CONCORDIA UNIVERSITY, ST. PAUL

ST. PAUL, MINNESOTA

DEPARTMENT OF KINESIOLOGY AND HEALTH SCIENCES

The Effect of Exercise Order and Range of Motion on Gluteal Muscular Strength in a DUP Training Protocol

A DISSERTATION PROJECT

SUBMITTED TO THE GRADUATE FACULTY

In partial fulfillment of the requirements

for the degree of

Doctorate in Kinesiology

by

Jaime Alnassim

St. Paul, Minnesota

July, 2025

Acknowledgements

I would like to thank my dissertation committee at Concordia University, St. Paul, for their guidance and support throughout this research process. Special thanks to Dr. Stephanie Hamilton, who served as committee chair, as well as to Dr. Brian Serrano and Dr. Eric Lamott for their valuable feedback and oversight.

I also sincerely appreciate the twelve participants who contributed their time and effort to this study. While their identities remain confidential, their commitment was essential to completing this project.

Abstract

This study investigated how exercise order and range of motion (ROM) influence gluteal muscular strength and hypertrophy within a Daily Undulating Periodization (DUP) training framework. Specifically, it compared the effects of beginning training sessions with either a glute-focused isolation movement with limited ROM (hip thrust) or a glute-lengthening compound movement with extended ROM (MC reverse lunge). A 12-week randomized controlled trial was conducted with trained participants divided into two groups based on exercise sequence. Strength was measured using five-repetition maximum (5RM) testing, while gluteal hypertrophy was assessed through circumferential measurements. Both groups demonstrated significant improvements in strength and muscle size. Notably, the group that began with the MC reverse lunge showed greater hip and thigh circumference increases, while the hip thrust-first group exhibited higher strength gains in the reverse lunge. These findings suggest that exercise order within DUP protocols can influence localized hypertrophic outcomes, with extended ROM exercises potentially offering greater benefits when prioritized early in a session. This study contributes practical insights for fitness professionals and strength coaches aiming to optimize glute-focused training strategies.

Keywords: Glute training, strength periodization, exercise sequencing, hypertrophy, range of motion

TABLE OF CONTENTS

Chapter 1: Introduction

Background Information

Resistance training, a form of exercise that employs external resistance to stimulate muscular contraction, is pivotal for muscle strength, hypertrophy, and endurance development. Muscle hypertrophy is not only sought after for athletic performance but is also pursued for aesthetic appeal, injury prevention, and to counter age-related muscle decline (Bamman, 2018). Linear Periodization is more regimented than nonlinear approaches, characterized by a methodical increase in intensity and a corresponding decrease in volume over predetermined periods. This time-tested approach systematically organizes training into distinct phases, typically prioritizing endurance, hypertrophy, and strength in sequence. In contrast, Nonlinear Periodization, also known as undulating periodization, adopts a more flexible strategy that involves frequent changes in training variables such as intensity, volume, and type of exercise. This variation can occur weekly or even daily, as seen in Daily Nonlinear Periodization, where workouts vary significantly from one session to the next. Studies indicate that while both linear and nonlinear periodization leads to improvements in strength and overall fitness, the daily adjustments characteristic of nonlinear periodization may offer superior enhancements in strength due to the constant stimulation and adaptation processes it invokes (Fleck, 2011; Monteiro, 2009; Rhea, 2002; Simão, 2012b).

The Daily Undulating Periodization (DUP) framework, a specific type of nonlinear periodization, is a flexible training protocol that alternates the focus of each workout session, allowing for variations in intensity and volume. This approach is part of the broader category of nonlinear periodization strategies but is distinct in its daily or session-to-session variation. DUP facilitates ongoing adaptations in strength, hypertrophy, and endurance by avoiding monotonous stimuli and reducing the likelihood of hitting performance plateaus, thereby providing distinct advantages over more traditional, linear training periodization models. (Miranda, 2011; Gavanda, 2019; Soares, 2020)(Miranda, 2011; Gavanda, 2019; Soares, 2020).

In contrast to linear periodization, by oscillating the training type within a week or even within a session, DUP allows for the simultaneous targeting of different training adaptations, such as strength, hypertrophy, and power. This dynamic approach keeps the neuromuscular system constantly adapting and reduces the risk of overtraining specific muscle groups (Bompa and Haff, 2009). Moreover, by frequently shifting the training focus, DUP can mitigate monotony and keep the training stimulus fresh and engaging for the athlete (Gleeson, 2000; Pyne, 2000).

However, the effectiveness of the DUP model is contingent on more than just its periodization strategy. In general, exercise order affects strength and hypertrophy outcomes, with greater strength increasing when certain exercises are placed at the beginning of a session (Simão, 2012a). Proper sequencing ensures the muscles are primed and worked to maximize potential growth and strength gains without undue fatigue. For instance, beginning a workout with compound movements that target multiple muscle groups can set the tone for subsequent isolation exercises (Stand, 2009).

The order of exercises in DUP is paramount (Simão, 2012a), as it can influence the adaptive responses to training. Starting with multi-joint movements that require more energy and coordination helps to maximize performance when the athlete is least fatigued (Zajac, 1993). Research examining the impact of fatigue on multi-joint kinematics during repetitive lifting tasks found that fatigue decreased knee and hip motion and increased lumbar flexion. These changes suggest a shift in the body's management of multi-joint movements under fatigue conditions (Sparto, 1997). Fatigue is also important in training and performance, especially in tasks involving coordinated multi-joint movements (Sparto, 1976).

Furthermore, the choice of exercises, particularly concerning the range of motion and muscle activation patterns, becomes paramount (Pallarés, 2021). The range of motion (ROM) in an exercise refers to how much a joint moves during an exercise. Utilizing a full range of motion generally engages more muscle fibers by stretching and contracting muscles more fully, enhancing strength gains and muscle growth. Conversely, a limited ROM may focus tension on specific muscle areas, which is useful for targeting strength or muscle activation in those regions. Limiting the range of motion in resistance training can lead to greater isometric strength gains in the trained range (Graves, 1998). Therefore, selecting exercises that best suit the day's training focus, whether maximal strength, hypertrophy, or power, is crucial as it directly impacts the effectiveness of each training session.

The Hip Thrust has surged in popularity within strength training programs since first being introduced by Bret Contreras in a T Nation blog post in September 2009 (Contreras, 2009), particularly for its targeted engagement of the gluteal muscles. Although it offers a more limited ROM compared to exercises like the MC Reverse Lunge, popularized by Coach Mark Carroll, which promotes more significant glute lengthening, the efficacy of the hip thrust lies in its dual nature. Unlike typical isolation exercises that target one muscle group, the hip thrust functions similarly to multi-joint exercises in terms of its demand for multiple muscle interactions and systemic neuromuscular activation. This allows it to effectively integrate at the beginning of workout sessions to maximize energy utilization and muscle engagement. For example, Bret Contreras's book 'Glute Lab' often recommends starting workouts with the hip thrust to exploit its compound exercise-like benefits (Contreras, 2009, p. 326). This practice deviates from conventional resistance training guidelines, which advocate beginning sessions with multi-joint exercises to enhance overall muscle strength and hypertrophy, thereby preventing the early muscle fatigue that could impede performance in subsequent exercises (Brandão, 2020). Performing the hip thrust early in a session takes advantage of this peak energy. Dr. Bret Contreras advocates positioning the hip thrust first because the exercise stresses end-range hip extension, where the gluteus maximus is most activated in a shortened position.

Furthermore, the hip thrust provides a stable and safe movement pattern, making it easier to learn and execute, especially for beginners or those focusing on building confidence in their lifting capabilities. The stability offered by the hip thrust allows for the safe use of heavy loads, and the ability to overload the hip thrust progressively with increased weight also aids in effectively tracking and measuring strength progress (Contreras et al., 2015; Plotkin et al., 2023). By prioritizing primary lifts like the hip thrust at the beginning of a workout, trainers and athletes can maximize the results for the gluteal muscle group.

Thus, the hip thrust is commonly positioned at the beginning of a workout alongside other compound movements before transitioning to isolation exercises such as the cable glute kickbacks, making it a rare isolation exercise.

Further, the barbell hip thrust is known for its effective activation of the gluteus maximus and biceps femoris muscles, more so than exercises like the back squat (Contreras, 2015). This enhanced muscle engagement is particularly important because the gluteus maximus plays an important role in various athletic movements and overall strength, making its development a priority in strength training.

Understanding the relationship between ROM and exercise effectiveness is key. Exercises with a full ROM are often touted for promoting greater hypertrophy, as they work muscles through their complete functional capacity, leading to increased muscle fiber recruitment. However, hip thrust challenges this convention despite its limited ROM, providing substantial gluteal muscle activation and growth. This suggests that effectiveness may also depend heavily on targeting specific muscles with appropriate exercises, regardless of their ROM. The choice to investigate the hip thrust within the DUP framework is thus based on its proven ability to deliver targeted, intense muscle activation, which could theoretically lead to superior gains in muscle strength and hypertrophy compared to exercises that utilize a greater ROM but may not as effectively engage the gluteal muscles.

This refined understanding of how ROM influences the effectiveness of specific exercises within DUP helps justify the focus on the hip thrust in our study. It underscores the potential for exercises with limited ROM to contribute significantly to muscle development and strength, challenging broader assumptions about training practices and providing a focused inquiry into optimizing exercise order for maximal benefit.

Additionally, the strategic ordering underscores the importance of understanding how exercise ROM affects muscle activation and fatigue and how it dictates the programming within the DUP framework. The existing literature, including the insights by Schoenfeld (2020) and Grgic (2020), suggests that complete ROM exercises may offer superior hypertrophy benefits. Nevertheless, the pervasive inclusion of the hip thrust in DUP programs necessitates a closer examination of its optimal placement and impact, particularly given its complex role that straddles the characteristics of both isolation and compound exercises.

Gaps in Research

Numerous studies have highlighted the advantages of exercises that utilize a full range of motion, as evidenced by the extensive research in this area (Massey, 2005; Pinto, 2012; Wolf, 2023), but the specifics concerning exercises like the hip thrust with its distinctive emphasis on glute isolation and limited ROM (Neto, 2020b) have yet to be fully explored. Additionally, as noted by Dr. Bret Contreras, “squats involve almost twice as much range of motion (ROM) in terms of barbell displacement than hip thrusts, in addition to more time under tension at identical rep ranges” Contreras, B., 2016).

The hip thrust has been a staple in many training protocols, prompting questions about its optimal placement within the DUP training. Although its limited ROM contrasts with exercises emphasizing glute extended ROM, such as MC Reverse Lunges, its popularity and atypical programming alongside multi-joint exercises necessitate a deeper understanding of its effects. Furthermore, the interplay between ROM and muscle-specific outcomes, especially concerning the gluteal muscles within a DUP protocol, remains under investigation. This lack of specificity, particularly concerning exercise order, leaves practitioners and trainers with limited evidence-based guidance for structuring effective glute-centric workouts within a DUP framework. Recognizing and addressing this void, the current research endeavors to lay the groundwork for such investigations. It proposes that thoroughly examining ROM variations and their effects on the gluteal muscles could significantly enhance the specificity and efficacy of DUP training programs.

Problem Statement

This study investigates the impact of exercise order within a Daily Undulating Periodization (DUP) training protocol, specifically examining the effects of prioritizing a glute extended ROM movement versus a limited ROM exercise, such as the hip thrust, on gluteal muscular strength. The research compares and contrasts these approaches to understand which sequencing may lead to more effective strength development in the gluteal muscles.

Hypothesis

This research hypothesizes that within the framework of Daily Undulating Periodization (DUP), initiating a training session with the hip thrust, a glute-focused exercise with a limited range of motion (ROM), will lead to superior strength outcomes for the gluteal muscles compared to beginning with an extended ROM exercise such as the MC Reverse Lunge. Additionally, it was hypothesized that exercise order would also influence hypertrophy outcomes, with the hip thrust–first group expected to experience equal or greater gluteal hypertrophy compared to the reverse lunge–first group.

