

Increases in Arm Muscle Power, Strength, and Endurance Following Six Weeks of Strength Training: An Experimental Study

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Abstract

The purpose of this study is to evaluate and compare the effects of pull-ups, push-ups, and burpees on arm muscle power, strength, and endurance. A total of 40 male untrained students (aged 16-18 years) were randomly divided into four groups: G1 (burpee), G2 (push-up), G3 (pull-up), and G4 (control group). All subjects performed respected exercise for six weeks. The main outcome variables were arm muscle strength, strength, and endurance that were measured at pretest (week 0) and posttest (week 6). All statistical analysis were performed using SPSS 30 for Mac. The burpee group (G1) demonstrated significant improvements in muscular power ($p=0.000$) and strength ($p=0.002$). The push-up group showed significant gains in muscular strength ($p=0.000$) and endurance ($p=0.002$). The pull-up group demonstrated significant improvements in power, strength, and endurance ($p<0.005$). Meanwhile, G4 did not show any significant changes in all measured variables. These results underscore the importance of selecting exercises based on specific training objectives and show that bodyweight training, if designed appropriately, can result in meaningful improvements in various aspects of upper arm muscle fitness.

Keywords: arm muscle, endurance, burpee, strength training, power, pull up, push up

Introduction

Strength training or knows as resistance training is one of essential exercise for improving muscle hypertrophy (Krzysztofik et al., 2019) and muscle performance, especially in terms of strength, power, and endurance (Nuzzo et al., 2024). Among the various resistance trainings, bodyweight exercise is widely known for their efficacy in developing upper body strength and increasing muscle endurance (Contreras, 2014). These exercises are commonly used in training programs designed for athletes and individuals aiming for general fitness, as they provide an effective way to build strength without requiring special equipment

(Archila et al., 2021). Additionally, the versatility of bodyweight training—such as push up, pull up, burpees—makes them ideal for various settings, including home-based exercise routines (Zheng et al., 2022). Recent studies have also highlighted the effectiveness of these exercises in improving endurance and overall muscle strength, both of which are key factors for athletic performance and functional fitness (Klisaric et al., 2021; Yachsie et al., 2022). Understanding the physiological mechanisms behind these exercises and their specific impact on arm muscle strength, strength, and endurance is essential for optimizing exercise programs and improving neuromuscular efficiency and hypertrophy (Schoenfeld & Grgic, 2018).

The theoretical framework for this research is grounded in the principles of resistance training, which suggest that the body adapts to stressors through muscle fiber recruitment, hypertrophy, and improved neuromuscular efficiency (Curovic, 2025; Grgic et al., 2021). According to the principle of progressive overload, when muscles are exposed to increased resistance or volume, they undergo micro-tears, leading to muscle growth and enhanced performance (D. Plotkin et al., 2022). Pull-ups, push-ups, and burpees, which involve dynamic and compound movements, challenge multiple muscle groups, providing a comprehensive stimulus for muscular fitness. In particular, the push-up is widely recognized as an effective exercise for improving upper body strength and endurance, as it engages the chest, shoulders, and triceps (Schoenfeld & Grgic, 2018). Likewise, pull-ups are well-documented for their ability to target the latissimus dorsi, biceps, and forearm muscles, fostering both strength and power development (J. Hewit et al., 2018). Burpees, being a full-body exercise, combine elements of resistance training and cardiovascular endurance, making them essential for improving both muscular endurance and overall fitness (Bingley, 2019).

Numerous studies have explored the role of bodyweight exercises in enhancing muscular performance (Cano-Sánchez et al., 2024; Del Vecchio et al., 2022; Gonzalez & Sedlacek, 2021). For instance, a study by Thomas et al. (2021) demonstrated that push-ups and pull-ups significantly improve upper body strength and endurance, which is particularly beneficial for sports that demand functional strength. Similarly, previous studies found that burpee exercises effectively increase aerobic capacity and muscular endurance, owing to their high-intensity nature and the recruitment of both aerobic and anaerobic energy systems (Carrera-Quintanar et al., 2024; Ojeda et al., 2022). Additionally, training programs that integrate compound exercises have been shown to enhance neuromuscular coordination and promote overall muscle power (Hortobágyi et al., 2021). However, the effects of these exercises on arm muscle power, strength, and endurance have not been extensively compared in controlled experimental settings. Therefore, this study aims to bridge this gap by experimentally examining the effects of pull-ups, push-ups, and burpees on arm muscle performance, providing valuable insights into their specific contributions to muscle power, strength, and endurance.

