

Comparative Effects of Core Training vs. Forearm Training on Increasing the Repetition of Pull-Ups Performance

1. Introduction

Pull-ups are universally recognized as one of the most effective exercises for assessing and developing upper-body strength, making them a staple in military, athletic, and fitness training programs (Vigouroux et al., 2019; Barnes et al., 2017). The exercise primarily engages the latissimus dorsi, biceps brachii, and forearm flexors, while also requiring core stability to maintain body alignment (Snarr & Esco, 2013). These muscle groups are fundamental for various athletic movements such as pulling, climbing, and maintaining postural control.

Pull-ups are particularly valuable for athletes in many sports like gymnastics, swimming, rock climbing, rowing, and football. For instance, in gymnastics, upper body pulling strength is essential for executing advanced maneuvers on rings and bars (Vigouroux et al., 2019). Similarly, in rock climbing, grip strength and upper-body endurance directly impact the athlete's ability to ascend efficiently. In swimming, research highlights the significant role of pull-up training in improving upper body strength and sprint swimming performance. For instance, incorporating pull-up exercises into training regimens led to significant improvements in 50-meter freestyle times, particularly in the initial 25 meters, by enhancing explosive upper body strength (Pardo-Atarés et al., 2024). Additionally, an analysis of pull-up mechanics revealed a strong correlation between pull-up strength and sprint swimming speed in short-distance events, affirming its role as a reliable predictor of swimming performance (Perez-Olea et al., 2018). Furthermore, post activation potentiation techniques using pull-ups as part of warm-ups have been shown to positively influence 50-meter freestyle performance, particularly in male swimmers, by enhancing speed and power during sprint events (Sarramian et al., 2015). Combining pull-ups with other dry-land training methods has also been found to improve the 50-meter breaststroke swimming speed, further reinforcing the effectiveness of pull-up exercises in enhancing aquatic athletic performance (Pambudi et al., 2020). In football, pull-ups play a critical role in tasks like long throw-ins during matches. One study demonstrated that football players who incorporated pull-up exercises into their training were able to execute longer throws, emphasizing the importance of upper-body strength in this context (Pauweni et al., 2014). Grip strength, which is closely linked to pull-up performance, has also been identified as a key factor in the physical performance of elite football players (Sánchez-Moreno et al., 2020; Krings et al., 2021). Moreover, pull-ups are an essential

component of general physical fitness and military assessments as well, where they serve as a standard measure of upper-body strength and endurance. Research has shown that many individuals, particularly untrained populations, struggle with performing pull-ups due to the challenge of lifting their entire body weight. This emphasizes the critical role of pull-up performance in enhancing overall physical fitness, as supported by previous studies demonstrating its effectiveness (Aandstad, 2020; McGuire et al., 2011).

Grip strength is a crucial factor in pull-up performance, as it is vital for maintaining a steady hold on the pull-up bar throughout the repetitions. Grip strength directly impacts endurance and overall performance (Bampalis, 2023; Hewit et al., 2018). A firm grip is essential for performing pull-ups efficiently, as it provides the necessary control and stability during the exercise (Snarr & Esco, 2013). The grip technique used in pull-ups can significantly impact muscle engagement and performance outcomes. Different grip variations can alter muscle activation patterns, influencing the effectiveness of the exercise (Barnes et al., 2017). Studies show that performing pull-ups with different grip types, such as small climbing holds, not only enhances grip strength but also affects biomechanical arm action, demonstrating the critical role of grip specific training for climbers (Vigouroux et al., 2019). Core stability is crucial for pull-up performance, as a strong core reduces energy leakage during motion, ensuring efficient force transfer between the upper and lower body (Clark et al., 2018; Luo et al., 2022). It maintains proper body alignment and prevents excessive swinging during pull-ups. Research highlights that core exercises in pull-up training improve stabilization, movement control, and athletic capability (Chen et al., 2023; Rodríguez-Perea et al., 2023). Tailored core training predicts better pull-up performance by enhancing force transmission and physical stability, with extracurricular core exercises playing a key role (Chen et al., 2023).