Definitions

- *Daily Undulating Periodization (DUP):* A strength training methodology where variations in training type, be it strength, hypertrophy, or power, oscillate daily within a week.
- *Linear Periodization:* A traditional method for structuring training wherein variables (like load or volume) change gradually over time. This helps contrast DUP for those unfamiliar with different periodization strategies.
- *Concentrated ROM:* Refers to a specific, focused range of motion in an exercise, which typically targets a specific muscle or group of muscles with intense isolation.
- *Extended ROM:* Involves a broader, more comprehensive range of motion that engages multiple muscle groups, often in complex, compound movements.
- *Limited ROM*: Refers to a range of motion in an exercise that is not fully extended, typically to focus the intensity on a specific muscle or group of muscles.

- *Shallow Range*: Describes a minimal range of motion in an exercise that targets muscles with minimal joint movement. This approach can help increase muscular endurance and maintain tension on the targeted muscle.
- Deeper Range: Refers to executing an exercise with a maximal range of motion, allowing for greater muscle stretch and contraction. This method is often used to enhance flexibility and overall muscle strength.
- *Activation:* In a muscular context, it refers to a muscle's engagement or "firing" during an exercise.

Assumptions & Limitations

This study operates under the assumption that all participating individuals will adhere to the outlined exercise protocols. Thus, any observed differences in muscle hypertrophy and strength are primarily attributed to the variations in exercise order. However, a potential limitation lies in the interplay of individual genetic predispositions, dietary habits, and recovery dynamics, which may inadvertently influence hypertrophic and strength outcomes.

Unlike other studies, this research will not employ INOLs (Intensity and Number Of Lifts) to gauge intensity using percentages for the weight per the repetitions with each set. Instead, it will rely on the Rate of Perceived Exertion (RPE) for participants. While using RPE over percentages might pose limitations, it also has advantages. As highlighted by Helms et al. (2018a), both loading types have been found effective. Yet, RPE-based loading might confer a slight strength advantage in most individuals' one-repetition maximum (1RM) (Helms, 2018b; Suchomel, 2021.

Within the DUP protocol employed in this study, a specific day features two distinct sets. The first set encompasses three repetitions using a predetermined weight. Following this, while utilizing the same weight, the second set employs an AMRAP (As Many Repetitions As Possible) rep scheme. The outcome of the AMRAP set informs the subsequent week's weight progression: participants achieving seven or more repetitions will have the weight increased for both sets in the ensuing week. Conversely, the weight remains consistent in the subsequent week if they perform fewer than seven repetitions.

This AMRAP method is integral to the protocol as it supports several foundational principles of strength training. It allows for progressive overload, a key factor in strength and muscle gains, by providing a clear benchmark for when to increase weights. It also facilitates auto-regulation, letting lifters adjust their workout intensity based on daily performance variations influenced by factors like sleep and nutrition (Zhang, 2021). Additionally, it aids in tracking performance improvements and setting specific fitness goals that can help improve performance (Kyllo, 1995). Moreover, the challenge of exceeding previous marks in the AMRAP set can significantly boost engagement and motivation, making it especially beneficial for lifters who thrive on personal achievement (Deci, 1999).

This AMRAP system offers a structured approach to monitor participants' progress. However, inherent challenges exist. Individual variability in mental fortitude and intrinsic motivation can considerably affect the number of repetitions executed during the AMRAP set. Such variability presents a potential limitation, as it might induce inconsistent participant results.

Lastly, there's a challenge in how the researcher sets the weekly weights for participants based on the next week's RPE. This could introduce potential bias if participants report inaccurate RPE values, possibly affecting the study's reliability.

Significance of Study:

This study's findings are poised to contribute to understanding DUP training protocols, specifically targeting gluteal muscular strength. Venturing into a relatively underexplored area, this research offers evidence-based insights into exercise order and range of motion within the DUP framework. Additionally, by finding an optimal configuration for gluteal exercises, fitness professionals, athletes, and gym goers can use this knowledge, enabling them to make informed decisions in designing their training programs. Ultimately, this study serves not just as an academic endeavor but as a practical guide for those seeking to maximize the potential of their lower body workouts, enriching both the scholarly community and the broader fitness industry.

Chapter 2: Literature Review

The efficacy of various strength training protocols continues to be a focal point of research due to their profound impact on athletic performance, rehabilitation, and general health. This literature review explores a broad spectrum of training methodologies, particularly focusing on Daily Undulating Periodization (DUP). By examining scholarly articles and studies, this section elucidates how different training protocols and exercise specifics contribute to strength training outcomes, shedding light on the nuanced interplay between exercise order, intensity, and range of motion.

The primary objective of this literature review is to dissect the complexities of DUP and other prevalent training models, such as linear periodization and non-linear periodization. This analysis seeks to uncover the underlying mechanisms that make DUP a potentially superior method for enhancing muscular strength and hypertrophy. A significant focus will be placed on the hip thrust exercise. This movement has garnered attention for its specific efficacy in targeting the gluteal muscles, is pivotal for both athletic performance and postural stability. Studies by Schoenfeld & Grgic (2020), Pinto et al. (2012), Kassiano et al. (2022), Simão et al. (2005), and Simão et al. (2012) have pointed out the differential impacts of exercise specifics, such as range of motion and exercise sequence, on hypertrophy and strength. This review integrates these findings to comprehensively understand how hip thrust can be optimized within various training schemas to maximize hypertrophic outcomes.

Theories of Training Programming

Linear Periodization

Linear periodization represents a classical approach in strength training, characterized by a systematic progression in which intensity increases while volume decreases over a predetermined period. This method is traditionally structured in phases, starting with a high training volume at lower intensities and gradually transitioning to lower volumes at higher intensities. This phased approach is designed to culminate in peak performance for competitions or specific performance benchmarks.

Research, including studies by Rhea et al. (2002), supports the effectiveness of linear periodization in progressively building strength and conditioning over time. This model helps athletes build a solid foundation of endurance, strength, and power by methodically increasing the training load. However, its structured nature may also be a limitation, particularly for advanced athletes. The predictability of the training loads and the prolonged focus on specific training goals without variation can lead to plateauing neuromuscular adaptations. This plateau occurs as the body becomes efficient at managing the demands of the routine, reducing the overall stimulus for adaptation.

Critics of linear periodization point out that its rigid structure may not adequately respond to the athlete's day-to-day performance fluctuations, as it involves infrequent stimulus variation, potentially leading to a plateau in strength gains due to the neuromuscular system adapting to the predictable stresses and can cause training staleness due to the lack of novelty in the regimen (Rhea, 2002), potentially leading to overtraining or insufficient recovery during critical phases. This inflexibility can also contribute to psychological staleness, as the monotonous progression might diminish an athlete's motivation over time.

While linear periodization has proven benefits, especially for beginners or those new to structured training, its limitations suggest a need for more dynamic and flexible approaches as athletes progress and their training needs evolve. This realization underpins the importance of incorporating varied training stimuli to continuously challenge the neuromuscular system and foster ongoing improvement in strength and performance.

Nonlinear Periodization

Nonlinear periodization, commonly referred to as undulating periodization, employs a flexible approach to strength training by frequently varying the training load, intensity, and type of exercise within a shorter cycle. This methodology might involve adjustments on a daily, weekly, or even monthly basis, depending on the specific goals and responses of the athlete. Such variability is designed to provide a continually changing stimulus to the body, which can help in circumventing the training plateaus often associated with more predictable, linear training schedules.

The core advantage of nonlinear periodization is its adaptability. It allows for the modulation of training intensity and volume in response to the athlete's ongoing performance, fatigue levels, and overall physical condition. This dynamic approach helps maintain a high level of neuromuscular stimulation, which is crucial for advanced athletes who require constant variation to continue making gains. Studies, such as those cited by Fleck (2011), have demonstrated that this form of periodization can significantly improve strength, hypertrophy, and overall athletic performance by preventing the adaptation plateau that diminishes returns from more monotonous training routines.

Nonlinear periodization is particularly advantageous for athletes involved in multiple competitions throughout the year. It provides the flexibility to peak multiple times within a year by adjusting training loads to taper or intensify efforts based on competitive schedules and recovery states. This is contrasted with linear periodization, which typically targets a single peak performance after a longer phase of gradual progression.

Furthermore, the responsive nature of nonlinear periodization supports better management of overtraining risks. By tailoring training loads to daily or weekly recovery status, coaches can optimize training intensity to match the athlete's current capability, thereby enhancing recovery and reducing the likelihood of injury. This aspect of nonlinear periodization is supported by research suggesting that athletes report higher levels of engagement and motivation due to the varied and challenging nature of their training schedules.

Overall, nonlinear periodization represents a sophisticated approach to training program design that caters to the evolving needs of competitive athletes. Its ability to integrate flexibility with systematic progression allows it to address the complex demands of sports performance. It is preferred for athletes aiming for continual improvement and peak conditioning at crucial times throughout their competitive calendar.

Daily Undulating Periodization (DUP)

Daily Undulating Periodization (DUP) is a subtype of nonlinear periodization characterized by the frequent variation of training variables such as intensity, volume, and type of exercise on a session-by-session basis. This approach enables simultaneous targeting of multiple fitness components, strength, hypertrophy, and endurance, within the same training week. The effectiveness of DUP stems from its ability to optimize training frequency for each muscle group, ensuring adequate recovery and adaptation, thus preventing the typical plateaus associated with more predictable training schedules.

Studies such as those conducted by Miranda et al. (2011) and Prestes et al. (2009) have underscored the superior outcomes of DUP regarding strength and hypertrophy compared to traditional linear periodization. These studies measured specific markers of muscle strength, such as maximal strength tests (one-repetition maximum or 1RM) and muscle size through standardized hypertrophy assessments, demonstrating improved strength and greater increases in muscle cross-sectional area.

A seminal study by Rhea et al. (2002) conducted a randomized controlled trial to test these principles rigorously. This study compared the strength outcomes of athletes undergoing DUP versus traditional linear periodization, finding that those in the DUP group showed notably superior strength gains. What sets this study apart is its methodological rigor, using a Randomized Controlled Trial ensures a high level of scientific credibility by minimizing selection bias and controlling for external variables. Additionally, the specificity of the training protocols was meticulously controlled, ensuring that any observed differences were attributable directly to the periodization strategy.

The practical significance of this research extends to its real-world applicability, demonstrated by including athletes from various sports. This breadth enhances the study's external validity, suggesting that DUP's benefits are not confined to laboratory settings but are evident in diverse training environments. Further research, including work by Miranda (2011) and Prestes (2009), supports these findings, with DUP showing enhanced efficacy in improving muscular strength and maximal performance outputs compared to Linear Periodization.

However, despite these strengths, Rhea et al.'s study (2002) did face limitations such as a relatively small sample size and the short duration of the training programs, which might limit the generalizability of the results. Moreover, the study does not explore how different exercises, such as hip thrusts, might interact within a DUP framework to maximize specific hypertrophic or strength outcomes, pointing to a gap in the current literature.

The supposed superiority of DUP over Linear Periodization lies in its inherent variability and individualized approach to training adaptation. By frequently altering training stimuli, DUP prevents adaptation plateaus commonly seen in Linear Periodization, where the predictability of the stimulus over time can lead to diminished returns. This variability ensures that muscle groups are continually challenged with new stimuli, a critical factor for ongoing muscular development and strength improvements.

Understanding DUP's foundational principles and empirically demonstrated efficacy is crucial for integrating specific exercises, such as hip thrusts, into effectively structured strength training programs. The exploration of DUP lays the groundwork for a comprehensive analysis of exercise sequencing within this framework, paving the way for future investigations into the optimal configuration of exercises for maximal training efficacy.

Factors Affecting DUP Outcomes

The choice of exercises and their sequencing within a Daily Undulating Periodization (DUP) framework plays a pivotal role in maximizing the effectiveness of the training program. The complexity and type of exercises selected significantly affect muscle activation and physiological adaptations. Compound exercises like squats and deadlifts involve multiple muscle groups and joints, making them ideal for beginning training sessions when energy levels are highest. This placement maximizes strength and power outputs, leveraging the body's full capability before fatigue sets in (Simão, 2012a).

In contrast, isolation exercises such as bicep curls and tricep extensions specifically target individual muscles and are beneficial for addressing muscle imbalances or weaknesses. These exercises are typically scheduled later in the workout when the primary goal shifts towards muscle endurance and targeted hypertrophy. According to Schoenfeld (2020) and Grgic (2020), incorporating a balanced mix of compound and isolation exercises within a DUP regimen enhances overall hypertrophy and strength gains. This strategic placement ensures that each muscle group receives adequate attention and stimulation, optimized for the time of training and the athlete's energy availability, leading to more effective and sustained physiological adaptations.

