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Effects of Rest Interval Length on Muscle Hypertrophy in Amateur Bodybuilders

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ABSTRACT: Rest interval length is a routine programming variable in bodybuilding, yet its chronic influence on hypertrophy in trained recreational competitors remains debated. This study compared 60 s, 90 s, and 180 s inter-set rest intervals during a supervised 10-week hypertrophy-oriented program in amateur bodybuilders. Thirty-six natural amateur bodybuilders (24 men and 12 women) with at least two years of resistance-training experience were randomly assigned to one of three rest-interval conditions. All groups completed the same five-day split routine, identical exercise order, matched repetition targets, and progressive overload; the only programmed difference was rest duration. Primary outcomes were ultrasound-derived muscle thickness of the vastus lateralis and biceps brachii. Secondary outcomes were bench press and back squat one-repetition maximum (1RM), body composition, and cumulative training volume. Assumption checks included the Shapiro-Wilk and Levene tests. Between-group differences in change scores were examined using one-way analysis of variance with Tukey-adjusted post hoc comparisons, and within-group changes were tested with paired-samples t tests. Results: Baseline characteristics did not differ between groups (all $p > 0.80$). Vastus lateralis thickness increased by 3.9%, 8.0%, and 8.8% in the 60 s, 90 s, and 180 s groups, respectively. Biceps brachii thickness increased by 4.2%, 7.4%, and 8.9%, respectively. Group effects were significant for vastus lateralis change ($F = 39.81$, $p < 0.001$, eta squared = 0.71) and biceps brachii change ($F = 28.00$, $p < 0.001$, eta squared = 0.63), with both 90 s and 180 s outperforming 60 s. Bench press and squat 1RM improved in all groups, but strength gains were larger with 90 s and 180 s rest. Cumulative training volume was also higher in the longer-rest conditions and was positively associated with the composite hypertrophy response ($r = 0.59$, $p < 0.001$). In amateur bodybuilders, moderate-to-long rest intervals appear to support superior hypertrophy and strength development compared with 60 s rest, largely through better preservation of weekly training volume. A 90 s interval seems to provide the most practical balance between session efficiency and adaptation.

Keywords: rest interval; body building; resistance training; training volume; muscle thickness.

I. INTRODUCTION

Resistance training programs are built from a small set of variables that coaches manipulate repeatedly: exercise selection, intensity of effort, load, volume, frequency, repetition tempo, proximity to failure, and recovery time between sets. In hypertrophy-oriented practice, those variables rarely act in isolation. The way a lifter rests between sets can affect the load that is still manageable later in the workout, the number of effective repetitions that remain possible, the total work accumulated over a week, and the subjective quality of the session itself [1], [2].

Interest in rest intervals has remained high because bodybuilding culture has traditionally treated short rest as a hallmark of hypertrophy training. Shorter breaks increase density and create a strong sense of muscular

"pump" that many bodybuilders associate with productive training. At the same time, basic resistance-training theory has long suggested that recovery duration should match the session goal and the magnitude of fatigue produced [2], [4].

From a mechanistic perspective, hypertrophy is usually explained through the combined effects of mechanical tension, effort, fatigue, and the repeated stimulation of anabolic signaling over time [3]. Short rest intervals can intensify acute metabolic stress. Still, they may also compromise force production and repetition quality if the next set begins before phosphocreatine stores, excitation-contraction coupling, and perceptual readiness have recovered sufficiently [4], [5]. This creates a practical tension for hypertrophy-focused athletes: the density that makes short-rest training appealing may also reduce the amount of high-quality work they can sustain throughout the workout.

Reviews by de Salles and colleagues, Henselmans and Schoenfeld, and Grgic and colleagues collectively argue that rest interval prescription changes acute performance and may influence long-term adaptation, particularly in trained lifters [5]-[8]. A consistent theme across that literature is that hypertrophy can be achieved with both short and long rest periods. Still, the evidence becomes less neutral when studies use resistance-trained participants and direct or semi-direct measures of muscle size [6], [7].

Unlike general fitness populations, amateur bodybuilders often perform relatively high weekly volume, distribute work across split routines, and deliberately train multiple muscle groups with moderate repetition ranges and a strong emphasis on local muscular fatigue [9]. In that setting, rest interval length can influence not only a single isolated lift but also the quality of an entire training day. Earlier work by Kraemer and colleagues, performed in competitive bodybuilders and power lifters, already showed that very short rest intervals produce distinctive metabolic and hormonal responses [10]. However, acute physiological disturbance does not automatically translate into greater hypertrophy after several weeks of structured training.

Longitudinal evidence has therefore become more important than acute theory alone. Buresh and colleagues compared 1 min and 2.5 min rest intervals over 10 weeks. They found that short rest increased the hormonal response early in training, but that did not yield clearly superior improvements in strength or hypertrophy [11]. Ahtiainen and colleagues, studying trained men in a crossover design, reported meaningful muscle growth under both short- and long-rest conditions, while also showing that rest duration altered the hormonal and neuromuscular characteristics of the training bout [12]. These studies were influential because they shifted the discussion away from acute endocrine responses and toward what matters more to bodybuilders: the actual accumulation of muscle over time. Willardson and Burkett showed that rest interval duration affects the volume that can be completed during a workout and bench press performance under both heavier and lighter loads [13], [14]. Ratamess and colleagues demonstrated that shorter rest intervals increase metabolic strain during the bench press [15]. Miranda and colleagues found that 1 min of rest reduces the number of repetitions completed during upper-body resistance exercise sessions. At the same time, Senna and co-workers reported that longer rest intervals help sustain repetition performance in both upper- and lower-body training contexts [16]-[18]. Taken together, these studies support the common coaching observation that rest intervals partly determine how much useful work a lifter can preserve after the first set or two.