2. Aim of the study

Previous research highlights the importance of grip strength and core stability independently, yet few studies have examined their comparative impact on pull-up performance (Luo et al., 2022; Clark et al., 2018). Furthermore, progression techniques, such as increasing resistance or intensity, are critical for sustained performance gains but are often overlooked in experimental designs (Hewit et al., 2018). Implementing progressive overload is essential for continuous improvement in strength and endurance (Medina et al., 2017; Barnes et al., 2017).

This research is essential for advancing scientific knowledge in fitness and conditioning by examining how supplementary exercises target specific muscle groups, like the forearms and core,

optimize pull-up performance. It emphasizes the role of auxiliary muscles in compound exercises and highlights the importance of training supporting muscles to achieve comprehensive upper-body strength. Understanding the distinct contributions of forearm and core training to pull-up performance provides valuable insights for designing specialized training programs tailored to various athletic needs and fitness goals. Pull-ups are not only fundamental for assessing upper-body strength but are also crucial for sport-specific performance across disciplines. By addressing the challenges of improving pull-up performance and exploring targeted training interventions, this research contributes to more effective strategies for enhancing strength, endurance, and athletic outcomes. The study aims to evaluate the comparative effects of 8 weeks of forearm-specific and core-specific training, alongside progressive overload techniques, on pull-up performance in physically inactive male university students.

Hypothesis

Based on our previous research, we made the following hypotheses.

H1: Pull-up performance will improve in all three groups.

H2: Forearm-specific training groups are expected to show the most significant improvements in pull-up performance, compared to core- and interval-specific training groups.

H3: Forearm-specific training group is expected to show greater improvements in maximum pull-up repetitions, grip strength, and dead hanging time compared to the core-specific training group.

H4: Interval specific training group will improve the least pull up performance compared to the forearm- and core-specific training groups.

3. Methods and materials

Participants

Thirty male university students ($n = 30$, age = $21 \pm 1,58$ years, weight = $73,25 \pm 18,03$ kg, height = 176.5 ± 21.92 cm) were recruited. Inclusion criteria were, physical inactivity in the last 6 months, no history of musculoskeletal injury or chronic illness, non-smokers and drug-free (Escamilla et al., 2021). Exclusion criteria were participation in any additional physical training during the intervention, use of supplements or failure to comply with dietary and sleep recommendations (Schoenfeld et al., 2021).

Study Design

This study was an 8-week experimental trial. Participants were divided into three groups of 10, pull-up and interval training group (PIT) (n=10), pull-up and forearm training group (PFT) (n=10), and pull-up and core training group (PCT) (n=10), based on their baseline pull-up performance, ensuring a balanced distribution of similar initial capabilities (McGill, 2022).

The training sessions were conducted twice a week, with each session lasting for one hour. To comprehensively assess the performance of participants, three tests were employed. We measured maximum pull-up performance, hand grip strength for both hands, and hanging time. All tests were conducted both at baseline (week 1) and post-intervention (week 8) on separate days to prevent fatigue from one test affecting the performance on another. A standardized warm-up of 5 minutes of light aerobic activity and dynamic stretching is conducted prior to the test (Vigouroux et al., 2019), except for hand grip strength. Additionally, all tests were administered in the same location within a one-hour time frame to ensure consistent environmental conditions and reduce variability (Gentilcore, 2019; Bampalis, 2023). To ensure that fatigue from one test did not influence the performance on subsequent tests, each test was scheduled on separate days. Additionally, all tests were conducted in the same location and within a one-hour period to maintain consistent testing conditions and minimize the impact of external variables (Gentilcore, 2019; Bampalis, 2023). The trial was conducted from late September to early November to avoid academic stress and minimize external confounding factors (Schoenfeld et al., 2021; Krieger, 2020).

