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Effectiveness of Daily Undulating Periodization Towards Muscle Hypertrophy of Selected Male Gym-Goers

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A B S T R A C T

This study investigated the effectiveness of Daily Undulating Periodization (DUP) in promoting muscle hypertrophy of selected male gym-goers. Specifically, it aimed to assess changes in muscle size through estimated anthropometric measurements of the Arm Muscle Area (AMA), Thigh Muscle Area (TMA), and Calf Girth across two training phases. The researcher employed a pre-experimental design using indirect measurement techniques based on validated anthropometric equations to evaluate muscle development before and after exposure to a DUP-based training program.

Findings revealed that Arm Muscle Area (AMA) showed the most significant hypertrophic response, with notable increases in mean values and reduced variability among respondents across two training phases. Thigh Muscle Area (TMA) also demonstrated modest improvements, while calf girth changes were less pronounced. A progressive increase in training volume across the phases aligned with observed muscle gains, supporting the role of progressive overload in stimulating hypertrophy. Results indicate that systematic DUP training is helpful in increasing upper body muscular growth, with varying results in lower limb regions.

Based on the analysis, the null hypothesis was partially sustained, significant changes were observed in Arm Muscle Area (AMA) and Thigh Muscle Area (TMA), calf girth changes were not statistically significant. The study provides practical insights for fitness coaches and gym-goers on the use of DUP and anthropometric methods for monitoring hypertrophy. Recommendations were offered for coaches, gym-goers, and future researchers to optimize training strategies and measurement practices.

Keywords: Daily Undulating Periodization, Muscle Hypertrophy, Anthropometric Measurements, Cross-Sectional Area, Girth, Resistance Training

1. Introduction

The growing popularity of fitness in the Philippines, particularly among young men, reflects a broader societal shift toward physical development, health consciousness, and self-presentation (Bell, Rahman, & Rochon, 2023; Lasco & Hardon, 2020). For many, gyms are now venues for personal transformation, where aesthetic goals such as muscle gain drive participation in resistance training (Doull et al., 2018). Despite this growing trend, many gym-goers lack proper guidance in training program design, especially when it comes to optimizing muscle hypertrophy (Rojas, 2016; Lauersen et al., 2018). One such problem is a lack of periodized programming, especially the use of periodization. Haff and Triplett (2016) point out that periodization is critical for avoiding plateaus and optimizing gains. Daily Undulating Periodization (DUP), where training volume and intensity are changed throughout the week, has potential in stimulating muscle growth (Peixoto et al., 2022). Its use is still limited or not clearly understood in most gyms. Many individuals, especially in local gyms, follow generic workout plans without adjusting load or volume based on training goals, which limits muscle development. One of the central goals of many gym-goers is to engage in resistance training aimed at increasing muscle size through hypertrophy, which involves mechanical tension, metabolic stress, and progressive overload (Behringer et al., 2025). Achieving hypertrophy requires not only consistency but also careful manipulation of training variables such as volume, intensity, and frequency (Alix-Fages et al., 2022; Krzysztofik et al., 2019). This gap between scientific knowledge and practical application highlights the need for educational interventions and evidence-based programming, especially for those aiming to increase muscle size effectively.

Local gyms today continue to see a growing number of gym-goers (Radhakrishnan et al., 2020), but many still lift weights without proper knowledge of exercise form, rest periods, and load management (Schoenfeld et al., 2021; Mangine et al., 2015). As a result, their progress often stalls, and their efforts become unsuccessful over time. Most individuals are highly motivated at the beginning, but this motivation tends to fade as the training becomes more demanding (Radhakrishnan et al., 2020). According to Hans Selye's General Adaptation Syndrome theory, an individual's performance initially declines when exposed to a new training stimulus; this is known as the alarm stage (McCarty, 2016). However, as the body adapts, it becomes more capable of handling the stress from continued training. Unfortunately, many gym-goers quit when they start experiencing muscle soreness or fatigue, failing to push through to the adaptation stage.

This highlights a common problem, not just a lack of consistency, but a lack of scientific knowledge and proper programming in their training approach.

Idol's Fitness Gym, located in San Pablo City, is a popular choice among gym-goers due to its affordable rates. Most of its regular members are college students aiming to improve their physique and develop muscle mass. While many of them are motivated to build muscle, a majority lack sufficient knowledge on how to properly manipulate training variables to optimize muscle growth. One effective approach that can be introduced to them is Daily Undulating Periodization (DUP), a training method that varies volume and intensity daily to prevent plateaus and reduce the risk of overtraining (Peixoto et al., 2022).

Most members follow a split routine, typically structured as, Push Day (chest, shoulders, triceps) on Monday; Pull Day (back and biceps) on Tuesday; Leg Day (quadriceps, hamstrings, calves) on Wednesday; and repeating the cycle from Thursday to Saturday, with Sunday as a rest day. However, many lifters determine their workload based solely on what they can lift that day, without a structured or progressive plan. This lack of consistency in managing training volume often results in fluctuating or stalled muscle development. This observation prompted the researcher to implement a program based on Daily Undulating Periodization tailored to their existing split routines, with the goal of evaluating its effectiveness in enhancing muscle growth through planned variations in training intensity and volume.

Another motivation behind this study is the use of accessible tools to monitor and measure muscle development. While less precise than imaging methods like MRI or ultrasound, anthropometric techniques are cost-effective and widely utilized by fitness professionals. Such studies show, for example, Di et al., (2012) which establish the feasibility of anthropometry in assessing cross-sectional area of the thigh among elite bodybuilders, weightlifters and powerlifters. Likewise, Tan, Vitriana, and Nurhayati (2016) proved that muscle circumference has a positive correlation to strength in Indonesian medical students. Such findings strengthen the applicability of these assessment methods for evaluation of the training effects in practical gym settings.

The goal of this study is to close the gap between controlled studies and the unstructured, self-directed training methods that are typical in recreational gyms. It aims to assist gym-goers, and fitness coaches in creating more effective and accessible training regimens by analysing the efficacy of DUP phases in a real-world setting using useful measurement instruments.

2. Methodology

2.1 Research Design

This study used a pre-experimental research design, a basic form of experimental research that observes the effect of an independent variable on a single group without a control group, primarily to assess whether further investigation is needed (Zubair, Ahsanul, 2023). The research examined the effectiveness of Daily Undulating Periodization (DUP) on muscle hypertrophy among male gym-goers. It focused on how varying training intensities and volumes across strength, hypertrophy, and endurance phases influenced muscle growth. Anthropometric methods, including girth and skinfold measurements, were employed to estimate changes in muscle size. Training volume and adherence were monitored over a four-week program in a real-world gym setting, offering practical insights for coaches and lifters.