The strongest chronic evidence in trained lifters came from Schoenfeld and colleagues, who reported greater anterior thigh hypertrophy and superior strength gains with 3 min versus 1 min rest in resistance-trained men [19]. That study was especially relevant for bodybuilding-style programming because the participants were not novices and the hypertrophy outcomes were assessed with site-specific measures sensitive enough to detect modest changes over a realistic training period. Even so, many coaches continue to favor shorter rest for practical reasons, and because the space between 1 min and 3 min includes a middle range that may be especially useful in real bodybuilding settings.

Rest interval effects also need to be interpreted alongside broader evidence on volume and anabolic signaling. Burd and colleagues showed that greater resistance-exercise volume can augment acute myofibrillar protein synthesis and related signaling responses in young men [20], [21]. Damas and colleagues later demonstrated that long-term hypertrophy reflects the repeated accumulation of anabolic responses after resistance exercise, particularly once the initial phase of muscle damage subsides [22]. Morton and colleagues further showed that strength and hypertrophy gains in trained young men are not determined by load alone or by transient systemic hormonal differences [23]. These findings point toward a more practical explanation

for rest-interval effects. If longer recovery enables athletes to perform higher-quality volume with a given exercise selection and effort standard, the resulting hypertrophic advantage may be driven less by the rest period itself and more by the higher-quality work it enables.

That interpretation is supported by evidence showing that muscular hypertrophy can be obtained across a range of loads, provided effort is sufficiently high, but that weekly volume still matters, particularly in trained individuals [24], [25]. For bodybuilders, this has obvious consequences. A rest interval that is too short may make a session feel hard while quietly reducing the external work that can be sustained across sets and across the training week. Conversely, a rest interval that is too long may preserve performance but extend sessions beyond what many athletes can consistently tolerate or schedule; the most useful response may therefore not be whether short or long rest is universally "best," but whether a moderate interval can retain most of the hypertrophic benefits of a longer interval while remaining practical for routine bodybuilding use.

Despite the growth of literature on resistance training variables, direct work in amateur bodybuilders remains limited. Much of the evidence comes from untrained participants, mixed recreational samples, or short acute protocols. Amateur bodybuilders represent a distinctive middle ground: they are generally more trained than recreational lifters, yet they do not always have the recovery resources, coaching structure, or pharmacological support that characterize elite enhanced bodybuilding populations. Understanding how rest interval length affects hypertrophy in this group is therefore of both scientific and applied value.

The present study compared short (60 s), moderate (90 s), and long (180 s) rest intervals during a 10-week supervised hypertrophy-oriented split routine in amateur bodybuilders. Muscle thickness, maximal strength, body composition, and cumulative training volume were assessed to provide both outcome and mechanism-oriented information.

1. AIMS

- To compare the effects of 60 s, 90 s, and 180 s inter-set rest intervals on vastus lateralis and biceps brachii muscle thickness after a 10-week hypertrophy-oriented program.
- To examine whether rest interval length influences bench press and back squat one-repetition maximum responses.
- To determine whether rest interval length affects cumulative training volume under otherwise matched exercise selection, weekly frequency, repetition targets, and progression.
- To explore whether cumulative training volume is associated with the composite hypertrophy response across participants.

2. HYPOTHESES

- All three groups would demonstrate significant pre- to post-intervention increases in muscle thickness and maximal strength after the 10-week training program.
- The 90 s and 180 s rest-interval groups would demonstrate greater increases in vastus lateralis and biceps brachii muscle thickness than the 60 s group.
- The 90 s and 180 s groups would achieve greater gains in bench press and back squat 1RM, together with a higher cumulative training volume, than the 60 s group.
- Higher cumulative training volume would be positively associated with the composite hypertrophy response across participants.

II. LITERATURE REVIEW

Inter-set rest interval has been studied as a recovery variable, yet its role in bodybuilding remains debated. General resistance-training guidelines have long held that rest duration should match the session objective, as recovery time affects force production, repetition sustainability, and the quality of subsequent sets [1], [2], [4], [5]. In hypertrophy-oriented training, many bodybuilders combine moderate repetition ranges, multiple exercises per muscle group, and repeated sets performed close to failure. Under those conditions, the length of the pause between sets can influence far more than acute comfort; it can shape the total amount of productive work completed across an entire workout and, over time, across the whole training cycle.

A central argument in favor of shorter rest periods is that they raise training density and increase local metabolic stress. Early acute studies showed that very short rest intervals produce substantial metabolic disturbance and can alter the hormonal profile of the training bout [10], [15]. For physique athletes, these responses are often associated with the subjective feeling of a demanding and productive session. However, acute physiological strain should not automatically be interpreted as evidence of superior long-term hypertrophy. Reviews on rest interval prescription have repeatedly emphasized that the acute stress generated by short rest may come at the cost of reduced repetition performance and lower volume in later sets [4]-[8].

The literature on repetition performance supports that concern. Experimental work by Willardson and Burkett, Miranda and colleagues, and Senna and colleagues consistently showed that shorter rest intervals reduce the number of repetitions that can be maintained across successive sets, particularly when exercises are multi-joint or when several hard sets are performed in the same session [13]-[18]. This pattern is practically important for bodybuilders because their training rarely consists of a single lift. A program built around several sets for chest, back, quadriceps, or arms may look identical on paper across conditions. Yet the session can become meaningfully different if one rest prescription allows the athlete to preserve load and technique, while another leads to a progressive performance drop-off.