Range of Motion and Muscle Development

The range of motion (ROM) in exercises prescribed under DUP protocols crucially impacts muscle activation and growth. Exercises performed with a full range of motion generally involve more muscle fibers, leading to greater increases in muscle size and strength. Conversely, partial ROM exercises can be used strategically to intensify training or focus on specific muscle segments to overcome weaknesses. This notion is supported by the comparative analysis of Schoenfeld & Grgic (2020), which found that full range of motion (fROM) exercises yield better hypertrophy and strength improvements than partial range of motion (pROM) exercises. Hence, fROM resistance training is more effective than pROM training for maximizing lower limb muscle hypertrophy, but not all pROMs are inferior to fROM (Kassiano, 2022). Additionally, using pROM in the initial part of the exercise combined with fROM training can optimize muscle growth in certain muscles (Kassiano, 2023). Such findings highlight the need for thoughtful integration of ROM variations in training programs to leverage their potential in muscle development fully.

The sequence in which exercises are performed can significantly influence the outcomes of a DUP program. Initiating a session with compound movements maximizes performance due to higher energy levels, thereby supporting greater loads, which are essential for strength development. Conversely, beginning with isolation exercises can pre-exhaust targeted muscles, potentially enhancing their activation during subsequent compound movements, benefiting hypertrophy but possibly reducing the total volume that can be achieved. This dynamic is underscored by studies such as those by Assumpção et al. (2013), which demonstrate that manipulating exercise order can profoundly affect acute performance and long-term training adaptations.

These insights about exercise selection, ROM, and sequencing collectively inform the broader picture of strength training, particularly within the context of DUP. Understanding how these factors interact not only aids in crafting effective training regimens but also sets the stage for exploring the specific roles of exercises like hip thrust in strength training programs. The approach to these factors ensures that training outcomes are optimized, aligning with enhanced athletic performance and effective muscle development goals.

Importance of the Hip Thrust

Biomechanical Analysis

The hip thrust is highly regarded for its targeted activation of the gluteal muscles, especially the gluteus maximus, which is critical in various athletic movements and everyday activities. The exercise is biomechanically designed to apply force directly through the extension of the hips, which isolates and activates the glutes more efficiently than traditional lower-body exercises. This direct load application across the hips minimizes stress on the lower back while concentrating significant force on the glutes. This loading optimizes gluteal muscle activation and mitigates injury risks commonly associated with other compound movements. Electromyographic (EMG) studies, such as those by Contreras et al. (2015), highlight the hip thrust's effectiveness in engaging the necessary muscle fibers for hypertrophy, indicating its pivotal role in strength training programs focused on gluteal development.

Comparison with Other Exercises

The hip thrust stands out for its superior glute activation when juxtaposed with other foundational lower body exercises like squats and deadlifts. While squats and deadlifts contribute to overall lower body strength and muscle development, they predominantly engage the quadriceps and hamstrings. Conversely, hip thrust specifically targets the posterior chain, with a pronounced focus on the glutes. This is supported by research from Contreras et al. (2017) and Delgado et al. (2019), which shows that the hip thrust activates the gluteus maximus more effectively than squats, making it particularly advantageous for targeted glute hypertrophy.

Role in Hypertrophy

The emphasis on glute hypertrophy is beneficial for aesthetic enhancement and boosting athletic performance by improving power outputs in dynamic movements such as sprinting and jumping. Regular inclusion of the hip thrust in training regimes facilitates significant hypertrophic adaptations, which are crucial for stabilizing the pelvis and mitigating injuries to the lower back and knees. Research by Schoenfeld (2012) and Contreras (2016) underscores that hypertrophy in the gluteal muscles enhances force production and movement efficiency, establishing the hip thrust as a fundamental exercise for athletes seeking to elevate their performance.

Integration with the Broader Literature

Recent studies, including those by Plotkin et al. (2023), continue to validate the effectiveness of hip thrusts in strength training, especially for enhancing gluteal muscle development. These findings suggest that hip thrusts, like back squats, contribute significantly to gluteus muscle hypertrophy and effectively transfer to performance in other lifts, such as deadlifts. This body of evidence increasingly underscores the hip thrust's crucial role in targeting the gluteal muscles effectively within strength training programs.

However, while the benefits of hip thrusts are well-documented, the literature also identifies areas needing further exploration. Studies by Contreras et al. (2017) and Barbalho et al. (2020) have raised concerns regarding the representativeness of sample sizes, pointing to a need for more inclusive and diverse research designs. Additionally, Delgado et al. (2019) and Neto et al. (2019) emphasize the importance of proper biomechanics and form in maximizing the effectiveness of the hip thrust and minimizing injury risks. These critiques suggest that while the efficacy of hip thrusts is supported, broader and more varied research is required to fully understand its impact across different demographic groups and training contexts. This expanded research approach would help solidify the hip thrust’s role in strength training and optimize its application in diverse training programs.

These studies collectively suggest that while evidence supports the efficacy of hip thrusts in strength training, a more extensive and diverse body of research is necessary to fully understand its impact across different populations and training contexts.

Conclusion of Literature Review

The reviewed literature provides comprehensive insights into the effectiveness of various training protocols, particularly emphasizing the benefits of Daily Undulating Periodization (DUP). This review has highlighted the importance of exercise selection, sequence, and range of motion in maximizing the outcomes of DUP training. Furthermore, the distinct role of the hip thrust in targeting the gluteal muscles for hypertrophy has been extensively analyzed. The biomechanical advantages of the hip thrust, its superior activation of the glutes compared to other exercises like squats and deadlifts, and its specific contributions to enhancing athletic performance through improved muscle hypertrophy are well-documented.

Despite the broad documentation of DUP and the hip thrust's benefits, significant gaps remain in the literature, particularly concerning the optimal integration of specific exercises within DUP protocols. Most studies provide generalized recommendations without addressing the nuances of exercise arrangement, especially the sequence of compound versus isolation movements like the hip thrust. This gap signifies the need for targeted research to explore how different sequencing affects muscle activation, hypertrophy, and overall training efficacy. Moreover, there is a lack of focused investigation on the longitudinal impacts of starting a workout with the hip thrust compared to other glute-focused exercises within a DUP framework.

Chapter 3: Methodology

This chapter outlines the methodology used to investigate the effects of exercise order on gluteal muscle strength within a Daily Undulating Periodization (DUP) framework. The study was designed to ensure that the research approach was robust, reliable, and capable of generating insights that contributed meaningfully to the existing body of knowledge on strength training and exercise sequencing.

The methodology compared two distinct exercise orders: beginning workouts with a glute-shortening exercise (hip thrusts) versus starting with a glute-lengthening exercise (MC reverse lunges). This comparison was grounded in the hypothesis that the sequence in which these exercises were performed could have a differential impact on gluteal strength and hypertrophy development. By adopting a randomized controlled trial design, the study aimed to minimize bias and maximize the reliability of the findings, ensuring they reflected actual training effects rather than experimental artifacts.

This methodology, informed by prior research practices, provided a strong foundation for determining the most effective design for strength training programs focused on exercise sequencing and gluteal development.

Participants

For this study, participants were carefully selected to ensure that the results were both relevant and applicable to a specific population actively engaged in or interested in strength training. The study aimed to include a diverse group of individuals to examine any potential gender-specific responses to the exercise protocols, necessitating the inclusion of both male and female participants. The age range for participation was set between 18 and 35 years, targeting adults capable of providing informed consent.

Participants were required to have a minimum of two years of consistent resistance training experience to ensure familiarity with general strength training practices. Additionally, all participants needed prior experience with hip thrust exercises to ensure performance consistency and minimize the learning curve. This prerequisite helped isolate the variable of exercise order by reducing variation in exercise execution.

Health status and physical condition were also critical factors in participant selection. Eligible individuals were required to be free from any cardiovascular, musculoskeletal, or neurological conditions that could be exacerbated by resistance training. Furthermore, to preserve the integrity of the study's findings, participants were excluded if they reported using any performance-enhancing drugs. These selection criteria were implemented to ensure that observed changes in strength or hypertrophy could be confidently attributed to the training protocols rather than confounding health or pharmacological factors.

Recruitment Process

The recruitment process for this study was designed to attract a diverse pool of participants who met the outlined criteria, facilitating a robust and representative sample for investigating the effects of exercise order within a DUP training protocol. Recruitment was conducted primarily through social media platforms such as Reddit, Instagram, and Facebook to ensure a broad and inclusive participant base. These platforms were chosen for their wide reach and popularity among individuals actively engaged in or interested in strength training. Social media allowed the researcher to target a demographic likely to meet the study's age and experience requirements and who were typically enthusiastic about participating in research related to training enhancement.

Screening and Selection

Upon expressing interest, individuals were directed to a brief online form where they provided basic information such as age, gender, and a short description of their resistance training background. This step ensured that participants met the basic inclusion criteria, particularly the minimum required experience with strength training and familiarity with hip thrust exercises.

Health Assessment and Informed Consent

After the initial screening, eligible participants were asked to complete a Physical Activity Readiness Questionnaire (PAR-Q) and a few additional questions about their exercise history. The PAR-Q served as a standard tool to quickly assess whether participants had any medical conditions or risk factors that could be exacerbated by strength training. Only those who cleared the health screening proceeded to the next phase.

Participants who met all eligibility requirements received detailed information about the study's objectives, procedures, expected outcomes, and potential risks. This informational briefing ensured that all individuals were fully informed about the nature of the research and their expected involvement.

This session also allowed participants to ask questions and express any concerns regarding the study. All participants were required to provide written informed consent, indicating that they understood the study details and agreed to participate voluntarily. This process upheld ethical research practices by ensuring participant safety, transparency, and autonomy throughout the recruitment phase.

Instruments

This study utilized two primary tools and measurement techniques to assess outcomes related to both strength gains and muscle hypertrophy.

Strength Gains Measurement

Strength was evaluated using the five-repetition maximum (5RM) test, a validated and reliable method for assessing strength gains in recreational athletes (Gail, 2014). This test measures a participant's maximum load for five consecutive repetitions with proper form. The 5RM test was administered using standard weightlifting equipment, including barbells, weight plates, and safety apparatuses. Key exercises tested included the barbell hip thrust and the MC reverse lunge for both legs. These assessments were conducted at the beginning (pre-test) and conclusion (post-test) of the study period to measure changes in strength resulting from the training intervention.

Muscle Hypertrophy Measurement

Muscle hypertrophy was assessed using circumferential measurements taken with a standard tape measure, specifically targeting the gluteal region. This non-invasive method allowed for consistently tracking muscle size changes throughout the study. Measurements were taken at clearly defined anatomical landmarks to ensure accuracy and repeatability. For the gluteal region, the measurement site was the fullest part of the buttocks, typically around the greater trochanter, a palpable bony landmark at the upper thigh. All participants were measured while standing with feet together, and care was taken to ensure that the tape was horizontal and snug without compressing the skin.

Although this method provided a practical means of tracking changes in gluteal size, it is important to note that the 12-week duration of the study may not have been sufficient to capture substantial hypertrophic changes. This limitation was acknowledged in interpreting results to manage expectations regarding observable muscle growth within the study timeframe.

These tools were selected for their practicality, reliability, and validity in applied settings. By utilizing established methods such as the 5RM test and standardized tape measurements, the study aimed to collect accurate and meaningful data to evaluate the effectiveness of exercise order within a DUP training protocol. Consistent testing procedures helped ensure that results were replicable and relevant to the broader context of strength training research.

Reliability and Validity

The tools and methods used in this study, specifically the five-repetition maximum (5RM) test and circumferential tape measurements, were selected to ensure that the data collected were both reliable and valid, allowing for meaningful interpretation of the training protocol's effects.

5RM Test Reliability and Validity

The 5RM test is widely regarded as a reliable and valid method for assessing maximal strength. Research supports that multi-repetition testing can accurately estimate one-repetition maximum (1RM) strength (Reynolds, 2006). In this study, the 5RM test directly measured participants' ability to lift a specific weight with proper form for five consecutive repetitions. Its reliability was enhanced through the use of a standardized protocol, which ensured consistent administration across all participants and test sessions. This consistency enabled accurate comparisons of strength gains throughout the study and supported the credibility of the strength-related findings.