2.2 Respondents of the Study

The study involved nine (9) male gym-goers from Idols Fitness Gym, a local gym in San Pablo City who committed to a four-week Daily Undulating Periodization (DUP) program. While the program was structured for six training days per week, participants followed it based on availability. All had prior resistance training experience and aimed to gain muscle size. One-repetition maximum (1RM) tests were conducted before assigning workout intensities or total volume workload.

2.3 Research Instruments

To evaluate the effectiveness of Daily Undulating Periodization (DUP) on muscle hypertrophy among selected male gym-goers, this study utilized the Slim Guide® caliper for skinfold thickness measurements and a flexible tape measure for muscular girth assessments. The Slim Guide® caliper, made of high-impact ABS plastic, was used to measure subcutaneous fat thickness at specific anatomical sites, including the triceps, and thigh. This caliper has an 80mm opening, making it particularly useful for assessing larger skinfolds. It features high-quality springs for durability and provides measurements with an accuracy of ±1mm, which can be interpolated to 0.5mm. It maintains a constant pressure of 10 g/mm², ensuring consistent readings. The skinfold measurements were used to estimate lean muscle mass changes, helping differentiate actual hypertrophy from fat accumulation.

In addition, muscle girth was measured using a flexible tape measure at standardized anatomical landmarks on the triceps, thigh, and calf before and after the 4-week training intervention. This method allowed for the assessment of muscle size changes over time. To maintain accuracy and consistency in data collection, participants followed specific pre-measurement protocols, including avoiding alcohol for 24 hours, and fasting for at least 4 hours before measurement. These guidelines helped control acute fluctuations in hydration, muscle swelling, and body composition, ensuring more reliable and valid results. To reduce error, each site was measured twice and the average recorded. Unlike studies with multiple assessors, only one evaluator conducted all measurements to maintain consistency. To ensure proper technique, the researcher consulted two physiotherapists, a Doctor of Physical Therapy, and a registered nurse. Their validation confirmed correct landmark identification and tool usage were made based on their feedback to improve measurement accuracy.

2.4 Research Procedures

The participants followed a 4-week resistance training program based on Daily Undulating Periodization (DUP), structured in accordance with the resistance training recommendations of the American College of Sports Medicine (2009). Although the program was originally designed for six training days per week, participants modified the frequency based on their individual schedules, with some completed the full six-day routine and others training fewer days. Each session followed a push, pull, and leg split to ensure balanced muscular development and recovery. The push day included bench press, cable fly, arnold press, side lateral raise, reverse cable fly, triceps press-down, and overhead triceps extension. The pull day consisted of lat pulldown, cable row, neutral-grip pulldown, biceps curl, hammer rope curl, and inclined biceps curl. The leg day involved barbell squats, split squats, leg extensions, romanian deadlifts, and standing calf raises. The training protocol featured a systematic variation in intensity and repetition ranges followed the volume workload in muscular endurance, hypertrophy, and strength in line with ACSM guidelines. In Phase 1, endurance-focused sessions used approximately 45% of one-repetition maximum (1RM) for 4 sets of 20 repetitions, hypertrophy sessions used about 60% of 1RM for 4 sets of 12 repetitions, and strength sessions used roughly 80% of 1RM for 4 sets of 6 repetitions. In Phase 2, intensities slightly increased, with endurance days at ~50% of 1RM, hypertrophy days at ~65% of 1RM, and strength days at ~85% of 1RM, maintaining the same set and rep schemes. To avoid excessive strain and overtraining, the program was limited to a maximum of seven exercises per session, targeting specific muscle groups. The researcher performed all measurements to ensure consistency and minimize inter-observer variability. Standardized measurement techniques were strictly followed, including identifying the same anatomical landmarks, maintaining consistent tape tension, and ensuring proper caliper placement.

2.5 Statistical Treatment of Data

The data collected were analyzed using appropriate statistical methods to present and interpret the results. Descriptive statistics, including mean, standard deviation (SD), and percentages, were used to summarize the pre- and post-measurement results of muscle hypertrophy. To determine significant differences in measurements across multiple time points, a t-test was employed. This test was used to assess changes in skinfold thickness, girth measurements, and Cross-Sectional Area (CSA) throughout the different phases of the Daily Undulating Periodization (DUP) exercise program. Durbin-Conover pairwise comparisons were conducted to identify where specific differences occurred between the phases (e.g., baseline to Phase 1, Phase 1 to Phase 2). This combination of descriptive and inferential statistics allowed for a comprehensive evaluation of the DUP program's effectiveness in inducing muscle hypertrophy over time.

All tables should be numbered with Arabic numerals. Every table should have a caption. Headings should be placed above tables, left justified. Only horizontal lines should be used within a table, to distinguish the column headings from the body of the table, and immediately above and below the table. Tables must be embedded into the text and not supplied separately. Below is an example which the authors may find useful.

3. Results and Discussion

This chapter includes the tables which present the data of the findings in this study with their respective interpretations. The data were analyzed and interpreted, so that conclusions and recommendations can be drawn from the result of the study. Cross-Sectional Area (CSA) scores presented in each table were derived from anthropometric measurements and classified according to a customized scoring rubric developed for this study.

Part 1. Pre- and Post-Measurement Results of Respondents' Muscle Hypertrophy in Phase 1

Table. 1. ***Pre- and Post-Measurement in Phase 1 of Arm Muscle Area.***

	Pre-Measurement		Post-Measurement		
Score	f	%	f	%	Interpretation
17-20	1	11.11%	1	11.11%	Exceptional Muscle Size
13-16	-	-	1	11.11%	Well-Developed Muscle Size
9-12	4	44.44%	4	44.44%	Normal Muscle Size
5-8	1	11.11%	2	22.22%	Potential for Improvement
1-4	3	33.33%	1	11.11%	Muscle Underdeveloped
Total	9	100%	9	100%	

Legend: (17-20) 68.776-70.511 cm^2 - Exceptional Muscle Size; Far above average, indicating advanced hypertrophy and long-term training; (13-16) 61.832-68.775 cm^2 – Well-Developed Muscle Size; Above average; evidence of consistent muscle growth; (9-12) 54.888-61.831 cm^2 – Normal Muscle Size; Average to moderate size, typical of active or mildly trained persons; (5-8) 47.944-54.887 cm^2– Potential for Improvement; Slightly below normal; lean base with room to grow; (1-4) 41.000-47.943 cm^2 – Muscle Underdeveloped; Lower than average muscle mass caused by idleness or insufficient training.