Test protocol

Maximum pull-up repetition

This test evaluates the maximum number of consecutive, unassisted pull-ups a participant can perform, assessing upper-body strength and muscular endurance (Barnes et al., 2022). Participants grasped the overhead bar with a pronated grip (palms facing away), pulled their body up until their chin was above the bar, and then lowered back down to the starting position with their arms fully extended. Participants performed the pull-ups until failure. Each participant was allowed a maximum of 3 attempts with 2-minute rest intervals between attempts. The highest number of successful pull-up repetitions out of the three attempts was recorded as the participant's score (Barnes et al., 2022).

Grip Strength

This test assesses the maximum isometric strength of the forearm muscles. We measured both the right hand and left hand as well, since both are crucial for maintaining grip during pull-ups (Bampalis, 2023). Participants stood in a hip width stance with flexing one elbow at right angle and holding the calibrated handheld dynamometer in their hand. They were instructed to squeeze the dynamometer with maximum effort for 3 seconds, while keeping the elbow beside the trunk. Three trials were conducted with 1-minute rest intervals between each trial (McGill, 2022). The average of three trials was calculated for data analysis of the grip strength value for the right and left hand (Bampalis, 2023).

Dead Hanging Test

This test evaluates the static strength endurance of the forearm and grip muscles by determining how long a participant can sustain a static hang from a pull-up bar (Kibele et al., 2021). Participants were instructed to hang from a pull-up bar with a pronated grip, shoulder-width apart, without performing any movements. The test ended when the participant could no longer maintain the hang due to fatigue and jumped off (Snarr & Esco, 2013). The total time in seconds was recorded as the performance metric (Kibele et al., 2021). Progressive overload was applied to maintain training intensity and prevent stagnation (Schoenfeld et al., 2021).

Interventions

All three groups performed the same regime of pull-up exercises, but each group had different compound exercises. PIT made extra interval running to avoid targeting specific muscle groups, PFT performed forearm-specific training to enhance grip strength and PCT made core-specific training to improve stability and movement efficiency.

General Pull-Up Training

A standardized 40-minute pull-up training protocol was implemented across all groups to improve upper-body strength and endurance (Brown et al., 2023; Kibele et al., 2021). For this study, the pronated grip (palms facing away, shoulder-width apart) was chosen to maintain consistency with standard pull-up technique while ensuring balanced activation of the primary pulling muscles (Vigouroux et al., 2019; Snarr & Esco, 2013). Loads were calibrated individually to ensure participants reached muscular failure within the prescribed repetition range (Brown et al., 2023).

Pull-Ups (4 sets of 12 reps) were selected for its direct relevance to the study objectives. Assisted pull-ups with resistance bands or partner support were used for participants unable to perform unassisted repetitions (Barnes et al., 2022). Australian Pull-Ups (4 sets of 15 reps) targeted horizontal pulling strength and mid-back muscles, complementing vertical pulling mechanics (Snarr & Esco, 2021). Reverse Pull-Ups (2 sets of 8 reps) introduced grip variation, engaging the biceps brachii and altering muscle activation patterns (Kibele et al., 2021). Negative Pull-Ups (2 sets of 8 reps, 4-second eccentric) focused on eccentric strength, emphasizing prolonged time under tension (McGill, 2022). (Table 1)

Table 1 General training for all groups

Name of the exercise	Number of Sets	Number of Reps
Pull-Ups	4	12
Australian Pull-Ups	4	15
Reverse Pull-Ups	2	8
Negative Pull-Ups	2	8 (4-second eccentric)

Specific Training

PIT completed 5 sets of 1 minute fast running with 3 minutes full rest in a 20-minute interval running session after the general pull-up training at each training session. PFT performed wrist curls, reverse wrist curls, reverse grip barbell curl, farmer walk after each pullup training. PCT made V-Ups, leg raises, cat and cow, and plank. (Table 2)

Table 2 Overview of the group specific training programs.