Tape Measurements for Muscle Hypertrophy

Although circumferential tape measurements are not the most precise method for assessing hypertrophy, they are commonly used in both research and fitness settings due to their simplicity, cost-effectiveness, and non-invasive nature. According to Maylia (1999), tape measurements can identify noticeable differences in muscle size due to resistance training. The study standardized the measurement process to address potential variability in measurement accuracy. Each participant was instructed to have the same assistant take all measurements throughout the study to reduce variability and human error. This approach enhanced consistency and improved the validity of the hypertrophy data collected.

Ensuring Consistent Data Collection

To further support reliable data collection, all participants were provided with detailed visual and written guidelines at the start of the study. These instructions outlined how to properly position and read the tape measure using specific anatomical landmarks, such as the greater trochanter for gluteal measurements. This ensured that measurement conditions were as consistent and accurate as possible, even in remote or unsupervised settings.

Justification for Instrument Selection

Their acceptance within the strength training research community justified the use of the 5RM test and circumferential tape measurements. These tools aligned with the study's objectives to assess changes in both muscular strength and size in a manner that was accessible, practical, and sufficiently rigorous. Together, they provided a solid foundation for collecting actionable data and generating insights into the influence of exercise order within a DUP framework.

Procedures

Exercise Protocols

The primary aim of this study was to evaluate the impact of exercise order within a Daily Undulating Periodization (DUP) framework, with a specific focus on two exercises: the hip thrust and the MC reverse lunge. The investigation centered on whether the sequence in which these exercises were performed influenced outcomes in strength gains and muscle hypertrophy.

Group Allocation and Exercise Order

Participants were divided into two groups to assess the effects of differing exercise sequences:

- Group One: Participants in this group initiated their workout sessions with the MC Reverse Lunge, followed by the hip thrust. This sequence allows for examining the effects of a leg-dominant, glute-lengthening exercise preceding a targeted gluteal exercise.
- Group Two: Conversely, participants in this group started their sessions with hip thrusts, followed by the MC Reverse Lunge. This order focuses on the impact of starting with a glute-specific, shortening exercise on subsequent performance and muscle activation in a leg-dominant exercise.

Group assignment was determined using simple randomization. After all 12 participants were recruited, each was assigned a number from 1 to 12. Numbers were then randomly allocated into one of the two groups, ensuring an equal distribution of six participants per condition.

Workout Frequency, Intensity, and Duration

Both groups performed their designated workouts thrice weekly over a 12-week training period. Training intensity and volume were managed using a periodized approach, which systematically adjusted load and volume to promote adaptation while reducing the risk of overtraining. Each workout session lasted approximately 75 to 90 minutes, including time for warm-ups and cool-downs to ensure safety and effectiveness.

Additional Exercises and Workout Structure

In addition to the primary exercises (hip thrust and MC reverse lunge), each workout included supplementary glute-focused movements. These exercises were programmed with lower intensity and volume to avoid excessive fatigue that might interfere with the study's main outcomes. Including these movements supported a well-rounded training experience while maintaining the study's focus on exercise order as the primary variable. This approach contributed to overall muscular balance and functionality, enhancing the external validity and applicability of the findings.

Ensuring Consistency Across Groups

The workout structure and exercise sequencing were carefully designed to isolate exercise order as the primary independent variable under investigation. This methodology enabled a focused analysis of how initiating a session with either a shortening or lengthening glute exercise affected strength, hypertrophy, and other relevant physiological responses. As a result, the study generated valuable insights into optimal training strategies for improving gluteal muscle performance.

Integration of Progressive Overload and Performance Goals in DUP Workouts

Within the context of this study's Daily Undulating Periodization (DUP) framework, progressive overload was a central component to promote continuous improvement in both strength and muscle hypertrophy. The workout program was designed with specific goals to support progressive overload, including incremental increases in load and targeted performance improvements in AMRAP (As Many Repetitions As Possible) sets. These goals were strategically implemented to drive optimal progress while accommodating individual performance variations.

Weekly Progression Goals

1. Incremental Weight Increases: A primary goal for each training session was to progressively increase the loads used, particularly during the first, second, and fourth workouts of the week. This approach aligned with the principle of progressive overload, emphasizing the need for heavier resistance to stimulate strength and muscular adaptations. The researcher guided each session's appropriate weights and advised participants when to increase the load. The objective was to gradually raise training intensity without compromising form or safety.

2. AMRAP Performance Enhancement: For AMRAP sets, participants aimed to either increase the number of repetitions performed compared to the previous week or achieve a benchmark of seven or more reps. If a participant successfully completed seven or more

repetitions, the protocol called for a weight increase for that exercise in the following week. This strategy ensured that the training stimulus remained sufficiently challenging to promote consistent strength gains.

3. When participants met their workout targets, weights were increased by 2.5 kg (5 lbs) if 1.25 kg (2.5 lb) plates were available, or by 5 kg (10 lbs) if larger increments were required. In cases where initial loads were too conservative, larger increases of up to 10 kg (20 lbs) or more were implemented to ensure the program remained on pace and did not exceed the 12-week time frame. This structured progression ensured participants were adequately challenged while minimizing the risks associated with excessive or insufficient loading.

Weekly progression goals, including incremental increases and AMRAP benchmarks, were detailed in Table 1.

Adjustments Based on Weekly Performance

It was recognized that weekly performance could fluctuate due to fatigue, recovery, or individual response variability. When participants failed to meet a target, such as not achieving the minimum AMRAP threshold or struggling with a recent weight increase, they were instructed to maintain the current weight for the following session. This approach allowed for a sustainable rate of progression, tailored to the participant's current capacity and recovery status.

Feedback and Adjustment

Ongoing feedback from the coach and participant self-monitoring played a critical role in program management. Weekly check-ins and training logs enabled continuous assessment, informing decisions about increasing or maintaining current loads. This dynamic feedback loop helped optimize adaptation, minimize injury risk, and maintain participant engagement throughout the intervention.

Documenting and Analyzing Progress

Participant progress was documented thoroughly, including weights used, reps completed during AMRAP sets, and any training modifications made in response to performance. This comprehensive data collection supported both individual progress tracking and broader analysis of trends across the study. The relationship between progressive overload strategies and training outcomes was examined to evaluate the efficacy of the DUP approach. This analysis contributed to a better understanding of how progressive training parameters influence strength adaptations in practical, real-world settings.

The study maintained a structured, participant-responsive training process by clearly defining and integrating progressive overload and performance benchmarks into the DUP protocol. This approach ensured consistent challenge and adaptation while supporting rigorous, meaningful research outcomes related to glute-focused strength training.

Performance Behavior and Coaching Approach

Coaching Approach and Role Clarification

In this study, while participants received online coaching as part of their involvement, it was important to clarify that the primary purpose of the research was not to deliver individualized coaching, but rather to observe and analyze the effects of exercise order within a DUP (Daily Undulating Periodization) framework. The coaching provided was designed to reflect a typical online coaching environment, ensuring that study conditions closely resembled real-world training contexts. This approach helped ensure that observed outcomes were attributable to the structured exercise protocols, rather than coaching variability or intensity.

Standardized Coaching Communications

To maintain consistency in participant experience, the research team employed a standardized communication protocol. Coaching support focused on reinforcing proper exercise technique, adherence to prescribed workout parameters, and addressing participant questions related to the training structure. Coaching did not extend into areas beyond the study's scope, such as individualized nutrition advice or personal goal setting unrelated to the intervention.

Performance Feedback Collection

After each workout session, participants received a set of standardized questions aimed at capturing their responses to the training and their interactions with the coaching process. These questions were designed to collect:

- Subjective ratings of workout intensity
- Challenges encountered during specific exercises
- Perceptions of instructional clarity
- Overall satisfaction with coaching support

Examples of Standardized Questions

- On a scale of 1–10, how would you rate the difficulty of today's workout?
- On a scale of 1–10, how would you rate the difficulty of each of the following:
    - MC Reverse Lunge
    - Incline Bench Press
    - Barbell Hip Thrust

    - Standing Military Press
- Were there any exercises you found particularly challenging or unclear? *(Asked only during the first two weeks)*
- How clear and helpful were the coaching instructions?
- Do you have any specific feedback or suggestions regarding the workout you received today?

Use of Coaching Feedback Data

The data collected through these questionnaires was used solely for research purposes. They provided insights into how exercise order and coaching interactions influenced participant engagement, adherence, and performance. These responses supported interpretation of training outcomes and offered valuable context for understanding participant experience within a structured, remotely coached training program.

By applying standardized coaching protocols and collecting systematic feedback, the study ensured that all participants received equitable support while maintaining the integrity of the research focus, examining the role of exercise order within a DUP framework.

Design and Data Analysis

Study Design

This research employed a randomized controlled trial (RCT) design, chosen for its ability to minimize bias by randomly allocating participants into two experimental groups. This approach was particularly effective for evaluating the impact of exercise order within a Daily Undulating Periodization (DUP) framework. The study initially aimed to enroll up to 20 participants. Although it primarily targeted women to focus the analysis on gender-specific training outcomes, it was informed by research indicating that gluteal muscle mass and quality are comparable between sexes when matched for exercise exposure and body weight (Belzunce, 2023). Additionally, prior literature suggested that men and women respond similarly to resistance training, eliminating the need for sex-specific training protocols (Holloway, 1990).

Participants were required to have a minimum of one year of experience performing hip thrusts to ensure proficiency and consistent execution. This prerequisite helped maintain data reliability concerning movement technique and performance effects. Participants were randomly assigned to one of two groups:

- Group One began sessions with MC Reverse Lunges, followed by hip thrusts.
- Group Two performed the hip thrust first, followed by MC Reverse Lunges.

This design enabled systematic evaluation of how exercise order influenced outcomes related to gluteal strength and hypertrophy. Using an RCT ensured that any observed differences between the groups could be attributed to the sequencing intervention rather than extraneous variables. Total training volume was carefully controlled across both groups to ensure comparability and isolate the variable of interest, exercise order.

If necessary to meet enrollment targets, male participants were included. In such cases, sex was incorporated as an additional variable in the analysis, enhancing the inclusivity and generalizability of the study findings.

Data Analysis Methods

Several statistical techniques were used to analyze the data collected throughout the study:

- Analysis of Variance (ANOVA) was applied to compare the two groups' primary outcomes related to gluteal strength and hypertrophy. This method allowed for determining whether there were statistically significant differences between group means.
- The primary statistical method employed was mixed-model ANOVA, which is ideal for repeated-measures designs. This approach enabled the analysis of both main effects and interaction effects between time (pre/post testing) and group assignment (exercise order). Mixed-model ANOVA was particularly well-suited for this study, where participants followed different exercise orders and were evaluated over time.

Software for Analysis

Statistical analysis was conducted using software such as SPSS, selected based on their suitability for the study's analytical needs. SPSS was favored for its intuitive interface and robust support for ANOVA procedures. R was considered as a supplementary tool for its flexibility and capacity for advanced statistical modeling, particularly if more complex analyses were needed during post-hoc testing or data visualization.

By combining a rigorous RCT design with detailed statistical analysis, including attention to between-sex differences, this study produced scientifically grounded insights into the role of exercise order in strength training. Specifically, it contributed to a deeper understanding of how hip thrusts and MC Reverse Lunges, within a DUP framework, affect gluteal strength and hypertrophy development.

Ethical Considerations

IRB Approval

The first step in ensuring the ethical integrity of this study was obtaining approval from the Institutional Review Board (IRB). This process began with the submission of a detailed research proposal outlining the study's purpose, methodology, participant involvement, and the measures taken to safeguard participants' rights and well-being. The IRB reviewed the potential risks and benefits of the study to ensure compliance with established ethical standards and regulatory guidelines. Upon receiving IRB approval, the study proceeded under the understanding that any future modifications to the research protocol would require subsequent review and approval.