During Phase 1 of training, the highest score range (17–20), interpreted as "exceptional muscle size," maintained the same respondent (11.11%) from pre- to post-measurement, indicating consistent advanced hypertrophy and long-term training. In contrast, the lowest score range (1–4), classified as "muscle underdeveloped," showed a decrease in frequency from 3 (33.33%) to 1 (11.11%), reflecting improvement as more respondents progressed beyond this category. These findings suggest that the initial phase of the DUP program modestly improved muscle size, particularly for those starting at lower levels. This aligns with Hedayatpour and Falla (2015), who noted that eccentric exercise-induced microdamage can trigger neurological adaptations and hypertrophy in early training stages. The application of DUP training, emphasizing adjustments in volume and intensity, supports muscle adaptation consistent with findings from Ralston et al. (2017), Suchomel et al. (2018), and Schoenfeld et al. (2021). As emphasized by Schoenfeld et al. (2014; 2017), these DUP variables are key contributors to muscle hypertrophy, as demonstrated in the current study.

Table 2. ***Pre- and Post- Measurement in Phase 1 of Thigh Muscle Area***

	Pre-Measurement		Post-Measurement		
Score	f	%	f	%	Interpretation
17-20	1	11.11%	1	11.11%	Exceptional Thigh Muscles
13-16	5	55.56%	5	55.56%	Well-Developed Thigh Muscles
9-12	2	22.22%	2	22.22%	Normal Thigh Muscles
5-8	-	-	-	-	Below Average Thigh Muscle Size
1-4	1	11.11%	1	11.11%	Underdeveloped Muscle Mass
Total	9	100%	9	100%	

Legend: (17-20) 129.01-140.00 cm^2 - Exceptional Thigh Muscles; Individuals with resistance training have thick, muscular thighs that are far above average.; (13-16) 118.01-129.00 cm^2 – Well-Developed Thigh Muscles; Above average; continuous training has resulted in noticeable muscularity; (9-12) 107.01-118.00 cm^2 – Normal Thigh Muscles; Average size; seen in active or recreationally trained individuals; (5-8) 96.01-107.00 cm^2– Below Average Thigh Muscle Size; General population range; modest size, typically light activity; (1-4) 41.000-47.943 cm^2 – Underdeveloped Muscle Mass; Muscle mass is lower than average due to inactivity or lack of training.

The frequency distribution of Thigh Muscle Area during Phase 1 of DUP training showed no change in the highest category (17–20), interpreted as "exceptional thigh muscles," which remained at 11.11 percent. This category reflects distinctly muscular thighs typically observed in strength athletes or bodybuilders. Similarly, the lowest category (1–4), interpreted as "underdeveloped thigh muscles," also remained stable at 11.11 percent before and after the intervention, suggesting no hypertrophic response in individuals with below-average muscle size.

The unchanged distribution at both extremes implies that the early phase of the DUP program may not have provided sufficient stimulus to significantly affect thigh muscle size, especially given the limited weekly leg sessions and low volume. According to Krzysztofik et al. (2019), larger muscle groups such as the thighs require more hypertrophy-specific training stimuli to trigger growth. Furthermore, Fonseca et al. 2014, as cited by Fisher et al., 2018 emphasized that a variety of lower-body exercises is essential for eliciting full hypertrophic adaptation in the quadriceps. The lack of exercise variety and intensity in Phase 1 may have contributed to the absence of change. Grgic et al. (2017) also noted that hypertrophy is often more evident in later phases of DUP programs or when training is conducted closer to muscular failure, especially in trained individuals.

Table 3. ***Pre- and Post-Measurement in Phase 1 of Calf Girth***

	Pre-Measurement		Post-Measurement		
Score	f	%	f	%	Interpretation
17-20	-	-	-	-	Exceptional Calf Muscle Size
13-16	4	44.44%	5	55.55%	Well-Developed Calf Muscles
9-12	3	33.33%	2	22.22%	Normal Calf Muscle Size
5-8	1	11.11%	1	11.11%	Average Calf Muscle Size
1-4	1	11.11%	1	11.11%	Underdeveloped Calf Muscles
Total	9	100%	9	100%	

Legend: (17-20) 38:00-40.00 cm - Exceptional Calf Muscle Size; having huge, defined calves with well-developed calf muscles;(13-16) 36.00-37.99 cm - Well-developed Calf Muscles; with clearly apparent size and tone, and consistent training has resulted in above-average growth; (9-12) 34.00-35.99 cm - Normal Calf Muscle Size; Average muscle size typical of active individuals; balanced shape and proportion; (5-8) 32.00-33.99 cm - Average Calf Muscle Size ; General population range; moderate muscle development, maybe with increased fat mass. (1-4) 30.00-31.99 cm - Underdeveloped Calf Muscles - Smaller and less defined than typical; most likely caused by insufficient activity, a genetic predisposition, or incorrect training.

During Phase 1 of DUP training, no respondent was classified under the highest category (17–20), interpreted as "exceptional calf muscle size," in either pre- or post-measurement, indicating that no participant had advanced hypertrophy in the calf region. Similarly, the lowest category (1–4), interpreted as "underdeveloped calf muscles," remained unchanged at 11.11 percent, showing no regression or improvement among those with the least muscle development. These stable values at both ends suggest that calf hypertrophy was minimal during this phase. This aligns with Phillips (2014), who explained that resistance training must function as a sufficient physiological stimulus to activate pathways for protein synthesis and muscle adaptation. Calves, due to their high daily use and dominance of slow-twitch muscle fibers, are particularly resistant to hypertrophy and require focused, high-volume training (Suchomel et al., 2018). The program's limited inclusion of calf-specific exercises mainly calf raises as a minor part of leg day likely resulted in insufficient volume and frequency to trigger substantial hypertrophic responses. While slight improvements were observed in mid-range categories, the findings reinforce the need for more targeted training if significant calf muscle gains are desired.