PIT= pull-up and interval training group, PFT= pull-up and forearm training group, PCT= pull-up and

PIT			PFT			PCT		
Exc	S	R	Exc	S	R	Exc	S	R
Running	5	1min run/ 3min rest	Wrist curl	3	12	V-Ups	3	15
			Reverse wrist curl	3	12	Leg raises	3	12
			Reverse grip wrist curl	3	12	Cat and cow	3	30
			Farmer walk	3	30s	Plank	2	1min

core training group, Exc= name of the exercise, S=number of series, R= number of repetitions

Statistical Analysis

Statistical analyses were conducted using Origin PRO software. Group means and standard deviations were computed for all measured and calculated variables. Baseline data were analyzed for equivalence across groups. The Shapiro–Wilk tests revealed that all variables were normally distributed, except the maximum pull-up repetition data of the PIT group. To detect and measure the improvements of the groups between Test 1 and Test 2 paired sample t-test with the appropriate Bonferroni adjustments were performed, and Wilcoxon test for PIT maximum pull-up performance. Between-group differences were assessed using one-way ANOVA test. Statistical significance was set at $p \leq 0.05$.

4. Results

Maximum pull-up repetition

After the 8 week pull-up training, the maximum pull-up repetition increased significantly in all groups, PIT by 57.14% ($p=0.008$), PFT by 181.2% ($p=0.000$) and PCT by 151.52% ($p=0.001$). (Figure 1). We found significant differences between groups based on the delta value of repetitions measured between test 1 and test 2. (Figure 2)

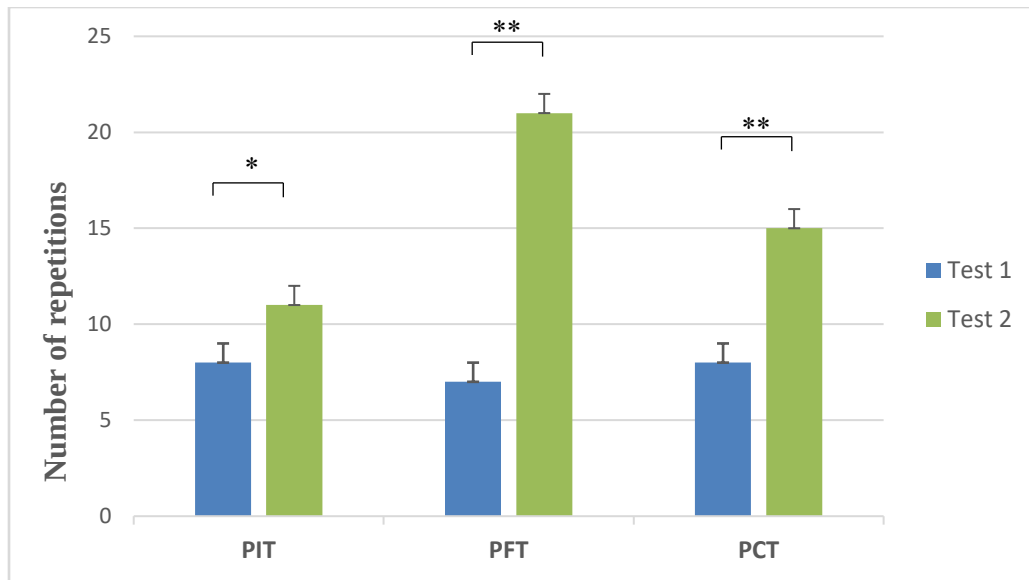


Figure 1 The number of pull up repetitions in the three training groups in Test 1 and Test 2.

*Significant difference ($p < 0.05$), **significant difference ($p < 0.005$)