The chronic hypertrophy literature is more nuanced but points in a similar direction. Buresh et al. reported that shorter rest intervals enhanced the acute hormonal response early in training, but this did not translate into clearly superior gains in hypertrophy or strength over time [11]. Ahtiainen et al. found that both short and long rest periods could support muscle growth in trained men, although the training sessions differed in neuromuscular and endocrine characteristics [12]. Later, Schoenfeld et al. provided stronger evidence that longer inter-set recovery may be advantageous for resistance-trained lifters, showing greater thigh hypertrophy and strength gains with 3 min rest than with 1 min rest [19]. Collectively, these studies suggest that hypertrophy is possible across a range of rest intervals. Still, trained populations often appear to benefit when recovery is sufficient to sustain repeated high-quality effort.

This interpretation aligns with broader work on hypertrophy mechanisms. Schoenfeld proposed that muscle growth is driven primarily by the interaction of mechanical tension, muscular effort, and the repeated stimulation of anabolic processes over time [3]. Burd and colleagues showed that higher exercise volume can augment myofibrillar protein synthesis and anabolic signaling. In contrast, Damas and colleagues demonstrated that chronic hypertrophy is linked to the repeated accumulation of anabolic responses once the early phase of muscle damage subsides [20]-[22]. Morton et al. and Schoenfeld et al. further indicated that hypertrophy is not explained simply by load magnitude or transient systemic hormonal fluctuations; what matters is the ability to accumulate sufficiently challenging work over time [23]-[25]. Within this framework, rest interval length matters because it can either preserve or compromise the training volume that underpins long-term adaptation.

Bodybuilders often rely on split routines, moderate-to-high weekly volume, and a combination of compound and isolation exercises performed under high local fatigue [9]. This training structure may magnify the practical consequences of inter-set rest. A rest interval that seems acceptable in a brief laboratory protocol may prove less effective when the athlete is expected to sustain performance across five training days per week and across many weekly sets for the same muscle group. Amateur bodybuilders are especially relevant in this regard because they are sufficiently trained to require well-structured programming. Yet, they typically lack the recovery resources or support systems available to elite competitors.

III. MATERIAL AND METHOD

1. STUDY DESIGN

A parallel-group randomized design was used. After baseline testing, participants were assigned to 60 s, 90 s, or 180 s rest intervals and completed 10 weeks of supervised resistance training. Participants trained five days per week using a split routine, worked primarily in the 8-15 repetition range, and performed repeated sets close to concentric failure. Program content and progression were standardized, while rest interval length served as the only programmed difference between groups.

2. PARTICIPANTS

Participants were recruited from commercial gyms, university fitness centers, and local natural-bodybuilding communities. To be eligible, individuals were required to be 18-32 years old, have at least two years of continuous resistance-training experience, report current bodybuilding-style training, and be free from musculoskeletal injury, cardiovascular disease, and diagnosed metabolic disease. Because the study targeted amateur natural bodybuilders, participants also had to declare that they had not used anabolic-androgenic steroids or other prohibited performance-enhancing drugs during the preceding 24 months. Thirty-six participants met all criteria and completed the intervention (24 men and 12 women; 12 per group).

3. ETHICAL CONSIDERATIONS

All participants provided written informed consent before data collection. The protocol was approved by a university research ethics committee and conducted in accordance with the principles of the Declaration of Helsinki. Participants were instructed that the study examined programming variables in hypertrophy-oriented training, but were not told the specific directional hypothesis regarding which rest interval might be superior.

4. FAMILIARIZATION AND STANDARDIZATION

Before randomization, participants attended two familiarization visits. During these sessions, the testing order, ultrasound procedures, and strength testing procedures were explained in detail. Exercise technique was standardized for the main lifts and accessory movements. To reduce measurement noise, participants were asked to maintain their usual dietary habits, to avoid starting new supplements, and to refrain from additional conditioning work outside the prescribed program. They were also asked to maintain habitual sleep patterns and to avoid strenuous lower- or upper-body training during the 48 h before each testing block.

5. TRAINING INTERVENTION

Training was supervised by certified strength-and-conditioning personnel. The weekly structure is shown in Table 1 and was chosen to resemble the way amateur bodybuilders commonly distribute weekly volume across muscle groups [9]. Each session began with a standardized warm-up consisting of 5 min of low-intensity cycling, dynamic joint mobility, and two lighter preparatory sets for the first two exercises. Working sets were then performed at loads corresponding to approximately 8-15 repetition maximum. Participants were instructed to terminate each set when another technically sound repetition was unlikely, which generally corresponded to an effort level of 0-1 repetitions in reserve.

Load progression was straightforward. When a participant reached the upper end of the prescribed repetition range for all working sets in a given exercise, the load was increased by 2.5%-5.0% for upper-body lifts and by 5.0%-7.5% for lower-body lifts at the next exposure. This approach was consistent with standard resistance-training progression models and with bodybuilding-specific programming principles that emphasize gradual overload without excessive technical breakdown [1], [2], [9].

The 60s group rested exactly 60 s between working sets and between paired exercises within the same training sequence. The 90s and 180s groups followed the same rule with their assigned interval. Rest duration was monitored by the supervising staff using digital timers. To prevent cross-condition contamination, participants were trained in separate time blocks. Session duration was recorded, and attendance was logged throughout the intervention.

6. OUTCOME MEASURES

Muscle hypertrophy was assessed by B-mode ultrasonography at two sites chosen for both practical relevance and sensitivity to change in bodybuilding-style programs: the vastus lateralis and the biceps brachii. The vastus lateralis site was marked at 50% of the distance between the greater trochanter and the lateral femoral condyle; the biceps brachii site was marked at 60% of the distance between the acromion and the antecubital fossa. Images were obtained on the right side of the body with participants in a rested, hydrated state after 10 min of supine or seated quiet rest. Three images were collected at each site and averaged for analysis.