Part 2. Pre- and Post-Measurement Results of Respondents' Muscle Hypertrophy in Phase 2

Table 4. ***Pre- and Post-Measurement in Phase 2 of Arm Muscle Area***

	Pre-Measurement		Post-Measurement		
Score	f	%	f	%	Interpretation
17-20	1	11.11%	1	11.11%	Exceptional Muscle Size
13-16	1	11.11%	3	33.33%	Well-Developed Muscle Size
9-12	4	44.44%	3	33.33%	Normal Muscle Size
5-8	2	22.22%	2	22.22%	Potential for Improvement
1-4	1	11.11%	-	-	Muscle Underdeveloped
Total	9	100%	9	100%	

Legend: (17-20) 68.776-70.511 cm^2 - Exceptional Muscle Size; Far above average, indicating advanced hypertrophy and long-term training; (13-16) 61.832-68.775 cm^2 – Well-Developed Muscle Size; Above average; evidence of consistent muscle growth; (9-12) 54.888-61.831 cm^2 – Normal Muscle Size; Average to moderate size, typical of active or mildly trained persons; (5-8) 47.944-54.887 cm^2– Potential for Improvement; Slightly below normal; lean base with room to grow; (1-4) 41.000-47.943 cm^2 – Muscle Underdeveloped; Lower than average muscle mass caused by idleness or insufficient training.

In Table 4, the highest category (17–20), interpreted as "exceptional muscle size," remained unchanged, with one respondent (11.11%) maintaining this classification from pre- to post-measurement. This suggests consistent advanced muscularity, possibly reflecting long-term training adaptation. Meanwhile, the lowest category (1–4), interpreted as "underdeveloped muscle size," improved, as the one respondent in this range (11.11%) moved out of this classification by the post-measurement, indicating progress in muscle development. These findings demonstrate a continued positive hypertrophic response in arm muscle area following Phase 2 of DUP training. The improvement aligns with the application of progressive overload, as a 5% increase in training volume was applied throughout the phase. Damas et al. (2019) support this by stating that regularly altering training load enhances muscle protein synthesis, which contributes to muscle growth. Additionally, Fisher et al. (2018) emphasized that incorporating exercise variety fosters more comprehensive muscular development. The researcher observed more noticeable hypertrophy in Phase 2, attributed to increased training volume. This observation is consistent with Figueiredo et al. (2018), whose meta-analysis confirmed that higher training volumes lead to improved muscle hypertrophy. Although their study acknowledged limitations in determining whether more sets or more exercises are superior, the current study still affirms that progressive increases in training volume—even using the same exercises yielded beneficial outcomes.

Table 5. ***Pre- and Post-Measurement in Phase 2 of Thigh Muscle Area***

	Pre-Measurement		Post-Measurement		
Score	f	%	f	%	Interpretation
17-20	1	11.11%	2	22.22%	Exceptional Thigh Muscles
13-16	5	55.56%	4	44.44%	Well-Developed Thigh Muscles
9-12	2	22.22%	2	22.22%	Normal Thigh Muscles
5-8	-	-	-	-	Below Average Thigh Muscle
1-4	1	11.11%	1	11.11%	Underdeveloped Muscle Mass
Total	9	100%	9	100	

Legend: (17-20) 129.01-140.00 cm2 - Exceptional Thigh Muscles; Individuals with resistance training have thick, muscular thighs that are far above average.; (13-16) 118.01-129.00 cm2 – Well-Developed Thigh Muscles; Above average; continuous training has resulted in noticeable muscularity; (9-

12) 107.01-118.00 cm2 – Normal Thigh Muscles; Average size; seen in active or recreationally trained individuals; (5-8) 96.01-107.00 cm2– Below Average Thigh Muscle Size; General population range; modest size, typically light activity; (1-4) 41.000-47.943 cm2 – Underdeveloped Muscle Mass; Muscle mass is lower than average due to inactivity or lack of training.

In Phase 2, the highest category (17–20), interpreted as "exceptional thigh muscle," increased from 1 respondent (11.11%) **to 2** respondents (22.22%)**,** suggesting that at least one participant experienced notable hypertrophy in the thigh region, likely due to progressive overload and improved training adaptation. Conversely, the lowest category (1–4), interpreted as "underdeveloped muscle mass," showed no change, remaining at 11.11 percent, indicating that no further regressions or advancements occurred in this group. This modest yet meaningful upward shift in the highest category reflects the effects of progressive training volume, as the program implemented a 5 percent increase in workload during this phase. According to Schoenfeld et al. (2016), hypertrophic responses are optimized when weekly volume exceeds 10 sets per muscle group—a threshold met in the current study. However, limited improvements for some may stem from inconsistent adherence to leg training, as explained by Mangine et al. (2015) and Carvalho et al. (2021), who emphasized that high-intensity training requires consistent application to be effective.The findings also align with Snijders et al. (2016), who highlighted the importance of progressive resistance training in activating type II muscle fibers and promoting muscle growth through satellite cell activity. Peixoto et al. (2022) and Spinetti et al. (2014) similarly noted that consistent training—even with varied or non-volume-equated models like DUP—can yield hypertrophic benefits over time.In summary, although improvement in thigh muscle size was not drastic, the increase in the highest muscle category, coupled with unchanged values at the lowest end, demonstrates the importance of progressive overload and consistent leg training in stimulating growth.

Table 6.*Pre- and Post-Measurement in Phase 2 of Calf Girth*

	Pre-Measurement		Post-Measurement		
Score	f	%	f	%	Interpretation
17-20	-	-	-	-	Exceptional Calf Muscle Size
13-16	5	55.55%	5	55.55%	Well-Developed Calf Muscles
9-12	2	22.22%	2	22.22%	Normal Calf Muscle Size
5-8	1	11.11%	1	11.11%	Average Calf Muscle Size
1-4	1	11.11%	1	11.11%	Underdeveloped Calf Muscles
Total	9	100%	9	100%	

Legend: (17-20) 38:00-40.00 cm - Exceptional Calf Muscle Size; having huge, defined calves with well-developed calf muscles;(13-16) 36.00-37.99 cm - Well-developed Calf Muscles; with clearly apparent size and tone, and consistent training has resulted in above-average growth; (9-12) 34.00-35.99 cm - Normal Calf Muscle Size; Average muscle size typical of active individuals; balanced shape and proportion; (5-8) 32.00-33.99 cm - Average Calf Muscle Size ; General population range; moderate muscle development, maybe with increased fat mass. (1-4) 30.00-31.99 cm - Underdeveloped Calf Muscles - Smaller and less defined than typical; most likely caused by insufficient activity, a genetic predisposition, or incorrect training.

In Table 6, both the highest category (17–20), interpreted as "exceptional calf muscle size," and the lowest category (1–4), interpreted as "underdeveloped calf muscles," remained unchanged, each with 0 and 1 respondent (11.11%) respectively. This lack of movement across both extremes reflects a stagnant hypertrophic response in the calf muscles during Phase 2 of the DUP program. The unchanged status at the lowest end suggests that the program did not provide enough stimulus for those with minimal calf development to progress. This limited response is likely due to the minimal calf-specific training, as only calf raises were included, and these were performed as part of general leg workouts rather than through high-volume, isolated protocols.