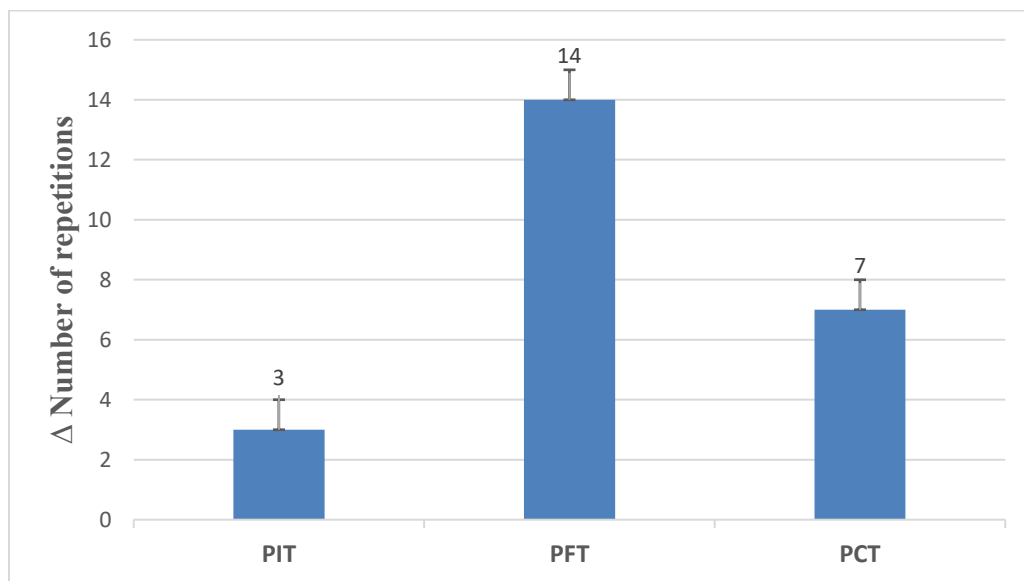


Figure 2 The differences in repetitions measured on test 1 and test 2.

Grip Strength

Following the 8-week pull-up training program, grip strength in the right hand showed significant improvement, with PIT increasing by 1.67% ($p=0.001$), PFT by 17.14% ($p=0.001$), and PCT decreasing slightly by -0.49% ($p=0.846$).

The left-hand grip strength improved significantly across all groups after the intervention. The PIT group showed an increase of 2.3% ($p=0.003$), the PFT group showed a substantial improvement of 17.3% ($p=0.001$), and the PCT group demonstrated an improvement of 10.9% ($p=0.012$). (Figure 3) According to the grip strength of the right hand we also found significant differences between groups ($p= 0.004$). (Figure 4)

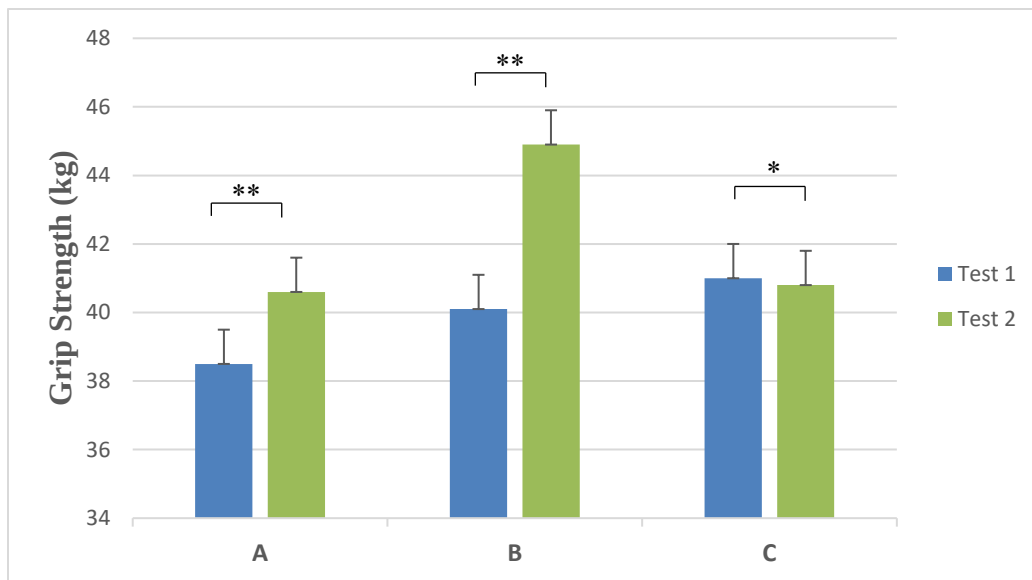


Figure 3 Right hand grip strength in Test 1 and Test 2.