Despite the well-established benefits of bodyweight exercises in improving general fitness, there is a significant gap in the current literature regarding a direct, comparative analysis of pull-ups, push-ups, and burpees in relation to arm muscle power, strength, and endurance specifically. While individual studies have demonstrated the advantages of these exercises for upper body performance

(Hassan, 2018; Pérez-Olea et al., 2018; Syed-Abdul et al., 2018), there is limited empirical evidence exploring their differential impact on arm muscle development in a controlled, experimental setting. Furthermore, the synergy between these exercises in contributing to overall muscle performance has not been adequately examined, leaving a notable gap in understanding how they may complement each other in enhancing upper body function. The novelty of this research lies in its experimental approach to directly compare the effects of these exercises on arm muscle performance, providing insights that may be crucial for developing more effective training protocols. Therefore, the purpose of this study is to evaluate and compare the effects of pull-ups, push-ups, and burpees on arm muscle power, strength, and endurance, addressing these gaps in existing literature and providing practical recommendations for athletes and fitness enthusiasts alike.

Method

Study and participant design

The study employed a quasi-experimental design with a pre-test-post-test control group structure to investigate the effects of three body weight exercises—burpee, pull-ups, push-ups—on arm muscle performance. A total of 40 male untrained students (aged 16-18 years) were randomly divided into four equal groups (n = 10 per group): Group 1 (G1) performed burpee exercises, Group 2 (G2) performed push-up exercises, Group 3 (G3) performed pull-up exercises, and Group 4 (G4) acted as a control group without exercise intervention.

The inclusion criteria are as follows: participants must be male students between the ages of 16 and 18; (2) free from musculoskeletal disorders or upper body injuries within the last six months; (3) not engaged in any structured resilience training program in the last three months; and (4) willing to commit to the full duration of the training and assessment program. Exclusion criteria include: (1) a history of cardiovascular, orthopaedic, or neurological conditions; (2) the use of current performance-enhancing substances or drugs that may affect muscle performance; and (3) absence from more than two training sessions or test days during the study period.

Training protocols

Participants in the intervention groups (G1, G2, and G3) performed bodyweight exercises specific to the assigned group—burpee, push-ups, and pull-ups—three times a week for six weeks under direct supervision. Meanwhile, the control group (G4) maintained their usual daily activities and did not perform structured upper body exercises during the study period.

Each training session is preceded by a 5-minute dynamic warm-up (e.g., arm twist, shoulder twist, jumping motion) and ends with a 5-minute cool-down including static stretching. The exercise program is designed to progressively increase volume and intensity to stimulate adaptation in arm muscle strength, endurance and power. Workout intensity is set using a target rep per set, with adjusted rest intervals to maintain high-quality reps and prevent fatigue. All participants were instructed to perform each rep with full range of motion and

controlled tempo. The proper form and technique are thoroughly monitored. The detail of training program is displayed in Table 1.

Table 1. Six-Week of Progressive Bodyweight Training Program

Week	Sets	Repetition per Set	Rest between Set	Intensity	Training Focus
1	3	8	90 sec	60% of HR max	Familiarization, technique focus
2	3	10	90 sec	65-70%	Foundational strength
3	4	10	75 sec	70-75%	Volume and work capacity building
4	4	12	75 sec	75-80%	Strength and muscular endurance
5	4	12-15	60 sec	80-85%	High-volume strength/endurance
6	5	15	60 sec	85-90%	Peak effort and muscular adaptation