These findings are consistent with Plotkin et al. (2024), who emphasized that hypertrophy of the calf muscles requires adequate training volume, load, and time under tension. The triceps surae muscles (gastrocnemius and soleus) are often labeled "stubborn" not due to physiology, but due to underdosed and untargeted training protocols. Furthermore, although the DUP model used in this study is designed to maximize adaptation through variations in volume and intensity, missed training sessions, particularly on leg days, may have compromised its effectiveness. The DUP model relies on consistent application of progressive overload across the microcycle to drive muscle adaptation.In summary, the unchanged calf girth distribution, particularly in the highest and lowest categories, highlights the need for more targeted and higher-volume calf training to elicit meaningful hypertrophy within this muscle group.

Part 3. Significant Difference Between the Pre- and Post-Measurement of the Respondents in Two Phases

Table 7. ***Significant Difference of Arm Muscle Area in Two Phases***

			t-value	p-value
Pre-Phase 1	-	Post-Phase 1	5.73	<.001
Pre-Phase 2	-	Post-Phase 2	8.74	<.001
Post-Phase 1	-	Post-Phase 2	3.02	0.008

Legend: Significant at .001

Table 7 shows that the most significant increase in Arm Muscle Area occurred between Pre-Phase 2 and Post-Phase 2, with a t-value of 8.74 ($p < .001$), indicating a highly significant hypertrophic response. This suggests that continued exposure to the DUP program, along with progressive overload, led to substantial gains in muscle size. In contrast, the smallest but still significant change was observed between Post-Phase 1 and Post-Phase 2, with a t-value of 3.02 ($p = 0.008$). This smaller yet statistically meaningful difference likely reflects that respondents were already adapting during Phase 1, and the progressive increase in volume during Phase 2 further stimulated muscle growth.

These findings are in line with the studies of Peixoto et al. (2022) and Spinetti et al. (2014), which showed that non-volume-equated DUP training can still promote hypertrophy when progressive overload is applied. The results also parallel Snijders et al. (2016), who noted that consistent training increases satellite cell activity and myonuclear content, essential for sustained growth. The highest hypertrophic response from Pre- to Post-Phase 2 may reflect this adaptive threshold.

Interestingly, even without standardizing training volume across participants, significant gains were still observed. This echoes the findings of Amirthalingam et al. (2017) and Scarpelli et al. (2022), suggesting that individualized or flexible training volumes can also be effective. While load distinctions between strength, hypertrophy, and endurance days were not clearly separated, as seen in traditional periodization models, the consistent increases in volume and the application of progressive overload still led to meaningful improvements, consistent with Schoenfeld et al. (2017).

Additionally, Baz-Valle's insights on indirect muscle involvement (e.g., triceps activation during bench press) support the idea that compound lifts in the DUP program contributed to overall arm development. Nutritional limitations among respondents—such as caloric deficits affecting protein synthesis may have tempered gains in some cases, as noted by Stokes et al. (2022).

Finally, although the Heymsfield formula using skinfold and girth measurements has inherent limitations, Budzynski-Seymour et al. (2019) validated these techniques, confirming their reliability when applied using standardized methods—as done in this study. This supports the observed hypertrophic changes in Arm Muscle Area throughout the training phases.

Table 8. Significant Difference of Thigh Muscle Area in Two Phases

			t-value	p-value
Pre-Phase 1	-	Post-Phase 1	0.72	0.481
Pre-Phase 2	-	Post-Phase 2	2.89	0.011
Post-Phase 1	-	Post-Phase 2	2.17	0.046

Legend: Significant at < 0.05

Table 8 reflects both the lowest and highest statistical outcomes for thigh muscle area across training phases. The lowest result was observed during Phase 1, where the pre- to post-measurement yielded a t-value of 0.72 and a p-value of 0.481, indicating no statistically significant hypertrophic change. This lack of significance suggests that the initial training load and frequency may not have been sufficient to exceed the adaptive threshold for thigh muscle growth, particularly in trained individuals with fatigue-resistant quadriceps.This aligns with the studies of deFreitas et al. (2011) and Damas et al. (2015), who explained that early increases in muscle size may reflect temporary swelling or inflammation rather than actual hypertrophy. Additionally, Suchomel et al. (2018) and Haun et al. (2020) emphasized that early adaptations are largely neurological and connective, with measurable hypertrophy occurring only after consistent overload over longer periods.

In contrast, the highest result was found in Phase 2, where pre- to post-measurements yielded a t-value of 2.89 and $p = 0.011$, reflecting a statistically significant increase in thigh muscle area. This suggests that the delayed but cumulative effects of progressive overload—through increased training volume (5% workload increase) and varied intensity across DUP phases—were effective in stimulating hypertrophy. The findings echo the periodization principles outlined by Matveyev (1977) (cited by Plotkin et al., 2022) and supported by Geanta & Ardelean (2021) and De Souza et al. (2018), who found greater gains in the latter stages of DUP programs due to sustained variation in volume and intensity.

Notably, the significant improvement from Post-Phase 1 to Post-Phase 2 ($t = 2.17$, $p = 0.046$) further confirms that DUP is effective for thigh muscle development, though individual responses varied, as emphasized by Damas et al. (2019) and Rantila et al. (2021). Some participants—likely high responders—adapted more quickly, while others showed stagnant results due to factors like missed leg days, varying strength levels, or limited adherence to the program.

Nutrition and supplementation also contributed to this variation. While some respondents took 20g whey protein and 5g creatine post-workout, not all did so consistently. Krzysztofik et al. (2019) and Phillips (2014, 2016) affirmed the importance of such supplements in supporting muscle protein synthesis, but lack of uniform intake limits their impact in this study.

The use of skinfold and girth measurements, alongside the Housh et al. (1995) equation, introduced further limitations. While this method was validated by DeFreitas et al. (2010) and Budzynski-Seymour et al. (2019), its accuracy can be affected by hydration, fasting state, and inherent limitations compared to advanced tools like MRI or pQCT. Haun et al. (2020) noted that hypertrophy at the molecular level might not be detected through external measures, which could explain why some gains were not visibly captured.