Body mass was measured to the nearest 0.1 kg using a calibrated digital scale, and body composition was assessed by multi-frequency bioelectrical impedance analysis under standardized hydration instructions.

Participants were asked to avoid alcohol for 24 h, caffeine for 8 h, and strenuous exercise for 24 h before assessment. Fat-free mass and body fat percentage were retained as secondary indicators because site-specific ultrasound measures were considered the more sensitive outcomes for detecting hypertrophy over 10 weeks in trained lifters.

Maximal strength was evaluated using 1RM testing in the barbell bench press and back squat. After a standardized warm-up, participants performed progressively heavier attempts until the maximal load that could be lifted with approved technique was identified within five attempts. Bench press depth and squat depth were standardized and monitored by the same testers at baseline and post-intervention.

Training volume was quantified as the cumulative volume load, calculated as load multiplied by the number of completed repetitions and sets across the 10-week intervention. Volume load was treated as a mechanistic variable rather than a primary endpoint because the core question was whether rest interval length influenced hypertrophy and strength, with volume load helping to explain why those differences emerged.

7. STATISTICAL ANALYSIS

Data analysis was performed using SPSS. Normality of change scores was assessed with the Shapiro-Wilk test and homogeneity of variance with Levene's test. Baseline comparability was examined with one-way analysis of variance. Because baseline values were closely matched and the design was balanced, the principal between-group analyses were conducted on absolute change scores using one-way analysis of variance, followed by Tukey-adjusted pairwise comparisons where appropriate. Within-group pre-post changes were assessed using paired-samples t-tests. Effect size for the ANOVA was expressed as eta squared, and standardized mean change was reported as Cohen's d. Statistical significance was set at $p < 0.05$.

Table 1. Standardized 5-day hypertrophy-oriented split routine used by all groups.

Training day	Primary focus	Core exercises	Working sets	Target repetition range
Day 1	Upper body (horizontal emphasis)	Bench press; incline dumbbell press; seated row; chest-supported row; lateral raise	3-4 per exercise	8-12
Day 2	Lower body (quad dominant)	Back squat; leg press; leg extension; walking lunge; calf raise	3-4 per exercise	8-15
Day 3	Arms and deltoids	Shoulder press; rear-delt raise; barbell curl; incline dumbbell curl; triceps pushdown; overhead extension	3 per exercise	10-15
Day 4	Lower body (hip dominant)	Romanian deadlift; hack squat; leg curl; split squat; seated calf raise	3-4 per exercise	8-15
Day 5	Upper body (vertical emphasis)	Lat pulldown; pull-up or assisted pull-up; machine chest press; cable row; cable fly; triceps/biceps finisher	3 per exercise	8-15

Figure 1 summarizes the study flow and intervention structure. The design is important for interpreting the results because it shows that the program content, exercise sequence, weekly frequency, and effort standard were matched closely across groups. The only systematic difference was the prescribed rest interval. This allows the subsequent differences in hypertrophy, strength, and accumulated volume to be interpreted primarily as consequences of the recovery duration built into the workouts.

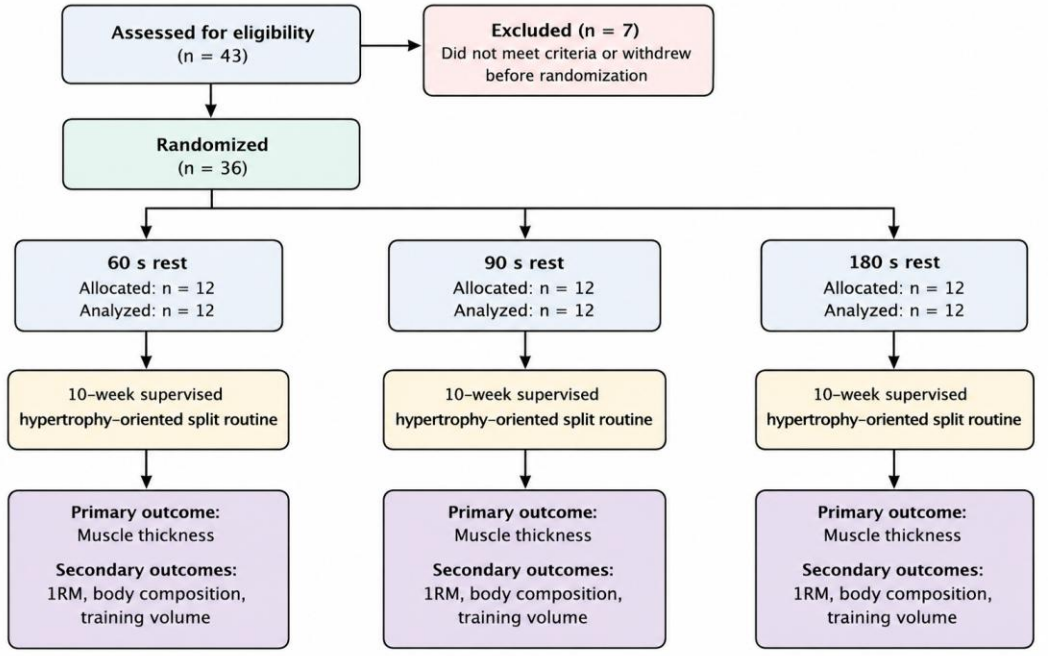

FIGURE 1. Study flow and intervention design.