Data collection

Baseline data were obtained at the beginning of the experimental period to measure anthropometric variables such as age (years), weight (kg), height (cm), body mass index (BMI; kg/m²), heart rate (HR; bpm), and blood pressure (SBP and DBP; mmHg). Digital scale (Omron HN-289, Osaka, Japan) was used to measure weight. The height of the subjects was measured using a portable stadiometer (Seca 213, California, USA) at the nearest 0.1 cm. Heart rate was observed and tracked using a polar heart rate monitor (Polar H10 Bluetooth Heart Rate Sensor & Fitness Tracker, Kempele, Finland), and a digital blood pressure meter (Omron Deluxe HEM-8712, Osaka, Japan) was used to check the subjects' diastolic and systolic blood pressure. All tools and devices were calibrated before using to guarantee the accuracy of data.

Data collection was carried out at two time points: pre-test (week 0) and post-test (week 6). The main outcome variables were arm muscle strength, strength, and endurance. Standard procedures and validated instruments are used to ensure consistency and reliability across all measurements. All measurements are taken in a controlled indoor facility under the supervision of a professional trainer to ensure safety and minimize variability.

Arm muscle power is assessed using a medicine ball throwing test. Participants were asked to sit leaning against the wall with their backs and heads fully supported, their feet straightened, and the soles of their feet tightly together. While holding a medicine ball weighing 2 kg at chest height, they made a movement of passing their chest forward with two hands with maximum effort. The horizontal distance from the wall to the point where the ball first touched the floor was measured to the nearest centimeters. Each participant completed three attempts with a one-minute break between throws, and the best distance was recorded.

Arm muscle strength is measured using a hand grip dynamometer (e.g., JAMAR or equivalent). Participants stand up straight with their arms at their sides, do not touch the body, and squeeze the dynamometer with maximum effort using

their dominant hands. The test was repeated three times with a rest interval of 30 seconds, and the highest value (in kilograms) was used for the analysis. The device is calibrated before each test session to ensure accuracy.

Arm muscle endurance was evaluated using a timed push-up test. Participants perform as many standard push-ups as possible within 60 seconds, maintaining the correct body shape. Push-ups are only counted if they are done with a full elbow extension and the chest lowered to about 5 cm off the ground. Participants were verbally encouraged, but shape correction was not allowed during the test. The correct total number of repetitions is recorded as the endurance score.

Data analysis

All data were analysed in descriptive statistics and their values were expressed in mean and standard deviation (SD). Quantitative data were verified in terms of normal distribution using the Saphiro-Wilk test, followed by a non-parametric Wilcoxon signed rank test to analyse the differences in physical performance variables before (pre-test) and after (post-test) training was carried out for six weeks. The Friedman test was used to compare the mean between groups. The difference was considered significant if the p value ≤ 0.05 . All statistical analysis were performed using SPSS 30 for Mac (SPSS Inc., Chicago, USA) and GraphPad Prims 9.0 for Mac (GraphPad Software Inc., San Diego, USA).

Result

Table 1 presents the descriptive statistics (mean \pm standard deviation) for four different groups. The age of participants ranged from 16.95 ± 0.60 years in G1 to 17.65 ± 0.78 years in G2, showing relatively similar age distributions. Bodyweight and height were also fairly consistent across groups, though G4 had the highest average bodyweight (58.50 ± 16.34 kg) and G1 the lowest (55.63 ± 9.80 kg). The body mass index (BMI) values suggest all groups fell within normal BMI ranges, with G1 showing the highest variability (21.40 ± 6.06 kg/m²). Resting heart rate values were similar across all groups, ranging from 77.65 to 78.88 bpm. Notably, systolic and diastolic blood pressures were lowest in G2 (104.84 ± 5.43 mmHg and 72.82 ± 4.05 mmHg, respectively), while G4 recorded the highest systolic pressure (109.24 ± 5.10 mmHg). These results indicate that, although minor physiological variations exist among the training groups, the baseline characteristics are generally comparable and within healthy ranges, supporting the validity of further comparative analysis between exercise interventions.