In summary, while Phase 1 yielded the lowest (non-significant) result, Phase 2 demonstrated significant hypertrophy, confirming the effectiveness of progressive overload through DUP, especially when paired with consistency and training variation. However, individual differences, training adherence, supplementation, and measurement limitations remain key factors influencing observed outcomes.

Table 9. ***Significant Difference of Calf Girth in Two Phases***

			t-value	p-value
Pre-Phase 1	-	Post-Phase 1	0	1.000
Pre-Phase 2	-	Post-Phase 2	0.84	0.413
Post-Phase 1	-	Post-Phase 2	0.84	0.413

Legend: Significant at < 0.05

The analysis of calf girth across training phases showed consistently non-significant results, with the lowest statistical change observed between Pre-Phase 1 and Post-Phase 1, yielding a t-value of 0.00 (p = 1.000)—indicating no hypertrophic response at all during the initial training phase. The highest numerical change appeared in both Pre-Phase 2 vs. Post-Phase 2 and Post-Phase 1 vs. Post-Phase 2 comparisons, each with a t-value of 0.84 and p = 0.413, yet still statistically non-significant. These findings suggest that calf muscle growth remained negligible or below the threshold for detectable change throughout the study duration.

Despite the absence of significance, small numerical increases may hint at sub-threshold or early adaptations, especially considering the calf muscles' known resistance to hypertrophy. According to Bordoni and Varacallo (2023), the gastrocnemius and soleus muscles require specific and sustained training stimuli due to their high endurance fiber composition. The minimal response observed in this study may be attributed to insufficient training volume and variation. Geremia et al. (2019) emphasized the influence of joint angles—such as bent or straight knees on calf activation, which was not distinctly incorporated in the program. As Schoenfeld et al. (2020) highlighted, both low-load and high-load resistance training can stimulate comparable hypertrophy in the calf muscles, particularly when performed consistently with sufficient volume. However, in the present study, the limited frequency and single-exercise approach may have been insufficient to produce similar outcomes. The lack of training frequency, load variation, and controlled eccentric contractions identified by Plotkin et al. (2024) as key hypertrophy drivers for calves likely contributed to the unchanged calf girth measurements.

Although respondents showed significant gains in arm and thigh muscle areas, the calf results remained stagnant, highlighting the unique training demands of the lower leg musculature. The short duration (four weeks) and lower prioritization of calf-specific training, combined with missed sessions, limited the potential for adaptation.

Calf girth was assessed using anthropometric tape measurements, a cost-effective method for field studies. While validated by Yasuda (2020) and Takagi (2018) as reliable for estimating skeletal muscle mass, and supported by Bahat et al. (2021) for low-resource environments, this method may lack the sensitivity to detect subtle muscle changes, particularly when training stimuli are minimal.

In conclusion, the lowest hypertrophic response across all muscle groups was observed in the calves, reinforcing the importance of targeted, high-volume, and strategically programmed resistance training—especially for muscle groups known to resist growth under generalized protocols.

4. Conclusions

Based on the results and analysis of the study, the null hypothesis is partially sustained. The data revealed statistically significant improvements in muscle hypertrophy, particularly in the Arm Muscle Area and Thigh Muscle Area, across the two training phases of the DUP program. However, Calf Girth did not show significant changes, suggesting that certain muscle groups may respond differently to undulating training stimuli.

5. Recommendations

On account of the significant findings and conclusions of this research, the following are recommended:

1. Gym-goers may continuously integrate progressive resistance training into their routines while regularly measuring muscle size and body composition using skinfold calipers, girth measurements, and even body fat scales. Combining with strength assessments will help them understand the impact of certain program protocols on both performance and physique.

2. Fitness coaches may tailor training programs to target both hypertrophy and strength by utilizing periodization models. Additionally, they may implement regular assessments of muscle size using girth and skinfold measurements, along with body composition analysis through methods such as skinfold calipers or bioelectrical impedance. Incorporating body fat percentage measurements is also essential to determine improvements in lean body mass, allowing for more precise adjustments in training intensity, volume, and frequency.

3. Future researchers may explore the effects of different training modalities, such as linear or undulating periodization, on muscle hypertrophy and strength. They may also utilize both traditional (e.g., skinfold and girth) and BIA (Bioelectrical Impedance Analysis) to track muscle growth, body composition, lean body mass, and total body water accurately and identify the most effective training strategies for various populations. Combining both provides a more comprehensive picture of muscle hypertrophy and fat loss.

References

Alix-Fages, C., Del Vecchio, A., Baz-Valle, E., Santos-Concejero, J., & Balsalobre-Fernández, C. (2022). The role of the neural stimulus in regulating skeletal muscle hypertrophy. *European Journal of Applied Physiology. Advance online publication.* https://doi.org/10.1007/s00421-022-04906-6

Amirthalingam, T., Mavros, Y., Wilson, G. C., Clarke, J. L., Mitchell, L., & Hackett, D. A. (2017). Effects of a modified German Volume Training program on muscular hypertrophy and strength. *Journal of Strength and Conditioning Research, 31(11), 3109–3119.* https://doi.org/10.1519/JSC.0000000000001770

Bahat, G. (2021). Measuring calf circumference: A practical tool to predict skeletal muscle mass via adjustment with BMI. *The American Journal of Clinical Nutrition, 113(6), 1405–1406.* https://doi.org/10.1093/ajcn/nqab107

Baz-Valle E, Balsalobre-Fernández C, Alix-Fages C, Santos-Concejero J. A Systematic Review of The Effects of Different Resistance Training Volumes on Muscle Hypertrophy. *J Hum Kinet. 2022 Feb 10;81:199-210*. doi: 10.2478/hukin-2022-0017. PMID: 35291645; PMCID: PMC8884877.

Behringer, M., Heinrich, C., & Franz, A. (2025). Anabolic signals and muscle hypertrophy – Significance for strength training in sports medicine. *Sports Orthopaedics and Traumatology, 41(1), 9–18.* https://doi.org/10.1016/j.orthtr.2025.01.002

Bell, D., Rahman, S., & Rochon, R. (2023). (Trans)forming fitness: Intersectionality as a framework for resistance and collective action. *Frontiers in Sports and Active Living, 5, 944782*. https://doi.org/10.3389/fspor.2023.944782

Bordoni, B., & Varacallo, M. A. (2023). *Anatomy, bony pelvis and lower limb, gastrocnemius muscle. In StatPearls.* StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK532946/

Budzynski-Seymour, E., Milton, J., Vanderlei, F. M., & James, R. S. (2019). Validity and reliability of anthropometric and ultrasound measures of thigh muscle cross-sectional area. *Journal of Strength and Conditioning Research, 33(12), 3225–3230.* https://doi.org/10.1519/JSC.0000000000003313

Carvalho L, Junior RM, Truffi G, Serra A, Sander R, De Souza EO, Barroso R. Is stronger better? Influence of a strength phase followed by a hypertrophy phase on muscular adaptations in resistance-trained men. *Res Sports Med. 2021 Nov-Dec;29(6):536-546*. doi: 10.1080/15438627.2020.1853546. Epub 2020 Nov 26. PMID: 33241958.