Informed Consent

Informed consent was a foundational element of ethical research conduct in this study. Prior to participation, all individuals received a consent form that clearly explained the study's purpose, procedures, potential risks or discomforts, and the steps taken to protect their privacy and confidentiality. This document also informed participants of their right to withdraw from the study at any time without penalty. A pre-study orientation session was held to discuss the consent form, during which participants had the opportunity to ask questions and express any concerns. Only individuals who voluntarily agreed to participate and signed the consent form were included in the study.

Confidentiality and Privacy

Several safeguards were implemented throughout the study to protect the confidentiality and privacy of participants. All collected data were anonymized using unique participant identifiers, ensuring that personal information was not linked to performance or feedback data. Electronic records were stored in password-protected cloud environments and were accessible only to the research team. Physical documents, including consent forms, were securely stored in locked cabinets. Access to raw data was restricted to the principal investigator and authorized research personnel. Any published results were reported in aggregate form to prevent identification of individual participants. After the study's conclusion, all data were retained for the duration specified by the IRB and then securely destroyed per ethical guidelines.

Ethical Considerations in Coaching

Although participants received coaching support as part of the study protocol, it was clearly communicated that the primary intent of the coaching was to support execution of the structured training program, not to deliver individualized or results-based coaching services. All interactions between the researcher and participants were conducted professionally and consistently to minimize potential bias and to avoid influencing participant behavior beyond the scope of the experimental design. Participants were also assured that their honest feedback, positive or negative, would have no bearing on their continued participation or eligibility for future studies.

Chapter 4: Results

Introduction

This chapter presents the results of a 12-week study investigating how exercise order affects gluteal strength and muscle development within a Daily Undulating Periodization (DUP) training model. Participants were divided into two groups: one began each workout with the hip thrust (a limited range of motion exercise). In contrast, the other started with the MC Reverse Lunge (an extended range of motion exercise).

The focus of this chapter is to present the measured outcomes in strength and circumferential changes, highlighting how different exercise sequences influenced training adaptations. Data is reported by group and exercise variable, offering a clear picture of the physical changes that occurred throughout the study.

Findings

Circumferential Measurements

Circumferential data were collected for the waist, hips, and thighs at the beginning and end of the 12-week training period. In addition, body weight was recorded but analyzed separately, as it is not a circumferential measurement. A paired-samples t-test was used to evaluate changes within each group between pre-test and post-test scores.

MC Group (Started with MC Reverse Lunge)

Several notable body composition changes were observed in the MC group (which began training sessions with the MC Reverse Lunge). There was a significant increase in hip circumference following the intervention. The mean pre-test score was M = 91.77 cm, SD = 11.55, and the post-test score was M = 93.65 cm, SD = 11.80, with a statistically significant difference, t(5) = 6.32, p = 0.0015, representing a mean gain of +1.88 cm. Thigh circumference also showed a significant increase, with a pre-test mean of M = 54.66 cm, SD = 5.58, and a post-test mean of M = 58.51 cm, SD = 4.14, resulting in t(5) = 2.74, p = 0.0408, reflecting a mean gain of +3.85 cm. In contrast, waist measurements decreased slightly from M = 71.32 cm to M = 70.74 cm (SD = 6.75 and 6.62, respectively), but this change was not statistically significant, t(5) = -0.68, p = 0.52. Body weight also decreased slightly from M = 58.56 kg to M = 58.14 kg (SD = 11.71 and 11.02, respectively), but this reduction did not reach statistical significance either, t(5) = -0.91, p = 0.40, reflecting a mean change of -0.42 kg.

Table 2: Circumference Changes – MC Group

Measure	Pre-Test	Post-Test	Mean Change	Std Dev	t–statisic	p-valuse
Weight	58.563	58.143	-0.42	1.125	-0.914	0.402
Waist	71.325	70.742	-0.583	2.09	-0.684	0.525
Hips	91.767	93.648	1.882	0.729	6.319	0.001
Thigh	54.662	58.513	3.852	3.444	2.739	0.041

HT Group (Started with Hip Thrust)

In the HT group, which began each training session with the hip thrust, body weight increased significantly (+0.67 kg; p = .025). Thigh circumference also increased significantly (+2.16 cm; p = .001). Hip circumference rose by +1.27 cm, though this change did not reach statistical significance (p = .124). Waist circumference decreased slightly (–0.33 cm), but the change was not significant (p = .175). Overall, the HT-first sequence produced clear strength improvements and measurable hypertrophy, particularly in the thigh, with hip growth trending positive.

Table 3: Circumference Changes – HT Group

Measure	Pre-Test	Post-Test	Mean Change	Std Dev	t–statisic	p-valuse
Weight	50.23	50.897	0.667	0.516	3.162	0.025
Waist	68.30	67.967	-0.333	0.516	-1.581	0.175
Hips	96.897	98.167	1.27	1.684	1.847	0.124
Thigh	55.173	57.333	2.16	0.744	7.111	0.001

While both groups demonstrated improvements in hip circumference, it remained unclear whether starting with a glute-extended range of motion exercise (MC Reverse Lunge) or a glute-isolation movement (Hip Thrust) led to superior hypertrophic outcomes. To explore this, an independent samples t-test was conducted comparing hip circumference change scores between the two groups. The MC group, which began with the MC Reverse Lunge, demonstrated a mean increase of 1.88 cm (SD = 0.73), while the Hip Thrust group, which began with the Hip Thrust, showed a mean increase of 1.27 cm (SD = 1.68). Although the MC group experienced a larger average gain, the difference between groups was not statistically significant, $t \approx 0.79$, $p = 0.45$. These results suggest that both training orders produced positive changes in hip circumference, but neither demonstrated a statistically clear advantage in this specific measure of localized hypertrophy.

Strength Measures (5RM Testing)

Strength was assessed using 5-repetition maximum (5RM) tests across four exercises: the Hip Thrust, MC Reverse Lunge (MC), Incline Press, and Overhead Press (OHP). Percentage changes from baseline were calculated to evaluate improvement. In the MC group, which began sessions with the MC Reverse Lunge, the most dramatic strength gain was observed in the MC exercise itself, with an average increase of 106.52%. Hip Thrust performance also improved substantially, showing a 58.29% increase. Upper body strength gains were also evident, with the Incline Press increasing by 72.81% and the Overhead Press by 55.94%. These results suggest that, despite the lower-body emphasis of the program, the DUP structure supported meaningful progress in both lower and upper-body lifts.

In the HT group, which began each session with the Hip Thrust, participants experienced an average strength increase of 61.68% in the Hip Thrust exercise. Interestingly, the MC Reverse Lunge, performed second in the session, showed an even greater improvement, with an average increase of 124.86%. This suggests that substantial strength gains were still possible even when the exercise was not prioritized in the sequence. Upper body lifts also demonstrated notable progress, with the Incline Press increasing by 71.81% and the Overhead Press by 74.09%. These findings highlight the effectiveness of the DUP model in promoting full-body strength improvements regardless of specific exercise order.

Table 4: Strength Gains – HT & MC Groups

Exercise	**Average % Gain (HT)**	**Average % Gain (MC)**
Hip thrust	61.68	58.29
Incline Press	71.81	72.81
MC Reverse Lunge	121.86	106.52
Overhead Press	74.09	55.94

In addition to summary statistics, individual raw strength data were compiled to illustrate the variability and magnitude of participant performance changes. The tables below display the starting and ending 5-repetition maximum (5RM) values for each major exercise. Participants were grouped by their initial exercise selection: MC Reverse Lunge or Hip Thrust.

Table 5 presents the raw strength data for individuals who began each training session with the MC Reverse Lunge. These figures highlight the pre- and post-intervention loads lifted in the Hip Thrust, Incline Press, MC Reverse Lunge, and Overhead Press exercises.

Table 5: Raw Strength Data – MC Group

Person ID Number	**Hip Thrust (Start)**	**Hip Thrust (End)**	**Incline (Start)**	**Incline (End)**	**MC(Start)**	**MC(End)**	**OHP (Start)**	**OHP (End)**
2	140.6	145.2	45.4	45.4	31.8	54.4	31.8	36.3
4	31.75	68.0	9	18.1	18.1	29.5	9.0	18.1
6	170.1	224.5	38.6	61.2	34.0	63.5	31.8	47.63
8	79.4	102.0	11.3	31.8	11.3	29.5	22.7	25.0
10	47.6	88.5	29.5	43.0	22.7	54.4	22.7	36.3
12	47.6	88.5	27.2	40.8	25.0	54.4	18.1	36.3

As shown in Table 5, participants in the MC-first group demonstrated a wide range of strength gains across all exercises. To compare, Table 6 below provides the same raw strength data for individuals in the Hip Thrust-first group, offering insight into how the change in exercise order may have influenced individual outcomes.

Table 6: Raw Strength Data – Hip Thrust Group

Person ID Number	**Hip Thrust (Start)**	**Hip Thrust (End)**	**Incline (Start)**	**Incline (End)**	**MC(Start)**	**MC(End)**	**OHP (Start)**	**OHP (End)**
1	115	145	30	40	16	24	32.5	37.5
3	80	155	40	60	20	50	20	37.5
5	140	180	10	25	20	40	10	25
7	60	115	25	40	16	42	20	35
9	120	180	40	65	25	55	30	45
11	50	90	20	35	15	40	15	25

Tables 6 and 7 provide a complete view of the training effects at the individual level. These raw scores support the summary trends observed earlier and offer additional context for evaluating the impact of exercise order on strength development. This data will be further interpreted in Chapter 5.

Conclusion

The data collected shows clear performance improvements in both groups. The MC-first group demonstrated significant increases in lower-body circumference, specifically in the hips and thighs. In contrast, the Hip Thrust-first group showed a statistically significant increase in body weight and strength gains across all exercises. Both groups exhibited notable increases in hip thrust and MC reverse lunge strength, reflecting measurable adaptations throughout the training program.

These findings will be interpreted and contextualized in Chapter 5, where implications, practical applications, and contributions to kinesiology practice will be explored.

Chapter 5: Discussion

This chapter interprets the findings presented in Chapter 4, situating them within the broader context of existing research and professional practice in the field of kinesiology. The discussion explores how exercise order influenced strength and muscle development, evaluates practical applications, outlines contributions to the field, and presents an action plan informed by the study. Limitations of the research are acknowledged, and recommendations for future investigation are offered.

Interpretation of Findings

The results of this 12-week study reveal that both exercise order conditions, beginning with the hip thrust or the MC reverse lunge, led to significant strength gains and body composition changes. Specifically, the MC-first group experienced statistically significant increases in hip and thigh circumference (hip: $p = 0.045$; thigh: $p = 0.032$), suggesting that initiating training sessions with a lengthened range of motion may more effectively target gluteal and lower-body hypertrophy. Conversely, despite placing it second in their exercise order, the Hip Thrust-first group saw a significant increase in overall body weight and greater average strength improvements in the MC reverse lunge.

These findings partially support the initial hypotheses, which predicted that beginning training sessions with the hip thrust would lead to greater gluteal strength gains. However, it was unexpectedly the group that started with a glute extended range of motion (ROM) movement, like the MC Reverse Lunge, that demonstrated more pronounced gluteal hypertrophy, particularly in the hip and thigh regions. This outcome was surprising and not initially anticipated. Both groups demonstrated substantial strength increases across lower and upper-body lifts, reinforcing that the Daily Undulating Periodization (DUP) model is effective regardless of exercise sequence. However, the observed differences in body composition, specifically, greater increases in hip and thigh circumference in the MC-first group, suggest that exercise order may meaningfully influence localized hypertrophy outcomes. These results imply that prioritizing extended ROM movements at the start of a session may enhance muscle growth in the targeted area, and future research is needed to explore these relationships more precisely.

When situated within existing literature, these results are consistent with prior research highlighting the influence of range of motion on hypertrophic adaptations (Pinto et al., 2012; McMahon et al., 2014; Pedrosa et al., 2022). The literature also supports the idea that prioritizing an exercise early in a workout tends to yield greater strength improvements in that movement (Simao et al., 2012). This study adds nuance by demonstrating that significant gains can occur even when a movement is placed second if the program is structured correctly and progressively overloaded.

Practical Applications

The findings of this study offer practical insights for strength coaches, personal trainers, and rehabilitation specialists. For practitioners seeking to maximize gluteal hypertrophy, beginning training sessions with a movement emphasizing lengthened range of motion, such as the MC reverse lunge, may be advantageous. Meanwhile, clients or athletes focused on total-body strength development may still benefit significantly from starting with more mechanically stable exercises like the hip thrust.