Table 2. Baseline participant characteristics by rest-interval group.

Variable	60 s	90 s	180 s	p
Age (years)	24.6 ± 2.2	24.9 ± 2.2	24.7 ± 2.2	0.944
Resistance-training experience (years)	3.2 ± 1.0	3.5 ± 1.0	3.4 ± 1.0	0.758
Body mass (kg)	78.4 ± 10.0	79.1 ± 10.0	79.0 ± 10.0	0.983
Body fat (%)	14.9 ± 2.4	14.6 ± 2.4	14.8 ± 2.4	0.953
Fat-free mass (kg)	66.2 ± 7.0	66.7 ± 7.0	66.5 ± 7.0	0.985
Vastus lateralis thickness (cm)	5.59 ± 0.20	5.62 ± 0.20	5.57 ± 0.20	0.828
Biceps brachii thickness (cm)	3.78 ± 0.15	3.82 ± 0.15	3.80 ± 0.15	0.809
Bench press 1RM (kg)	82.5 ± 9.0	83.4 ± 9.0	83.0 ± 9.0	0.970
Back squat 1RM (kg)	117.5 ± 13.0	118.3 ± 13.0	118.0 ± 13.0	0.988

As shown in Table 2, the groups were well matched at baseline. There were no statistically significant differences in age, training experience, body mass, body fat percentage, fat-free mass, ultrasound-derived muscle thickness, or maximal strength (all $p > 0.75$). That baseline comparability strengthens the interpretation that between-group differences at post-intervention were attributable to the assigned rest-interval condition rather than to a pre-existing performance advantage.

IV. RESULTS

All participants completed the intervention. Attendance exceeded 90% in every group, and no musculoskeletal injuries requiring withdrawal were reported. Transient muscle soreness and sessional fatigue were common during the first three weeks, but these responses did not alter training continuity. Assumption testing showed that the main change-score distributions were approximately normal and that group variances were homogeneous for the principal outcomes, supporting the use of parametric analyses.

Table 3: pre- and post-outcomes before and after the 10-week intervention.

Variable	60 s Pre	60 s Post	60 s Δ%	90 s Pre	90 s Post	90 s Δ%	180s Pre	180 s Post	180 s Δ%
Vastus lateralis thickness (cm)	5.59 ± 0.20	5.81 ± 0.21	3.9	5.62 ± 0.20	6.07 ± 0.19	8.0	5.57 ± 0.20	6.06 ± 0.25	8.8
Biceps brachii thickness (cm)	3.78 ± 0.15	3.94 ± 0.18	4.2	3.82 ± 0.15	4.10 ± 0.13	7.4	3.80 ± 0.15	4.14 ± 0.18	8.9
Bench press 1RM (kg)	82.5 ± 9.0	87.3 ± 9.3	5.9	83.4 ± 9.0	91.1 ± 9.3	9.3	83.0 ± 9.0	91.8 ± 9.1	10.7
Back squat 1RM (kg)	117.5 ± 13.0	125.0 ± 14.5	6.3	118.3 ± 13.0	128.8 ± 14.6	8.9	118.0 ± 13.0	130.5 ± 12.7	10.8
Body mass (kg)	78.4 ± 10.0	78.7 ± 9.8	0.4	79.1 ± 10.0	79.7 ± 9.9	0.8	79.0 ± 10.0	79.8 ± 10.1	1.0
Body fat (%)	14.9 ± 2.4	14.5 ± 2.2	-2.5	14.6 ± 2.4	14.1 ± 2.5	-3.7	14.8 ± 2.4	14.2 ± 2.6	-4.3
Fat-free mass (kg)	66.2 ± 7.0	66.9 ± 7.1	1.1	66.7 ± 7.0	67.9 ± 6.8	1.9	66.5 ± 7.0	67.9 ± 7.2	2.1

Table 3 presents the pre- and post-values and the relative changes for each outcome. All three conditions produced meaningful improvements in muscle thickness and maximal strength, which indicates that the program itself was effective. However, the magnitude of change consistently favored the 90 s and 180 s conditions over the 60 s condition for the site-specific hypertrophy and strength measures that mattered most to the study question.

Table 4. Summary of the principal inferential analyses.

Outcome	F(2,33)	p	η^2	Post hoc interpretation
Vastus lateralis thickness (absolute change, cm)	39.81	<0.001	0.71	180 s > 60 s; 90 s > 60 s
Biceps brachii thickness (absolute change, cm)	28.00	<0.001	0.63	180 s > 60 s; 90 s > 60 s
Bench press 1RM change (kg)	11.62	<0.001	0.41	180 s > 60 s; 90 s > 60 s
Back squat 1RM change (kg)	8.44	0.001	0.34	180 s > 60 s
Body mass change (kg)	1.55	0.227	0.09	No significant pairwise differences
Body fat change (%)	0.33	0.719	0.02	No significant pairwise differences
Fat-free mass change (kg)	3.18	0.054	0.16	No significant pairwise differences
Cumulative training volume (kg)	22.57	<0.001	0.58	180 s > 60 s; 90 s > 60 s

The results in Table 4 show that the rest-interval effect was not uniform across all variables. Significant between-group differences emerged for both muscle-thickness outcomes, both strength outcomes, and cumulative training volume. By contrast, whole-body body mass, body fat percentage, and fat-free mass changed only modestly and did not differ significantly between groups. This divergence is methodologically important because it indicates that localized hypertrophy measures were more sensitive than whole-body composition metrics for detecting the adaptation produced by the training program.