*Significant difference ($p < 0.05$), **significant difference ($p < 0.005$)

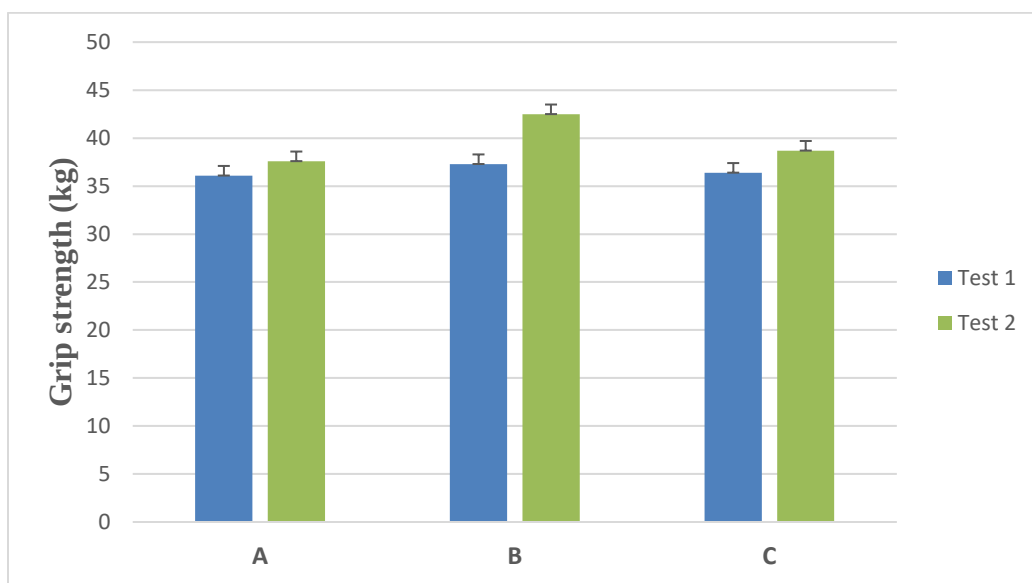


Figure 4 left hand grip strength in Test 1 and Test 2 for all groups.

Dead hanging time

After the 8-week pull-up training, dead hanging time improved significantly in all groups, PIT by 33.33% ($p=0.003$), PFT by 112.5% ($p=0.001$), and PCT by 85.71% ($p=0.001$). (Figure 5) ANOVA analysis indicated no statistically significant differences among the groups for hanging time improvement. (Figure 6)

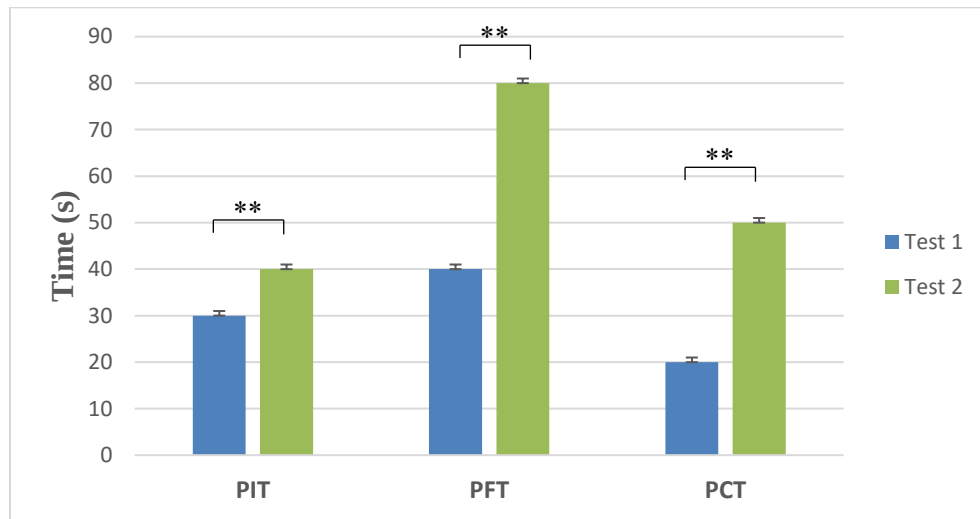


Figure 5 The time spent in the dead hanging test in Test 1 and Test 2.