Given that both groups experienced large strength increases across exercises, the DUP model appears to be a flexible and effective approach regardless of exercise order. Therefore, professionals can structure programs based on individual client needs, injury considerations, or equipment availability without compromising effectiveness. These insights are especially relevant when time constraints or logistical limitations require adaptable programming.

Contribution to Knowledge and Profession

This study contributes to the kinesiology field by addressing a gap in the literature regarding exercise order in DUP-based lower-body training. While existing studies have examined DUP and exercise sequencing independently, few have explored the specific interaction between ROM-focused exercises and performance outcomes within a DUP framework. The evidence gathered here supports the efficacy of both movement-first strategies, but also highlights that gluteal-focused hypertrophy may be enhanced by placing extended ROM exercises earlier in the session.

This insight is particularly useful for professionals aiming to refine programming strategies to meet aesthetic or performance goals. By providing empirical evidence for how sequencing affects hypertrophy and strength gains, this study empowers coaches and clinicians to make more informed decisions about program design. Additionally, it contributes to a growing body of literature promoting the importance of exercise-specific planning rather than solely relying on volume or intensity.

Action Plan

Practitioner-Researcher and Site Information

A practitioner-researcher conducted the original study remotely and included 12 healthy adult participants (6 per group), each completing a 12-week glute-focused resistance training program at their local gyms. Training data, such as RPE, AMRAP performance, and session compliance, were collected and monitored through weekly digital check-ins using an online coaching platform.

To expand on this design, a future study could retain the remote coaching model but increase both the sample size and study duration to capture longer-term training adaptations. Specifically, recruiting 40–60 participants and extending the intervention to 24 or 36 weeks would allow for more statistical analysis and help identify plateau points or delayed responses in gluteal hypertrophy and strength.

A major improvement would be the addition of a midpoint strength assessment, a "mid-max" testing phase conducted at Week 12, to re-evaluate each participant’s 5RM or estimated 1RM. This would ensure more precise load adjustments for the program's second half and provide insight into the rate of adaptation over time.

The study could also explore the use of wearable fitness technology (e.g., bar velocity trackers, heart rate monitors, or mobile apps) to supplement subjective data like RPE. While the research used online coaching software, which was effective in the original study, future researchers could use any coaching platform capable of supporting individualized remote programming and scalable data collection across larger cohorts.

Targeted Focus and Research Goals

The study explored how exercise order within a Daily Undulating Periodization (DUP) framework influences gluteal strength and hypertrophy outcomes. Specifically, it compared two sequencing strategies: one group initiated each training session with a limited range of motion (ROM) exercise, the hip thrust, while the other began with an extended ROM movement, the MC reverse lunge. The goal was to determine whether exercise order, in the context of ROM variation, impacts the effectiveness of glute-focused resistance training.

Specific Objectives

The original study had four primary objectives: (1) to examine how exercise order influences localized hypertrophy and gluteal strength, (2) to implement a replicable load progression model using RPE and AMRAP performance, (3) to assess the feasibility of individualized remote coaching, and (4) to offer practical recommendations for exercise sequencing in glute-focused programs.

Future studies could build on these objectives by refining and expanding their scope. First, it could explore additional variations in exercise sequencing, such as alternating the order weekly or combining limited and extended ROM exercises within the same set structure, to test whether this produces greater hypertrophy or strength gains. Second, the progression model could incorporate real-time velocity-based training tools or AI-driven load adjustments to improve accuracy and reduce reliance on subjective RPE reporting

Third, the study could further test the scalability of remote coaching by involving a larger and more demographically diverse participant base over an extended timeline (24–36 weeks), helping validate the model across different populations and experience levels. Lastly, future research could aim to develop a standardized, evidence-backed framework for glute training that accounts for order, ROM, progression style, and coaching format, bridging the gap between academic research and real-world program design.

Load Selection Method for Week 1

In current research, before beginning the training program, participants completed a 5-repetition maximum (5RM) test for the primary glute-dominant exercises, including the barbell hip thrust and the MC reverse lunge. These values were then used to estimate each participant's one-repetition maximum (1RM) using a standard repetition-to-percentage conversion chart:

% of 1RM	Reps
100%	1
95%	2
90%	4
85%	6
80%	8
75%	10
70%	12
65%	14
60%	16

Initial training loads in Week 1 were deliberately conservative to promote technical proficiency, adaptation, and fatigue management. Load targets were set relative to the estimated 1RM as follows:

- 12-repetition sets: ~60% of 1RM (approximate 16-rep max)
- 1-repetition sets: ~90% of 1RM (approximate 4-rep max)
- 3-repetition AMRAP sets: ~75% of 1RM (approximate 10-rep max)

Progression Strategy and Weekly Load Adjustments

Progressive overload was implemented through a dual approach, using both objective performance data and subjective effort ratings:

- RPE-Based Adjustments: If a participant rated a working set at an RPE of 8 or lower, the load for that exercise was increased in the subsequent week.
- AMRAP-Based Adjustments: If a participant achieved 7 or more repetitions during a 3-repetition AMRAP set, the load was increased the following week.

All adjustments were made through the online platform, using participant training logs and qualitative feedback to ensure progression while maintaining safety and adherence to the program.

In a future study building on this research, a refined load selection protocol could be implemented to improve both standardization and outcome sensitivity. Rather than estimating 1RM through 5RM testing, future participants could undergo direct submaximal 1RM testing for key glute-dominant lifts (e.g., hip thrust, MC reverse lunge), supported by velocity-based training tools or load–velocity profiling for increased precision.

In Week 1, participants would be assigned loads based on velocity thresholds or verified rep-max efforts, reducing estimation errors and improving initial programming accuracy. Load assignments could also be stratified by training age or experience level to control for performance variance in early training stages.

Additionally, the study could extend the intervention duration from 12 weeks to 24–36 weeks to observe more meaningful hypertrophic outcomes, particularly when using imaging tools such as DEXA or ultrasound to measure gluteal cross-sectional area rather than relying solely on circumference measurements.

Weekly progression in this future study could rely on both:

- Bar speed metrics (using wearable tech or apps) to automate load adjustment
- RPE + AMRAP thresholds, refined with individual baseline profiles to improve auto-regulation.

Implementing these upgrades would enhance training fidelity, allow deeper analysis of strength adaptations, and create a more rigorous foundation for evaluating how exercise order and range of motion influence glute development.

Participant Monitoring: DUP Daily and Weekly Feedback

In the original study, participants completed structured self-assessments following each workout and at the end of each training week. These check-ins helped monitor safety, track perceived difficulty, and support individualized load progression. Questions included RPE-style difficulty ratings for each lift, session compliance, recovery status, and qualitative feedback about confidence, pain, or clarity (see Appendix B for the full list of questions).

This feedback process could be enhanced and made more scalable for a future study. A mobile app or wearable-compatible dashboard could be used to automate the delivery and collection of daily and weekly check-in questions. This would reduce participant friction and allow researchers to gather real-time metrics like bar speed, recovery scores (e.g., HRV), or sleep data to complement subjective ratings.

The core set of questions could remain similar but be expanded to capture longitudinal changes in mental engagement, exercise confidence, and training fatigue over a 24–36 weeks. For example, the weekly questions could include scaled check-ins on motivation, soreness, and perceived recovery, all timestamped and visualized to help track trends over time.

Additionally, future studies could test whether real-time feedback loops (e.g., adaptive coaching responses within 24 hours) improve adherence, motivation, or performance compared to passive data collection models. These feedback systems would allow researchers to respond to issues like pain or burnout quickly and analyze how subjective perceptions align with objective performance over a long-term glute-focused training program.

Strategies and Timeline

The original study spanned 14 weeks, including pre-testing, a 12-week glute-focused training phase, and post-testing in the final week. Baseline strength was assessed in Week 1 using 5-repetition maximum (5RM) tests for key exercises to estimate 1RM values and assign initial training loads. Week 2 marked the start of the training program, which followed a standardized rep-to-1RM chart to guide load selection. Participants trained independently while logging performance data, such as RPE scores, AMRAP reps, and structured feedback. Weekly remote check-ins enabled the researcher to monitor progress, adjust loads, and clarify technique or tracking expectations as needed.

This structure could be extended for future research to 24 or 36 weeks, allowing more time for meaningful muscular hypertrophy and improved analysis of long-term training adaptations. A midpoint testing phase, conducted at Week 12 or 18, could be added to re-test 5RM strength and reassess training loads. This would serve both as a recalibration checkpoint and as an opportunity to measure the adaptation rate during the program's first half.

In the proposed extended model, the weekly check-in and progression system could remain, but enhanced with automated performance tracking (e.g., velocity-based tools or wearable data) to reduce reliance on subjective feedback and provide richer datasets. Post-testing at the end of the intervention would include not only 5RM retesting and circumference measurements but potentially more advanced imaging (e.g., ultrasound or DEXA) to quantify hypertrophy outcomes better.

Full details of the original DUP program design, including session structure, exercise order, and weekly sets/reps, are available in Appendix A. These elements could be used as a foundation while iterating and expanding in future long-term studies.

Evaluation Techniques

In the original study, evaluation was conducted using a combination of formative, summative, and practitioner-reflective methods. Weekly formative evaluation involved reviewing participant logs, RPE scores, AMRAP performance, and feedback submitted through the online coaching platform to guide real-time load and program adjustments. Summative evaluation included pre- and post-program 5RM tests and hip/thigh circumference measurements to assess changes in strength and hypertrophy. Additionally, the practitioner-researcher maintained reflective journals to evaluate coaching decisions, program effectiveness, and participant engagement.

A future study could enhance this evaluation framework by incorporating more frequent checkpoints and objective, tech-supported assessments. For instance:

- Add a midpoint testing phase (Week 12 or 18) for both strength (5RM) and body composition to monitor adaptation rate and adjust training intensity accordingly.
- Incorporate ultrasound or DEXA scanning at baseline, midpoint, and post-test to improve accuracy in measuring hypertrophic changes, particularly in gluteal muscle thickness and volume.
- Use velocity-based training tools or bar path trackers to quantify effort objectively, bar speed, and fatigue over time, supplementing or partially replacing RPE scores.

Formative evaluation could also be supported by automated data visualization dashboards, allowing researchers to quickly identify stagnation, excessive fatigue, or irregular patterns in load progression. Self-reflection could continue but be expanded into a structured practitioner debrief protocol at each testing milestone, guiding researcher development and transparency in coaching influence.

By improving the frequency, objectivity, and depth of evaluation, future research can gain a more nuanced understanding of training effectiveness and better inform evidence-based programming decisions.

Resources Needed

Successful execution of the study required all participants to have access to standard gym equipment, including barbells, dumbbells, benches, and other resistance training tools. A digital platform was used for logging workouts, collecting feedback, and facilitating weekly communication between the researcher and participants; however, any comparable tool capable of supporting remote coaching and data collection would suffice. The researcher also dedicated weekly time to reviewing training data, adjusting programming as needed, and providing individualized feedback to ensure participant progress and adherence.

Limitations

Several limitations should be acknowledged. First, the sample size was relatively small (n = 12), which limits generalizability. Additionally, the study was conducted over 12 weeks; longer training periods might reveal further distinctions in hypertrophy or strength development. Participant adherence, diet, and training history were not controlled beyond baseline screening, which may have introduced outcome variability.

Another limitation relates to the use of Rating of Perceived Exertion (RPE) to gauge training intensity. While RPE is widely applied in strength training research, not all participants were equally familiar with the method, which may have introduced variability in load selection.

Further, most participants had prior experience with the hip thrust but limited exposure to the MC reverse lunge. As a result, some of the large relative strength gains in this exercise may reflect a learning effect rather than purely physiological adaptation.

There were also limitations in the precision of circumference measurements. Although measurements were performed consistently by the same tester, the use of manual tape measurements inherently carries some degree of human error. Finally, the study did not evaluate muscle activation via EMG or muscle architecture via imaging, which could have provided more specific physiological insights.

Recommendations for Further Research

Future research should replicate this study with a larger sample and longer training duration. Investigating sex differences in response to exercise order could also provide valuable insights, especially given the noted variations in lower-body hypertrophy responses between males and females. Further studies might incorporate EMG analysis or muscle imaging to validate hypertrophy results at a muscular level.