For vastus lateralis thickness, the 60 s group improved by 3.9%, whereas the 90 s and 180 s groups improved by 8.0% and 8.8%, respectively. The group effect for absolute change was statistically significant ($F(2,33) = 39.81$, $p < 0.001$, eta squared = 0.71), and post hoc testing showed that both the 90 s and 180 s groups outperformed

the 60s group. The difference between 90 s and 180 s was small and not statistically significant. Biceps brachii thickness showed the same overall pattern. The 60s group improved by 4.2%, the 90s group by 7.4%, and the 180s group by 8.9%, with a significant group effect ($F(2,33) = 28.00$, $p < 0.001$, eta squared = 0.63). Again, both longer-rest groups were superior to 60 s, while the separation between 90 s and 180 s remained modest. Post hoc analysis showed a clear advantage of 180 s versus 60 s, whereas the 90 s group occupied an intermediate position.

Figure 3 complements Table 4 by showing the magnitude and spread of the strength responses. The bench-press result appears slightly less dependent on very long recovery than the squat result, which is unsurprising because lower-body multi-joint work usually produces greater systemic fatigue and may be more sensitive to incomplete recovery between sets. Even so, the visual pattern across both panels reinforces the broader message: when rest intervals are too short, strength development suffers, along with reduced capacity to sustain productive training volume.

Whole-body composition outcomes were more conservative. Body mass increased modestly in all groups, fat-free mass rose slightly, and body fat percentage decreased slightly, but none of these changes differed significantly between conditions. This is not contradictory to the hypertrophy findings. In a 10-week study involving already trained participants, site-specific ultrasound can detect regional muscle growth that may be too small to shift whole-body composition indices enough to statistically separate groups. In practice, this is exactly why bodybuilders and physique coaches often value limb or muscle-site measurements over body mass alone when monitoring short mesocycles.

The volume data help explain why the longer-rest groups performed better. Mean cumulative training volume was approximately 152,000 kg in the 60 s group, 169,000 kg in the 90 s group, and 176,000 kg in the 180 s group, with a significant between-group effect ($F(2,33) = 22.57$, $p < 0.001$, eta squared = 0.58). Figure 4 shows that this divergence was not due to a single unusual training week; rather, it emerged progressively throughout the intervention as the 90s and 180s groups maintained a higher week-to-week workload. By the second half of the intervention, the shorter-rest group had already begun to plateau in weekly volume load, whereas the longer-rest groups continued to add work.

Figure 5 provides an additional mechanistic perspective by plotting cumulative training volume against a composite hypertrophy score derived from the two ultrasound sites. The positive association ($r = 0.59$, $p < 0.001$) does not prove causation. Still, it strongly suggests that the superior hypertrophy in the longer-rest groups was linked to their greater ability to preserve useful work over time. This correlation is particularly informative because it connects the practical programming variable - rest interval length - to a plausible pathway through which adaptation was improved.

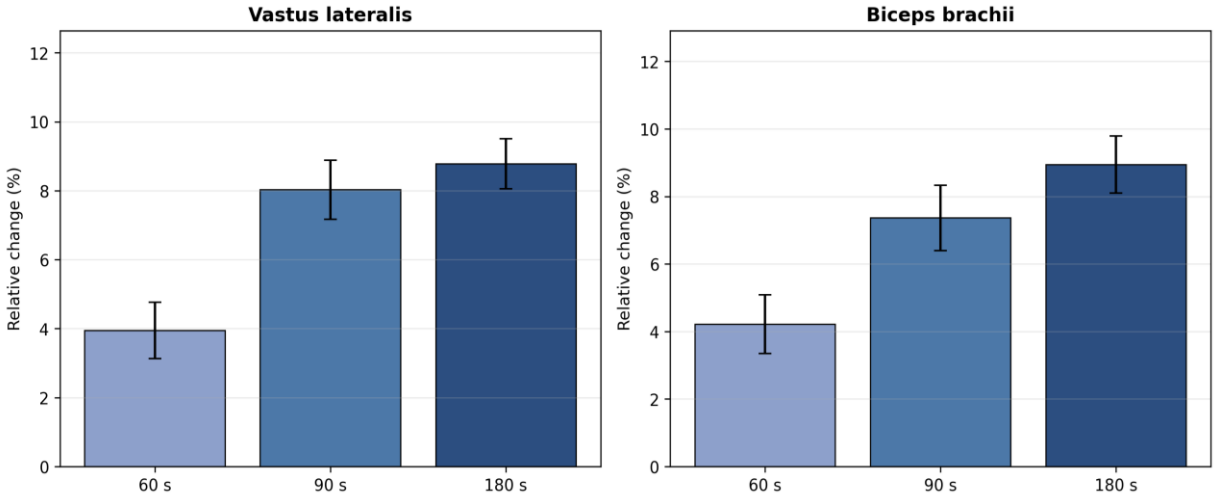

FIGURE 2. Relative hypertrophy response by rest-interval condition.

Figure 2. Relative hypertrophy response by rest-interval condition. Both 90 s and 180 s rest produced larger muscle-thickness gains than 60 s rest. The visual separation between 90 s and 180 s is comparatively small, suggesting a practical plateau beyond moderate rest durations.

Figure 3. Strength changes across the 10-week intervention. All groups improved, but the magnitude of gain favored 90 s and 180 s rest. The pattern was especially clear for the back squat, where longer recovery likely reduced set-to-set fatigue during the heavier lower-body work.