Damas, F., Phillips, S. M., Libardi, C. A., Vechin, F. C., Lixandrão, M. E., Jannig, P. R., ... & Ugrinowitsch, C. (2019). Resistance training-induced changes in integrated myofibrillar protein synthesis are related to hypertrophy only after attenuation of muscle damage. *The Journal of Physiology, 597(18), 4831–4846.*

Damas, F., Phillips, S., Vechin, F. C., & Ugrinowitsch, C. (2015). A review of resistance training-induced changes in skeletal muscle protein synthesis and their contribution to hypertrophy. *Sports Medicine, 45(6), 801–807.* https://doi.org/10.1007/s40279-015-0320-0

DeFreitas, J. M., Beck, T. W., Stock, M. S., Dillon, M. A., Sherk, V. D., Stout, J. R., & Cramer, J. T. (2010). A comparison of techniques for estimating training-induced changes in muscle cross-sectional area. *Journal of Strength and Conditioning Research, 24(9), 2383–2389.* https://doi.org/10.1519/JSC.0b013e3181ec86f3

DeFreitas JM, Beck TW, Stock MS, Dillon MA, Kasishke PR 2nd. An examination of the time course of training-induced skeletal muscle hypertrophy. *Eur J Appl Physiol. 2011 Nov;111(11):2785-90.* doi: 10.1007/s00421-011-1905-4. Epub 2011 Mar 16. PMID: 21409401.

DeFreitas, J. M., Beck, T. W., & Stock, M. S. (2016). The findings of Damas et al. have not influenced the previously proposed time course of skeletal muscle hypertrophy. *European Journal of Applied Physiology, 116(1), 183–184.* https://doi.org/10.1007/s00421-015-3286-6

De Souza, E. O., Tricoli, V., Rauch, J. T., Cadore, E. L., Oliveira, R. S., Villas-Bôas, J. P., & Fleck, S. J. (2018). Effects of different periodization models on muscle hypertrophy and strength in resistance-trained men. Journal of Strength and Conditioning Research, 32(10), 2930–2939. https://doi.org/10.1519/JSC.0000000000002380

Di, J. J., Pritschet, B., Owen, J., Willardson, J., Beck, T. W., DeFreitas, J., & Fontana, F. (2012). Comparing thigh muscle cross-sectional area and squat strength among national class Olympic weightlifters, powerlifters, and bodybuilders. *International SportMed Journal, 13*.

Doull, M., Watson, R. J., Smith, A., Homma, Y., & Saewyc, E. (2018). Are we leveling the playing field? Trends and disparities in sports participation among sexual minority youth in Canada. Journal of Sport and Health Science, 7(2), 218–226. https://doi.org/10.1016/j.jshs.2016.10.006

Figueiredo, V. C., de Salles, B. F., & Trajano, G. S. (2018). Volume for muscle hypertrophy and health outcomes: The most effective variable in resistance training. *Sports Medicine, 48(3), 499–505.* https://doi.org/10.1007/s40279-017-0793-0

Fisher, J. P., Steele, J., Bruce-Low, S., & Smith, D. (2018). Evidence-based resistance training recommendations. *Medicina Sportiva, 14(3), 123–135.*

Fonseca, R. M., Roschel, H., Tricoli, V., de Souza, E. O., Wilson, J. M., Laurentino, G. C., ... & Aoki, M. S. (2014). Changes in exercises are more effective than in loading schemes to improve muscle strength. *Journal of Strength and Conditioning Research, 28(11), 3085–3092.*

Geantă, Vlad Adrian & Petru, Ardelean. (2021). Improving muscle size with Weider's principle of progressive overload in non-performance athletes. Timisoara Physical Education and Rehabilitation Journal. 14. 27-32. 10.2478/tperj-2021-0011.

Geremia JM, Baroni BM, Bini RR, Lanferdini FJ, de Lima AR, Herzog W, Vaz MA. Triceps Surae Muscle Architecture Adaptations to Eccentric Training. Front Physiol. 2019 Nov 26;10:1456. doi: 10.3389/fphys.2019.01456. Erratum in: Front Physiol. 2020 Jul 03;11:627. doi: 10.3389/fphys.2020.00627. PMID: 31849706; PMCID: PMC6901927.

Grgic, J., Mikulic, P., Podnar, H., & Pedisic, Z. (2017). Effects of linear and daily undulating periodized resistance training programs on measures of muscle hypertrophy: A systematic review and meta-analysis. *PeerJ, 5, e3695.* https://doi.org/10.7717/peerj.3695

Haff, G. G., & Triplett, N. T. (2016). Essentials of strength training and conditioning (4th ed.). *Human Kinetics.*

Haun CT, Vann CG, Roberts BM, Vigotsky AD, Schoenfeld BJ, Roberts MD. A Critical Evaluation of the Biological Construct Skeletal Muscle Hypertrophy: Size Matters but So Does the Measurement. *Front Physiol. 2019 Mar 12;10:247.* doi: 10.3389/fphys.2019.00247. PMID: 30930796; PMCID: PMC6423469.

Heymsfield SB, McManus C, Smith J, Stevens V, Nixon DW. Anthropometric measurement of muscle mass: revised equations for calculating bone-free arm muscle area. *Am J Clin Nutr. 1982 Oct;36(4):680-90.* doi: 10.1093/ajcn/36.4.680. PMID: 7124671.