Additionally, future research should explore how exercise order affects performance in sport-specific movements and functional tasks. This would broaden the applicability of these findings to athletic populations.

Conclusion

This study investigated how exercise order, beginning with hip thrust or MC reverse lunge, affects strength and muscle development in a 12-week DUP program. Both training sequences resulted in significant improvements in strength and measurable changes in body composition, with notable distinctions in hypertrophy patterns. These findings provide practical guidance for training design and contribute to the broader understanding of exercise sequencing in resistance training.

Overall, this research supports the value of strategic exercise ordering and reinforces the effectiveness of DUP programming. As the field of kinesiology continues to evolve, such evidence-based insights will be vital for advancing both academic knowledge and professional practice.

References

Abdi, N., Hamedınıa, M., Izanloo, I., & Hedayatpour, N. (2019). The effect of linear and daily undulating periodized resistance training on the neuromuscular function and the maximal quadriceps strength. Baltic Journal of Health and Physical Activity. https://doi.org/10.29359/BJHPA.11.1.05.

Assumpção, C., Tibana, R., Viana, L., Willardson, J., & Prestes, J. (2013). Influence of exercise order on upper body maximum and submaximal strength gains in trained men. Clinical Physiology and Functional Imaging, 33. https://doi.org/10.1111/cpf.12036.

Bamman, M., Roberts, B., & Adams, G. (2018). Molecular Regulation of Exercise-Induced Muscle Fiber Hypertrophy.. Cold Spring Harbor perspectives in medicine, 8 6. https://doi.org/10.1101/cshperspect.a029751.

Barbalho, M., Coswig, V., Souza, D., Serrão, J. C., Hebling Campos, M., & Gentil, P. (2020). Back Squat vs. Hip Thrust Resistance-training Programs in Well-trained Women. International journal of sports medicine, 41(5), 306–310. https://doi.org/10.1055/a-1082-1126

Brandão, L., Painelli, V., Lasevicius, T., Silva-Batista, C., Brendon, H., Schoenfeld, B., Aihara, A., Cardoso, F., Peres, B., & Teixeira, E. (2020). Varying the Order of Combinations of Single- and Multi-Joint Exercises Differentially Affects Resistance Training Adaptations.. Journal of Strength and Conditioning Research. https://doi.org/10.1519/JSC.0000000000003550.

Belzunce, M., Henckel, J., Laura, A., Horga, L., & Hart, A. (2023). Similarities and differences in skeletal muscle and body composition between sexes: an MRI study of recreational cyclists. BMJ Open Sport & Exercise Medicine, 9. https://doi.org/10.1136/bmjsem-2023-001672.

Bompa and Haff, 2009 T.O. Bompa, G.G. Haff P eriodization: Theory and Methodology of Training: Human Kinetics (2009)

Camera, D., Smiles, W., & Hawley, J. (2016). Exercise-induced skeletal muscle signaling pathways and human athletic performance.. Free radical biology & medicine, 98, 131-143 . https://doi.org/10.1016/j.freeradbiomed.2016.02.007.

Contreras, B. (2009, September 16). Dispelling the glute myth. T NATION. Retrieved from https://t-nation.com/t/dispelling-the-glute-myth/284458

Contreras, B. (2016, October 10). Squats versus hip thrusts part III: Force-time data. BretContreras.com. Retrieved from https://bretcontreras.com/squats-versus-hip-thrusts-part-iii-forcetime-data/

Contreras, B. (2019). Glute lab: The art and science of strength and physique training. Victory Belt Publishing.

Contreras, B., Vigotsky, A., Schoenfeld, B., Beardsley, C., & Cronin, J. (2015). A Comparison of Gluteus Maximus, Biceps Femoris, and Vastus Lateralis Electromyographic Activity in the Back Squat and Barbell Hip Thrust Exercises.. Journal of applied biomechanics, 31 6, 452-8 . https://doi.org/10.1123/jab.2014-0301.

Contreras, B., Vigotsky, A. D., Schoenfeld, B. J., Beardsley, C., McMaster, D. T., Reyneke, J. H., & Cronin, J. B. (2017). Effects of a Six-Week Hip Thrust vs. Front Squat Resistance Training Program on Performance in Adolescent Males: A Randomized Controlled Trial. Journal of strength and conditioning research, 31(4), 999–1008. https://doi.org/10.1519/JSC.0000000000001510

Delgado, J., Drinkwater, E. J., Banyard, H. G., Haff, G. G., & Nosaka, K. (2019). Comparison Between Back Squat, Romanian Deadlift, and Barbell Hip Thrust for Leg and Hip Muscle Activities During Hip Extension. Journal of strength and conditioning research, 33(10), 2595–2601. https://doi.org/10.1519/JSC.0000000000003290

Deci, E., Koestner, R., & Ryan, R. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation.. Psychological bulletin, 125 6, 627-68; discussion 692-700 . https://doi.org/10.1037/0033-2909.125.6.627.

Fisher, J. P., Carlson, L., Steele, J., & Smith, D. (2014). The effects of pre-exhaustion, exercise order, and rest intervals in a full-body resistance training intervention. Applied physiology, nutrition, and metabolism = Physiologie appliquee, nutrition et metabolisme, 39(11), 1265–1270. https://doi.org/10.1139/apnm-2014-0162

Fleck, S. (2011). Non-Linear Periodization for General Fitness & Athletes. Journal of Human Kinetics, 29A, 41 - 45. https://doi.org/10.2478/v10078-011-0057-2.

Gail, S., & Künzell, S. (2014). Reliability of a 5-Repetition Maximum Strength Test in Recreational Athletes. Deutsche Zeitschrift Fur Sportmedizin, 2014, 314-317. https://doi.org/10.5960/DZSM.2014.138.

Gavanda, S., Geisler, S., Quittmann, O., & Schiffer, T. (2019). The Effect of Block Versus Daily Undulating Periodization on Strength and Performance in Adolescent Football Players.. International journal of sports physiology and performance, 1-8 . https://doi.org/10.1123/ijspp.2018-0609.

Gleeson, M. (2000). The scientific basis of practical strategies to maintain immunocompetence in elite athletes.. Exercise immunology review, 6, 75-101 .

Graves, J., Pollock, M., Jones, A., Colvin, A., & Leggett, S. (1989). Specificity of limited range of motion variable resistance training.. Medicine and science in sports and exercise, 21 1, 84-9 . https://doi.org/10.1249/00005768-198902000-00015.

Helms, E. R., Byrnes, R. K., Cooke, D. M., Haischer, M. H., Carzoli, J. P., Johnson, T. K., Cross, M. R., Cronin, J. B., Storey, A. G., & Zourdos, M. C. (2018a). RPE vs. Percentage 1RM Loading in Periodized Programs Matched for Sets and Repetitions. Frontiers in physiology, 9, 247. https://doi.org/10.3389/fphys.2018.00247

Helms, E., Byrnes, R., Cooke, D., Haischer, M., Carzoli, J., Johnson, T., Cross, M., Cronin, J., Storey, A., & Zourdos, M. (2018b). RPE vs. Percentage 1RM Loading in Periodized Programs Matched for Sets and Repetitions. Frontiers in Physiology, 9. https://doi.org/10.3389/fphys.2018.00247.

Kassiano, W., Costa, B., Nunes, J., Ribeiro, A., Schoenfeld, B., & Cyrino, E. (2022). Partial range of motion and muscle hypertrophy: not all ROMs lead to Rome. Scandinavian Journal of Medicine & Science in Sports, 32. https://doi.org/10.1111/sms.14121.

Holloway, J., & Baechle, T. (1990). Strength Training for Female Athletes. Sports Medicine, 9, 216-228. https://doi.org/10.2165/00007256-199009040-00003.

Kassiano, W., Costa, B., Nunes, J., Ribeiro, A., Schoenfeld, B., & Cyrino, E. (2023). Which ROMs Lead to Rome? A Systematic Review of the Effects of Range of Motion on Muscle Hypertrophy. Journal of Strength and Conditioning Research, 37, 1135 - 1144. https://doi.org/10.1519/JSC.0000000000004415.

Kyllo, L., & Landers, D. (1995). Goal Setting in Sport and Exercise: A Research Synthesis to Resolve the Controversy. Journal of Sport & Exercise Psychology, 17, 117-137. https://doi.org/10.1123/JSEP.17.2.117.

Massey, C., Vincent, J., Maneval, M., & Johnson, J. (2005). INFLUENCE OF RANGE OF MOTION IN RESISTANCE TRAINING IN WOMEN: EARLY PHASE ADAPTATIONS. Journal of Strength and Conditioning Research, 19, 409–411. https://doi.org/10.1519/R-14643.1.

Maylia, E., Fairclough, J., Nokes, L., & Jones, M. (1999). Can Thigh Girth Be measured Accurately? A Preliminary Investigation. Journal of Sport Rehabilitation, 8, 43-49. https://doi.org/10.1123/JSR.8.1.43.

Miranda, F., Simão, R., Rhea, M., Bunker, D., Prestes, J., Leite, R., Miranda, H., Salles, B., & Novaes, J. (2011). Effects of Linear vs. Daily Undulatory Periodized Resistance Training on Maximal and Submaximal Strength Gains. Journal of Strength and Conditioning Research, 25, 1824-1830. https://doi.org/10.1519/JSC.0b013e3181e7ff75.

Monteiro, A., Aoki, M., Evangelista, A., Alveno, D., Monteiro, G., Piçarro, I., & Ugrinowitsch, C. (2009). Nonlinear Periodization Maximizes Strength Gains in Split Resistance Training Routines. Journal of Strength and Conditioning Research, 23, 1321-1326. https://doi.org/10.1519/JSC.0b013e3181a00f96.

Neto, W. K., Vieira, T. L., & Gama, E. F. (2019). Barbell Hip Thrust, Muscular Activation and Performance: A Systematic Review. Journal of sports science & medicine, 18(2), 198–206.

Neto, W. K., et al. (2020a). Gluteus Maximus Activation during Common Strength and Hypertrophy Exercises: A Systematic Review. Journal of sports science & medicine, 19(1), 195–203.

Neto, W., Soares, E., Vieira, T., Aguiar, R., Chola, T., Sampaio, V., & Gama, E. (2020b). Gluteus Maximus Activation during Common Strength and Hypertrophy Exercises: A Systematic Review.. Journal of sports science & medicine, 19 1, 195-203.

Oliver, J. M., Jagim, A. R., Sanchez, A. C., Mardock, M. A., Kelly, K. A., Meredith, H. J., Smith, G. L., Greenwood, M., Parker, J. L., Riechman, S. E., Fluckey, J. D., Crouse, S. F., & Kreider, R. B. (2013). Greater gains in strength and power with intraset rest intervals in hypertrophic training. Journal of strength and conditioning research, 27(11), 3116–3131. https://doi.org/10.1519/JSC.0b013e3182891672

Pallarés JG, Hernández-Belmonte A, Martínez-Cava A, Vetrovsky T, Steffl M, Courel-Ibáñez J. Effects of range of motion on resistance training adaptations: A systematic review and meta-analysis. Scand J Med Sci Sports. 2021 Oct;31(10):1866-1881. doi: 10.1111/sms.14006. Epub 2021 Jul 5. PMID: 34170576.

Pinto, R., Gomes, N., Radaelli, R., Botton, C., Brown, L., & Bottaro, M. (2012). Effect of Range of Motion on Muscle Strength and Thickness. Journal of Strength and Conditioning Research, 26, 2140–2145. https://doi.org/10.1519/JSC.0b013e31823a3b15.

Plotkin, D. L., Rodas, M. A., Vigotsky, A. D., McIntosh, M. C., Breeze, E., Ubrik, R., Robitzsch, C., Agyin-Birikorang, A., Mattingly, M. L., Michel, J. M., Kontos, N. J., Frugé, A. D., Wilburn, C. M., Weimar, W. H., Bashir, A., Beyers, R. J., Henselmans, M., Contreras, B. M., & Roberts, M. D. (2023). Hip thrust and back squat training elicit similar gluteus muscle hypertrophy and transfer similarly to the deadlift. bioRxiv : the preprint server for biology, 2023.06.21.545949. https://doi.org/10.1101/2023.06.21.545949

Prestes, J., Frollini, A., Lima, C., Donatto, F., Foschini, D., Marqueti, R., Figueira, A., & Fleck, S. (2009). Comparison Between Linear and Daily Undulating Periodized Resistance Training to Increase Strength. Journal of Strength and Conditioning Research, 23, 2437-2442. https://doi.org/10.1519/JSC.0b013e3181c03548.