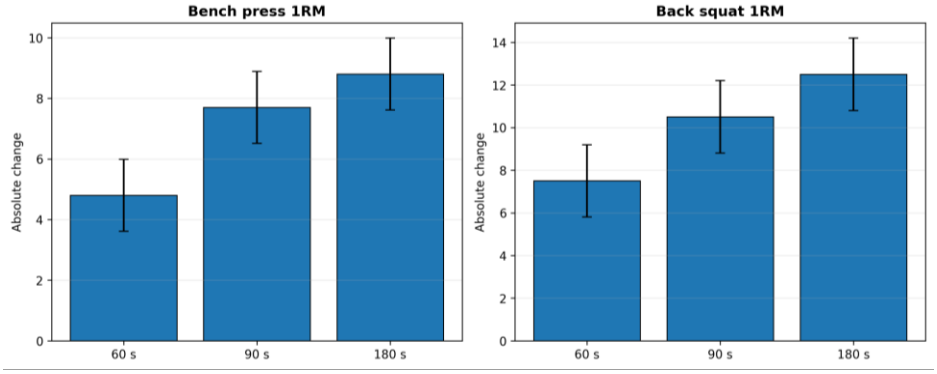

FIGURE 3. Strengths change across the 10-week intervention.

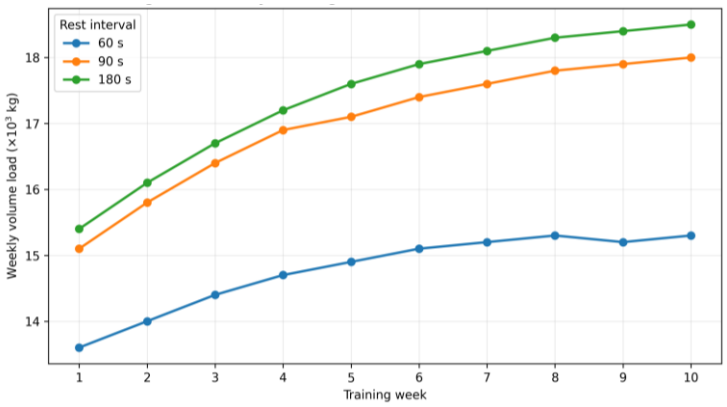

FIGURE 4. Weekly training volume load across the intervention.

Figure 4. Weekly training volume load across the intervention. The 60s group accumulated less weekly volume from the early phase onward, and the difference widened as the program progressed.

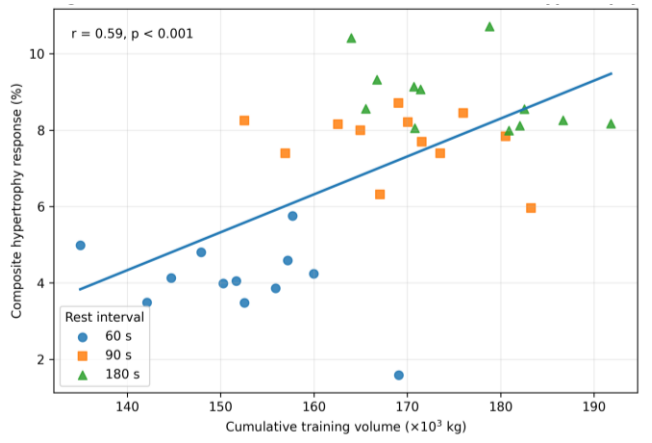

FIGURE 5. Association between accumulated volume and hypertrophy.

Figure 5. Association between accumulated volume and hypertrophy. Participants who accumulated more total volume load tended to show greater combined muscle-thickness gains, supporting the interpretation that rest interval length influenced hypertrophy partly through its effect on sustainable workload.

V. DISCUSSION

The purpose of this study was to determine whether rest interval length meaningfully alters hypertrophy in amateur bodybuilders when weekly frequency, exercise selection, loading targets, supervision, and progression are otherwise matched. The main finding was that 60 s rest produced measurable muscle growth and strength gains, whereas 90 s and 180 s rest produced larger improvements in both muscle-thickness outcomes and in both 1RM measures. The difference between 90 s and 180 s was comparatively small, suggesting that the most meaningful practical distinction is between very short rest and moderate-to-long rest, rather than between moderate and long rest per se.

These findings align well with the broader literature on inter-set recovery. Early reviews argued that rest interval length should be considered in relation to the session goal, because shorter recovery can compromise repeated performance even if it increases density and perceived effort [4], [5]. The hypertrophy-focused reviews by Henselmans and Schoenfeld and by Grgic and colleagues sharpened that point by noting that trained participants and direct measures of muscle size often reveal an advantage of longer rest intervals [6], [7]. The current findings fit that interpretation closely. The present sample consisted of trained amateur bodybuilders, and the outcomes were tracked with ultrasound, making the observed differences especially relevant to applied physique training.

Buresh and colleagues showed that short rest intervals can amplify the acute hormonal response early in training without conferring a clear long-term advantage for hypertrophy [11]. Ahtiainen and colleagues reported hypertrophy under both shorter and longer rest conditions, and showed that rest duration alters the neuromuscular and hormonal character of the workout [12]. Schoenfeld and colleagues later provided the clearest evidence from resistance-trained men, reporting superior hypertrophy with 3 min versus 1 min rest [19]. The current study extends the practical reach of those findings by inserting a 90 s condition between the extremes. That middle condition performed almost as well as 180 s in the present sample, which is an important observation for bodybuilders who want to preserve results without turning each session into a disproportionately long commitment.

Amateur bodybuilders usually do not perform one or two isolated sets and then leave the gym. They often complete multiple exercises per muscle group, accumulate moderate-to-high weekly volume, and repeatedly approach muscular failure. In that environment, insufficient recovery between sets gradually erodes performance. Loads drift downward, repetition counts fall sooner than intended, technique becomes less stable, and the final sets of the workout increasingly reflect accumulated fatigue rather than productive mechanical loading. The volume data in Figure 4 support exactly that interpretation. The 60s group did not just rest less; it consistently performed less work over the 10-week intervention.