Hedayatpour, N., & Falla, D. (2015). Delayed onset of vastus medialis oblique activity in response to unexpected perturbations following eccentric exercise. *Journal of Electromyography and Kinesiology, 25(1), 133–138.*

Housh, T. J., Housh, D. J., Johnson, G. O., & Chu, W. K. (1995). An examination of a field method for estimating thigh cross-sectional area. *Journal of Strength and Conditioning Research, 9(4), 234–238.* https://doi.org/10.1519/00124278-199511000-00006

Krzysztofik, M., Wilk, M., Wojdała, G., & Gołaś, A. (2019). Maximizing muscle hypertrophy: A systematic review of advanced resistance training techniques and methods. *International Journal of Environmental Research and Public Health, 16(24), 4897.* https://doi.org/10.3390/ijerph16244897

Lasco, G., & Hardon, A. P. (2020). Keeping up with the times: Skin-lightening practices among young men in the Philippines. *Culture, Health & Sexuality, 22(7), 838–853.* https://doi.org/10.1080/13691058.2019.1671495

Lauersen, J. B., Andersen, T. E., & Andersen, L. B. (2018). Strength training as superior,dose-dependent and safe prevention of acute and overuse sports injuries: A systematic review, qualitative analysis and meta-analysis. British Journal of Sports Medicine, 52, 1557–1563.

Mangine, G. T., Hoffman, J. R., Gonzalez, A. M., Townsend, J. R., Wells, A. J., Jajtner, A. R., Beyer, K. S., Boone, C. H., Miramonti, A. A., Wang, R., LaMonica, M. B., Fukuda, D. H., Ratamess, N. A., & Stout, J. R. (2015). The effect of training volume and intensity on improvements in muscular strength and size in resistance-trained men. *Physiological Reports, 3, e12472.* https://doi.org/10.14814/phy2.12472

McCarty, R. (2016). The alarm phase and the General Adaptation Syndrome: Two aspects of Selye's inconsistent legacy. *In G. Fink (Ed.), Stress: Concepts, Cognition, Emotion, and Behavior (pp. 13–19).* Elsevier. https://doi.org/10.1016/B978-0-12-800951-2.00002-9

Peixoto, R. C. C., Ferreira-Júnior, J. B., Chaves, S. F. L., & Vieira, C. A. (2022). Effects of daily undulating periodization and modified daily undulating periodization on strength and body composition. *Journal of Sports Science and Medicine, 21(1), 81–88.*

Phillips, S. M. (2014). A brief review of critical processes in exercise-induced muscular hypertrophy. *Sports Medicine, 44(S1), 71–77.* https://doi.org/10.1007/s40279-014-0152-3

Phillips SM. The impact of protein quality on the promotion of resistance exercise-induced changes in muscle mass. *Nutr Metab (Lond). 2016 Sep 29;13:64.* doi: 10.1186/s12986-016-0124-8. PMID: 27708684; PMCID: PMC5041535.

Plotkin, D. L., et al. (2024). Calf muscle hypertrophy: A systematic review and meta-analysis. *Journal of Sports Sciences, 42(2), 123–135.* https://doi.org/10.1080/02640414.2023.2212345

Radhakrishnan, M., Misra, A., Balan, R., & Lee, Y. (2020). Gym usage behavior & desired digital interventions: An empirical study. *In Proceedings of the 22nd International Conference on Human-Computer Interaction with Mobile Devices and Services (pp. 97–107).* Association for Computing Machinery. https://doi.org/10.1145/3421937.3422023

Ralston, G. W., Kilgore, L., Wyatt, F. B., & Baker, J. S. (2017). The effect of weekly set volume on strength gain: A meta-analysis. *Sports Medicine, 47(12), 2585–2601.* https://doi.org/10.1007/s40279-017-0762-7

Räntilä, H., Ahtiainen, J. P., Peltonen, H., Walker, S., & Häkkinen, K. (2021). *Muscle hypertrophy and strength adaptations in different training frequency and volume conditions in trained men.* Journal of Strength and Conditioning Research, 35(3), 681–689. https://doi.org/10.1519/JSC.0000000000002930

Rojas, A. (2016). I'm super-setting my life! An ethnographic comparative analysis of the growth of the gym market. *Sport Science Review, 25(1–2), 15–32.* https://doi.org/10.1515/ssr-2016-0015

Scarpelli MC, Nóbrega SR, Santanielo N, Alvarez IF, Otoboni GB, Ugrinowitsch C, Libardi CA. Muscle Hypertrophy Response Is Affected by Previous Resistance Training Volume in Trained Individuals. *J Strength Cond Res. 2022 Apr 1;36(4):1153-1157.* doi: 10.1519/JSC.0000000000003558. PMID: 32108724.

Schoenfeld, B. J., Ratamess, N. A., Peterson, M. D., Contreras, B., Tiryaki-Sonmez, G., & Alvar, B. A. (2014). Effects of different volume-equated resistance training loading strategies on muscular adaptations in well-trained men. *Journal of Strength and Conditioning Research, 28(10), 2909–2918.* https://doi.org/10.1519/JSC.0000000000000480

Schoenfeld, B. J., Grgic, J., Van Every, D. W., & Plotkin, D. L. (2021). Loading recommendations for muscular hypertrophy: A critical review. *Sports Medicine, 51(5), 987–1010.* https://doi.org/10.1007/s40279-020-01373-7

Schoenfeld, B. J., Ogborn, D., & Krieger, J. W. (2017). Dose-response relationship between weekly resistance training volume and increases in muscle mass: A systematic review and meta-analysis. *Journal of Sports Sciences, 35(11), 1073–1082.* https://doi.org/10.1080/02640414.2016.1210197

Spineti, Juliano & Miranda, Humberto & de Salles, Belmiro & Oliveira, Liliam & Simão, R.. (2014). The effects of exercise order and periodized resistance training on maximum strength and muscle thickness. *International SportMed Journal. 15. 374-390.*

Snijders, T., Nederveen, J. P., McKay, B. R., Joanisse, S., Verdijk, L. B., van Loon, L. J. C., & Parise, G. (2016). Satellite cells in human skeletal muscle plasticity. *Frontiers in Physiology, 7, 583.* https://doi.org/10.3389/fphys.2016.00583

Stokes, T., Hector, A. J., Morton, R. W., McGlory, C., & Phillips, S. M. (2018). Recent perspectives regarding the role of dietary protein for the promotion of muscle hypertrophy with resistance exercise training. *Nutrients, 10(2), 180*. https://doi.org/10.3390/nu10020180

Suchomel, T. J., Nimphius, S., Bellon, C. R., & Stone, M. H. (2018). The importance of muscular strength: Training considerations. *Sports Medicine, 48, 765–785.* https://doi.org/10.1007/s40279-018-0862-z

Tan, Y. B., Vitriana, & Nurhayati, T. (2016). Correlation between mid-upper arm muscle area/size and muscle strength. *Althea Medical Journal, 3(3), 355–359.* https://journal.fk.unpad.ac.id/index.php/amj/article/view/944/0

Zubair, Ahsanul. (2023). Experimental Research Design-types & process. *Academia Open.*