Pyne, D., Gleeson, M., Mcdonald, W., Clancy, R., Perry, C., & Fricker, P. (2000). Training Strategies to Maintain Immunocompetence in Athletes. Int J Sports Med, 21, 51 - 60. https://doi.org/10.1055/s-2000-1452.

Reynolds, J., Gordon, T., & Robergs, R. (2006). PREDICTION OF ONE REPETITION MAXIMUM STRENGTH FROM MULTIPLE REPETITION MAXIMUM TESTING AND ANTHROPOMETRY. Journal of Strength and Conditioning Research, 20, 584–592. https://doi.org/10.1519/R-15304.1.

Rhea, M. R., Ball, S. D., Phillips, W. T., & Burkett, L. N. (2002). A comparison of linear and daily undulating periodized programs with equated volume and intensity for strength. Journal of strength and conditioning research, 16(2), 250–255.

Simão, R., Salles, B., Figueiredo, T., Dias, I., & Willardson, J. (2012a). Exercise Order in Resistance Training. Sports Medicine, 42, 251-265. https://doi.org/10.2165/11597240-000000000-00000.

Simão, R., Spineti, J., Salles, B., Matta, T., Fernandes, L., Fleck, S., Rhea, M., & Strom-Olsen, H. (2012b). Comparison Between Nonlinear and Linear Periodized Resistance Training: Hypertrophic and Strength Effects. Journal of Strength and Conditioning Research, 26, 1389–1395. https://doi.org/10.1519/JSC.0b013e318231a659.

Schoenfeld, B. (2002). Accentuating Muscular Development Through Active Insufficiency and Passive Tension. Strength and Conditioning Journal, 24, 20–22. 2.0.CO;2" target="_blank">https://doi.org/10.1519/1533-4295(2002)024<0020:AMDTAI>2.0.CO;2.

Schoenfeld, B. J., & Grgic, J. (2020). Effects of range of motion on muscle development during resistance training interventions: A systematic review. SAGE open medicine, 8, 2050312120901559. https://doi.org/10.1177/2050312120901559

Soares, V., Soares, W., Zanetti, H., Neves, F., Silva-Vergara, M., & Mendes, E. (2020). Daily Undulating Periodization Is More Effective Than Nonperiodized Training on Maximal Strength, Aerobic Capacity, and TCD4+ Cell Count in People Living With HIV. Journal of Strength and Conditioning Research, 36, 1738 - 1748. https://doi.org/10.1519/JSC.0000000000003675.

Sparto, P., Parnianpour, M., Reinsel, T., & Simon, S. (1997). The Effect of Fatigue on Multijoint Kinematics and Load Sharing During a Repetitive Lifting Test. Spine, 22, 2647–2654. https://doi.org/10.1097/00007632-199711150-00013.

Sparto PJ, Parnianpour M, Reinsel TE, Simon S. The effect of fatigue on multijoint kinematics and load sharing during a repetitive lifting test. Spine (Phila Pa 1976). 1997 Nov 15;22(22):2647-54. doi: 10.1097/00007632-199711150-00013. PMID: 9399451.

Stand, P. (2009). American College of Sports Medicine position stand. Progression models in resistance training for healthy adults.. Medicine and science in sports and exercise, 41 3, 687-708 . https://doi.org/10.1249/MSS.0b013e3181915670.

Suchomel, T., Nimphius, S., Bellon, C., Hornsby, W., & Stone, M. (2021). Training for Muscular Strength: Methods for Monitoring and Adjusting Training Intensity. Sports Medicine, 51, 2051 - 2066. https://doi.org/10.1007/s40279-021-01488-9.

Wolf, M., Androulakis-Korakakis, P., Fisher, J., Schoenfeld, B., & Steele, J. (2023). Partial Vs Full Range of Motion Resistance Training: A Systematic Review and Meta-Analysis. International Journal of Strength and Conditioning. https://doi.org/10.47206/ijsc.v3i1.182.

Zajac, F. (1993). Muscle coordination of movement: a perspective.. Journal of biomechanics, 26 Suppl 1, 109-24 . https://doi.org/10.1016/0021-9290(93)90083-Q.

Zhang, X., Li, H., Bi, S., Luo, Y., Cao, Y., & Zhang, G. (2021). Auto-Regulation Method vs. Fixed-Loading Method in Maximum Strength Training for Athletes: A Systematic Review and Meta-Analysis. Frontiers in Physiology, 12. https://doi.org/10.3389/fphys.2021.651112.

Tables

Table 1: Weekly Workout Goals and Adjustments

Workout Day	Performance Goal	If goal not hit
Day 1	RPE of 7 or below	Repeat same weight the following week
Day 2	RPE of 7 or below	Repeat same weight the following week
Day 4	aim for 7+ to increase load next week	Repeat same weight the following week

Table 2: Circumference Changes – MC Group

Measure	Start Mean	End Mean	Mean Change	Std Dev	t–statisic	p-valuse
Weight	58.563	58.143	-0.42	1.125	-0.914	0.402
Waist	71.325	70.742	-0.583	2.09	-0.684	0.525
Hips	91.767	93.648	1.882	0.729	6.319	0.001
Thigh	54.662	58.513	3.852	3.444	2.739	0.041

Table 3: Circumference Changes – HT Group

Measure	Start Mean	End Mean	Mean Change	Std Dev	t–statisic	p-valuse
Weight	50.23	50.897	0.667	0.516	3.162	0.025
Waist	68.30	67.967	-0.333	0.516	-1.581	0.175
Hips	96.897	98.167	1.27	1.684	1.847	0.124
Thigh	55.173	57.333	2.16	0.744	7.111	0.001

Table 4: Strength Gains – HT & MC Groups

Exercise	Average % Gain (HT)	Average % Gain (MC)
Hip thrust	61.68	58.29
Incline Press	71.81	72.81
MC Reverse Lunge	121.86	106.52
Overhead Press	74.09	55.94

Table 5: Raw Strength Data – MC Group

Person ID Number	Hip Thrust (Start)	Hip Thrust (End)	Incline (Start)	Incline (End)	MC(Start)	MC(End)	OHP (Start)	OHP (End)
2	140.6	145.2	45.4	45.4	31.8	54.4	31.8	36.3
4	31.75	68.0	9	18.1	18.1	29.5	9.0	18.1
6	170.1	224.5	38.6	61.2	34.0	63.5	31.8	47.63
8	79.4	102.0	11.3	31.8	11.3	29.5	22.7	25.0
10	47.6	88.5	29.5	43.0	22.7	54.4	22.7	36.3
12	47.6	88.5	27.2	40.8	25.0	54.4	18.1	36.3

Table 6: Raw Strength Data – Hip Thrust Group

Person ID Number	Hip Thrust (Start)	Hip Thrust (End)	Incline (Start)	Incline (End)	MC(Start)	MC(End)	OHP (Start)	OHP (End)
1	115	145	30	40	16	24	32.5	37.5
3	80	155	40	60	20	50	20	37.5
5	140	180	10	25	20	40	10	25
7	60	115	25	40	16	42	20	35
9	120	180	40	65	25	55	30	45
11	50	90	20	35	15	40	15	25

Appendix A

This appendix provides the complete training programs used during the 12-week intervention. It includes the specific Daily Undulating Periodization (DUP) workout plans for both groups, those who began each session with the MC Reverse Lunge (MC group) and those who began with the Hip Thrust (HT group). The tables outline each week's exercise sequence, sets, and reps. This information directly supports the methodology and findings presented in the dissertation by allowing for replication and transparency regarding exercise selection and order, which were central to the study's hypotheses. While summary data and key results appear in the main text, this appendix contains the full programming details to avoid overcrowding the results section and to provide a reference for practitioners and researchers.

note: * means each side

Starting with MC Reverse Lunge

Day 1

Exercise Name	Sets	Reps
MC Reverse Lunge	3	8*
Barbell Incline Bench Press	3	12
Barbell Hip Thrust	3	12
Barbell Shoulder Press (Military Press)	3	12
Dips	3	AMRAP
Single Leg Dumbbell Romanian Deadlift	3	8
Dumbbell Frog Pumps	3	12
Side Plank	3	15-45 Seconds*

Day 2

Exercise Name	Sets	Reps
MC Reverse Lunge	3	1*

Barbell Incline Bench Press	3	1
Barbell Hip Thrust	3	1
Barbell Shoulder Press (Military Press)	3	1
Single Leg Horizontal Leg Press	3	12*
Cable Face Pulls	3	12
Dumbbell Lateral Raise	3	12
45 Degree Hyperextension	3	12

Day 3

Exercise Name	Sets	Reps
Single Arm Dumbbell Row	3	12*
Chin-Ups	3	AMRAP
Prone Hamstring Curl Machine	3	8
Heel Elevated Goblet Squat	3	12
Single Leg Horizontal Leg Press	3	12
Cable Face Pulls	3	20
Dumbbell Lateral Raise	3	20
Leg Raises	3	10

Day 4

Exercise Name	Sets	Reps
MC Reverse Lunge	2	3, AMRAP*
Barbell Incline Bench Press	2	3, AMRAP
Barbell Hip Thrust	2	3, AMRAP
Barbell Shoulder Press (Military Press)	2	3, AMRAP
Pallof Press	3	12*
Swiss Ball Crunch	1	25-100

Starting with Hip Thurst

Day 1

Exercise Name	Sets	Reps

Barbell Hip Thrust	3	12
Barbell Incline Bench Press	3	12
MC Reverse Lunge	3	8*
Barbell Shoulder Press (Military Press)	3	12
Dips	3	AMRAP
Single Leg Dumbbell Romanian Deadlift	3	8
Dumbbell Frog Pumps	3	12
Side Plank	3	15-45 Seconds*

Day 2

Exercise Name	Sets	Reps
Barbell Hip Thrust	3	1
Barbell Incline Bench Press	3	1
MC Reverse Lunge	3	1*
Barbell Shoulder Press (Military Press)	3	1
Single Leg Horizontal Leg Press	3	12*
Cable Face Pulls	3	12
Dumbbell Lateral Raise	3	12
45 Degree Hyperextension	3	12

Day 3

Exercise Name	Sets	Reps
Single Arm Dumbbell Row	3	12*
Chin-Ups	3	AMRAP
Prone Hamstring Curl Machine	3	8
Heel Elevated Goblet Squat	3	12
Single Leg Horizontal Leg Press	3	12
Cable Face Pulls	3	20
Dumbbell Lateral Raise	3	20
Leg Raises	3	10

Day 4

Exercise Name	Sets	Reps
Barbell Hip Thrust	2	3, AMRAP
Barbell Incline Bench Press	2	3, AMRAP
MC Reverse Lunge	2	3, AMRAP*
Barbell Shoulder Press (Military Press)	2	3, AMRAP
Pallof Press	3	12*
Swiss Ball Crunch	1	25-100

Appendix B

Daily Questions (after each DUP workout):

1. On a scale of 1–10, how would you rate the overall difficulty of today's workout?
2. Rate the difficulty (1–10) of the following exercises:
    - MC Reverse Lunge
    - Incline Bench Press
    - Barbell Hip Thrust
    - Standing Military Press
3. Were you able to complete all sets and reps as prescribed? If not, what adjustments did you make?
4. Did you experience any discomfort or pain during the workout? If yes, please specify.

Weekly Questions (end of each week):

1. On a scale of 1–10, how fatigued did you feel after your workouts this week?
2. How did you feel mentally and physically after completing this week's workouts?
3. Did you feel stronger or more confident in any particular exercise compared to last week? If yes, which one(s)?
4. Were there any exercises you found particularly challenging or unclear this week?
5. How effective did you find the progression of weights/resistance compared to prior weeks?
6. On a scale of 1–10, how motivated did you feel to complete this week's workouts?
7. How recovered did you feel between workouts this week?

8. Do you have any specific feedback or suggestions regarding this week's workouts or coaching support?