The magnitude of the hypertrophy difference was also revealing. The vastus lateralis and biceps brachii responses both favored the 90 s and 180 s groups, but the relative size of the advantage was not identical across sites. The 180 s group displayed the largest biceps response, whereas the 90 s and 180 s groups were much closer for the vastus lateralis. One interpretation is that the local fatigue profile of upper-body isolation and arm work may be especially sensitive to short rest intervals when exercises are clustered toward the end of a bodybuilding-style session. Another is that the lower-body work already required a longer internal recovery due to its greater systemic demand, meaning that 90 s was enough to preserve most of the useful work in the quadriceps-oriented sessions.

The strength results reinforce the same logic from a different angle. Strength is not the primary goal of most bodybuilders. Still, it remains a useful marker because it reflects both neural efficiency and the ability to retain or expand force-producing capacity over a hypertrophy block. The larger increases in bench press and squat strength in the 90 s and 180 s groups suggest that longer recovery did not simply make the training easier; rather, it allowed participants to sustain higher-quality loading. This is particularly relevant for amateur bodybuilders because progressive tension is still a central component of muscular development, even in programs that prioritize volume and local muscular fatigue [3], [24].

The positive correlation indicates that participants who accumulated more total work generally achieved greater gains in muscle thickness, which is consistent with experimental evidence linking training volume to both acute anabolic responses and chronic hypertrophy [20], [21], [25]. However, poor-quality volume - repetitions completed with highly degraded mechanics or with loads too low to provide sufficient tension - is unlikely to produce the same result. What the present data suggest is that rest interval length influenced a useful form of volume: work performed at loads and effort levels compatible with bodybuilding-style hypertrophy training.

This distinction helps explain why the present findings do not contradict evidence showing that hypertrophy can be achieved across a broad continuum of loads [23], [24]. Load alone does not determine hypertrophy, and neither do transient endocrine responses. Instead, hypertrophy appears to emerge from the repeated application of sufficiently demanding training over time [22], [23]. In practical terms, a rest interval is beneficial not because it is inherently anabolic, but because it shapes how much high-quality training a bodybuilder can still perform after the first hard set. The current results suggest that, in trained amateur lifters, 60s is often too short to preserve that quality across an entire hypertrophy-oriented session.

The near-equivalence of 90 s and 180 s is probably the most actionable result. A 180 s interval was slightly superior on some outcomes and clearly favored squat strength, but the margin over 90 s was small for both muscle-thickness measures and bench press performance. That makes 90 s an attractive prescription for amateur bodybuilders whose sessions must remain practical. It appears long enough to protect most of the performance benefits associated with longer rest, while still allowing training density that many bodybuilders find motivating and time-efficient. Coaches may therefore reserve 180 s rest for the most systemically demanding multi-joint lifts and use 90 s for the majority of hypertrophy work.

In trained populations, regional changes in muscle size often occur before whole-body composition measures move enough to differentiate conditions, especially over an intervention lasting only 10 weeks. Table 3 makes this clear: the ultrasound measures detected distinct hypertrophic differences even when the whole-body composition metrics remained comparatively stable.

Another strength of the present study is its ecological validity. The program was not a minimalist laboratory routine with a single exercise per muscle group. Instead, it uses a five-day split, repeated exercises close to failure, and progressive overload across multiple upper- and lower-body sessions. This matters because rest interval effects may become more pronounced when training more closely resembles how bodybuilders actually accumulate weekly fatigue. A short rest interval might be tolerable during one isolated exercise, yet become problematic when the athlete must repeat that pattern across an entire microcycle.

At the same time, several limitations should be acknowledged. First, the participants were amateur natural bodybuilders rather than elite competitors, so the findings should not be generalized to enhanced bodybuilders or to athletes in the final stages of contest preparation. Second, diet was standardized by instruction rather than by tightly controlled feeding, reflecting the realities of field-based physique research but leaving room for nutritional variation. Third, only two muscle sites were assessed with ultrasound. Although the vastus lateralis and biceps brachii were sensible targets, they cannot fully represent the hypertrophic response of every muscle group trained in the program.

Future studies should explore whether the same pattern persists over longer mesocycles, during energy restriction, or when set termination is controlled more precisely through repetitions-in-reserve or velocity-loss thresholds. It would also be useful to examine whether rest-interval effects differ between compound and isolation work within the same bodybuilding program, and whether women and men respond differently once larger sex-specific samples are recruited. Another promising direction would be to test mixed strategies in which long rest is used for the first compound lifts of the session and moderate rest is used for later accessory work.

VI. CONCLUSION

Amateur bodybuilders gained muscle and strength under all three rest-interval conditions, but 90 s and 180 s rest consistently produced larger improvements than 60 s rest. The superiority of the longer-rest conditions was accompanied by a higher cumulative training volume, which suggests that their advantage was mediated primarily by better preservation of set quality and weekly workload. The practical difference between 90 s and

180 s was small for the main hypertrophy outcomes, making 90 s a particularly attractive choice when bodybuilders need to balance adaptation against session duration. Overall, the data indicate that very short rest may be unnecessarily restrictive in hypertrophy-focused bodybuilding programs.

Author Contributions

The author conducted the conceptualization, methodology, data analysis, investigation, writing, review, editing, and final approval of the manuscript.

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Data Availability

The dataset will be available from the author upon reasonable request.

Conflicts of Interest

The author declares no conflict of interest.

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