*Significant difference ($p < 0.05$), **significant difference ($p < 0.005$)

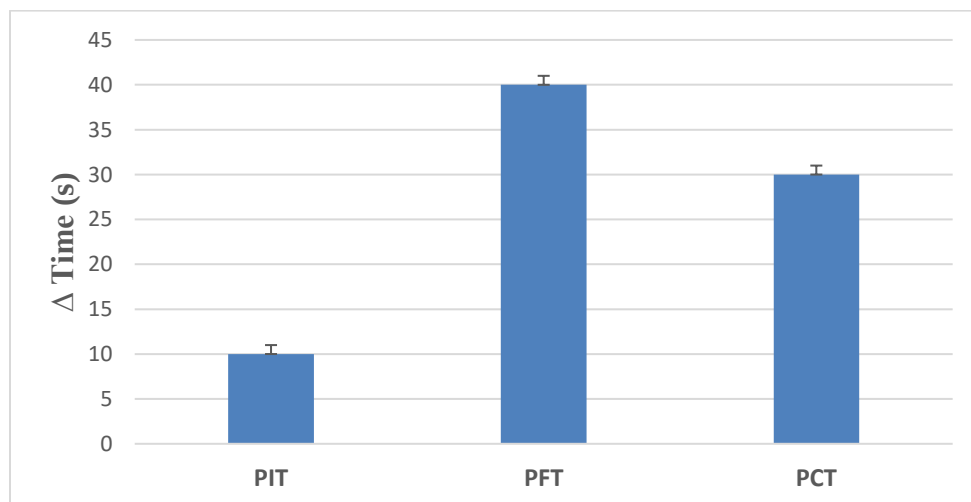


Figure 6 The delta time value between Test 1 and Test 2 measurements

5. Discussion

In this study, we compared the effects of core-specific and forearm-specific training on pull-up performance, grip strength, and dead-hanging endurance in physically inactive male university students. The findings highlight the superior efficacy of forearm-specific training in improving all measured parameters, with moderate benefits observed in core-specific training. The results provide valuable insights for designing targeted interventions to enhance upper-body strength and endurance.

H1: Pull-up performance will improve in all three groups.

Our results confirmed the first hypothesis, as all groups demonstrated significant improvements in pull-up performance. The forearm-specific training group exhibited the highest increase, followed by the core-specific training group and the interval training group. This finding aligns with previously published studies emphasizing the importance of targeted strength training for performance enhancement (Trossman et al., 2020; Lee et al., 2018). The substantial improvement in performance following forearm-specific training can be attributed to the role of forearm endurance in sustaining grip strength and reducing fatigue, which are crucial for completing a higher number of repetitions. Studies have demonstrated the effectiveness of forearm endurance training in improving grip strength and pull-up performance (Brown et al., 2019; Johnson & Morris, 2021).

The moderate gains observed in performance following core-specific training highlight the role of core stability in force transfer and movement efficiency. This is supported by prior research indicating the significant contribution of core strength to upper-body performance (Smith et al., 2017; Wang & Taylor, 2016). On the other hand, the limited progress observed in the interval training group underscores the need for muscle-specific interventions to optimize pull-up performance, a concept corroborated by studies comparing generalized versus muscle-targeted training approaches (Anderson & Carter, 2019; Green et al., 2022).

H2: Forearm-specific training groups are expected to show the most significant improvements in pull-up performance, compared to core- and interval-specific training groups.

Our second hypothesis proposed that forearm-specific training would yield the most significant improvements in pull-up performance. The findings strongly support this, as the forearm-specific training group outperformed both the core-specific training group and the interval training group in maximum pull-up repetitions, grip strength, and dead-hanging endurance. The specific forearm

exercises, such as wrist curls and reverse wrist curls, directly targeted grip strength and endurance, enabling participants to perform more pull-up repetitions with reduced fatigue. These results are consistent with previous studies that emphasize the primacy of grip strength in pull-up mechanics (Dunn, 2017; 2017; Vigouroux et al., 2022).

