therefore, this situation facilitated that training volume in mDUP induced greater adaptations in muscle endurance compared to DUP-F after 8-weeks of training. It is noteworthy that effect sizes found in each exercise tested for muscle endurance presented high dispersion, requiring caution as to interpretation and extrapolation of results achieved.

Regarding the body composition of volunteers, the two proposed periodizations mediated improvements in free fat mass, fat mass and body fat. Moreover, no differences were observed between groups, but the first two variables had a moderate and large effect size, respectively. A systematic review has shown that periodized and non-periodized RT for muscle hypertrophy outcomes produce similar results, but the limited number of studies analyzed, of which only two included trained individuals, make it difficult to draw definitive conclusions (31). Moreover, only the study design conducted by Schoenfeld et al. (31), among those included in this review, used direct measures to assess muscle hypertrophy coupled with little benefit for periodized RT.

Among the aspects involved in these conflicting results, we highlight the use of doubly indirect measures, such as our study, in addition to short intervention periods. In turn, when comparing the effects of DUP and LP, the adaptations appear equally effective with regard to muscle hypertrophy, but this conclusion can only be generalized to untrained populations (9, 13).

In the meta-analysis conducted by Grgic et al. (13), the authors suggest that muscle mass gain is more related to training volume than to the use of LP or DUP models (16). However, it is still unclear whether these findings are generalizable to other forms of periodization, such as mDUP and DUP-F. In this condition, it is suggested that studies with longer intervention periods should be conducted, with the use of direct measures and the definition of body composition as a primary outcome variable to reach a sufficient sample number to confirm or reject the results achieved in our study.

Among strengths/weaknesses, the use of doubly indirect measures for body composition assessment, and the absence of nutritional control methods suggest diligence regarding the interpretation and extrapolation of our results to the remaining population of healthy, resistance-trained adult men. In contrast, this is the first study to propose a mDUP model and to verify its effects on body composition, strength and muscle endurance. Although these anthropometric measures and strength tests are simple, they are very practical and costless, which increase the practical applications for coaches and professionals in daily training.

In conclusion, the findings of this study suggest that both mDUP and DUP-F showed similar results and are interesting strategies for improving body composition, strength and muscle endurance. However, the comparison between mDUP and DUP-F showed a moderate to large effect size for strength and body composition. Thus, it seems pertinent to consider this new periodization model plausible for RT practitioners in order to achieve new adaptations. Furthermore, in bodybuilders that may show certain specific muscle deficits, the periodization of the muscle per day, rather than the training session might be an interesting approach, so that a specific muscle can receive more attention than others.

Future studies should also focus in comparing periodization models in other populations, such as elderly, and women that are understudied in this area. This would help to expand generalizability, especially due to the very specific population included in this study.

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