The effectiveness of forearm-specific training in improving grip strength has been highlighted in studies examining pull-up variations and their impact on muscle activation. Additionally, grip strength's role in enhancing upper-body performance has been supported by research investigating muscle engagement during pull-ups and related exercises (Youdas et al., 2010; Vigouroux et al., 2022). Furthermore, the targeted nature of forearm-specific exercises aligns with findings that emphasize the importance of focused interventions for maximizing performance outcomes (Dunn, 2017; Silfies et al., 2015)

H3: Forearm-specific training group is expected to show greater improvements in maximum pull-up repetitions, grip strength, and dead hanging time compared to the core-specific training group. Our third hypothesis was also supported by our findings. The forearm-specific training group demonstrated the highest increase in grip strength and dead-hanging endurance, significantly outperforming the core-specific training group. This result underscores the specificity of forearm training in enhancing isometric endurance and strength, both of which are essential for prolonged hanging and pull-up performance. These findings are consistent with previous research highlighting the critical role of forearm strength in pull-up mechanics and isometric performance (Sánchez-Moreno et al., 2015; Prieske et al., 2016).

Although the core-specific training group achieved moderate improvements in both metrics, its effects were secondary to the forearm-specific training group. Research has shown that while core stability contributes to improved body alignment and overall athletic performance, it plays a supporting role in tasks requiring grip-specific strength (Prieske et al., 2016). This aligns with the observed indirect benefits of core-specific training on pull-up performance.

H4: Interval specific training group will improve the least pull up performance compared to the forearm- and core-specific training groups.

Our fourth hypothesis was supported by our results. The interval training group demonstrated the lowest increases in all measured parameters. These findings emphasize the limited effectiveness of general conditioning without targeted strength interventions. Interval training, while beneficial

for cardiovascular fitness, does not directly address the muscle groups critical for pull-up performance (Buchheit & Laursen, 2013; Ronai & Scibek, 2014).

The findings of this study offer evidence-based recommendations for practitioners. Forearm-specific training should be prioritized for individuals seeking to maximize pull-up performance, particularly for tasks requiring sustained grip strength and endurance. Exercises such as wrist curls, reverse wrist curls, and grip holds are highly effective (Medina et al., 2017). Core training should be incorporated as a supplementary strategy to enhance overall stability and movement efficiency, particularly for minimizing compensatory movements during pull-ups. A combined approach targeting both forearm and core muscles may provide synergistic benefits and warrants further investigation (Ronai & Scibek, 2014).

This study had several limitations. The small sample size limited the generalizability of the findings. Additionally, compliance with dietary control was self-reported, introducing potential variability. Future studies should incorporate larger sample sizes, include female participants, and utilize advanced measurement tools such as electromyography to assess neuromuscular adaptations. Exploring the combined effects of forearm and core-specific training in diverse populations could provide deeper insights into optimizing pull-up performance and developing more effective training strategies.

6. Summary

This study compared the effects of forearm-specific and core-specific training on pull-up performance, grip strength, and dead-hanging endurance in physically inactive male university students. The findings demonstrated that forearm-specific training led to the most significant improvements in all parameters, highlighting the critical role of grip strength in pull-up mechanics. Core-specific training showed moderate benefits by enhancing stability and movement efficiency, while interval training resulted in minimal progress. These results underscore the importance of targeted interventions for optimizing upper-body strength and endurance.

Moreover, these findings hold critical implications for various sports, such as gymnastics, rock climbing, swimming, and football, where upper-body strength, grip endurance, and core stability are vital. By integrating forearm and core-specific exercises into training programs, coaches and practitioners can significantly maximize athletes' performance, enabling them to excel in sport-specific tasks such as climbing, sprint swimming, and executing long throws. These targeted

interventions not only enhance performance but also support the development of essential strength and endurance, contributing to long-term athletic success.

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