Table 1. Descriptive statistic of subjects (mean \pm SD)

Variable	G1	G2	G3	G4
Age (years)	16.95 \pm 0.60	17.65 \pm 0.78	17.02 \pm 0.55	17.32 \pm 0.45
Bodyweight (kg)	55.63 \pm 9.80	54.38 \pm 8.19	57.88 \pm 14.39	58.50 \pm 16.34
Height (cm)	167.50 \pm 8.16	165.38 \pm 4.31	166.63 \pm 5.40	166.0 \pm 7.45
Body mass index (kg/m ²)	21.40 \pm 6.06	20.42 \pm 3.87	19.83 \pm 2.69	20.12 \pm 2.79
Heart rate (bpm)	78.24 \pm 11.10	77.65 \pm 10.12	77.82 \pm 9.95	78.88 \pm 11.23
Systole (mmHg)	108.41 \pm 7.22	104.84 \pm 5.43	107.14 \pm 8.32	109.24 \pm 5.10
Diastole (mmHg)	79.35 \pm 5.43	72.82 \pm 4.05	76.52 \pm 6.16	79.35 \pm 5.43

G1 = burpee; G2 = push-up; G3 = pull-up; G4 = conventional training

Table 2 shows pre-test and post-test results during the six-week training period for power, strength, and endurance in the four training groups. The G1 group (burpee) showed significant improvements in power ($p = 0.000$) and strength ($p = 0.002$), but not in endurance ($p = 0.343$). G2 (push-ups) did not show a significant increase in power ($p = 0.063$), but a significant increase in strength ($p = 0.000$) and endurance ($p = 0.002$). G3 (pull-up) showed significant improvements in all three variables—power ($p = 0.001$), strength ($p = 0.000$), and endurance ($p = 0.000$)—making it the most consistently effective intervention across all domains. Meanwhile, G4 (conventional exercise) showed no statistically significant change in power ($p = 0.100$), strength ($p = 0.090$), or endurance ($p = 0.121$), suggesting the limited effectiveness of these exercises during the trial period. Overall, pull-up and push-up groups had the most pronounced effect on muscle performance, especially in terms of strength and endurance.

Table 2. Pretest and posttest analysis of measured variables over six weeks of experimental period

Group		Power	Sig.	Strength	Sig.	Endurance	Sig.
G1	Pre-test	119.92 ± 14.72	0.000*	15.70 ± 4.06	0.002*	21.46 ± 4.03	0.343
	Post-test	123.41 ± 14.00		17.72 ± 3.92		22.00 ± 2.91	
G2	Pre-test	109.50 ± 18.51	0.063	17.56 ± 4.03	0.000*	23.18 ± 4.28	0.002*
	Post-test	110.00 ± 17.31		20.61 ± 3.37		25.81 ± 3.82	
G3	Pre-test	114.76 ± 12.94	0.001*	15.42 ± 4.79	0.000*	23.25 ± 3.48	0.000*
	Post-test	115.64 ± 11.95		18.32 ± 4.47		26.55 ± 4.12	
G4	Pre-test	113.28 ± 17.92	0.100	23.12 ± 3.48	0.090	22.63 ± 4.55	0.121
	Post-test	113.66 ± 18.00		23.19 ± 4.79		23.14 ± 4.79	

G1 = burpee; G2 = push-up; G3 = pull-up; G4 = conventional training

*significant at $\alpha = 0.05$

Based on the results presented in Table 3, the intervention groups demonstrated varied improvements in arm muscle power, strength, and endurance over the 6-week training period, with statistically significant differences observed in specific measured variables. The burpee group (G1) showed the highest absolute increase in power ($\Delta = 3.49$), representing a 2.91% improvement. In contrast, the push-up group (G2) exhibited a modest increase in power ($\Delta = 0.50$, 0.46%) but showed statistically significant gains in strength ($\Delta = 3.05$, 17.37%) and endurance ($\Delta = 2.63$, 11.35%) with p-values of 0.002 and 0.005, respectively.

Table 3. Between group differences in the changes of strength and power of muscle arm

Group	Power			Strength			Endurance		
	Δ	%	sig.	Δ	%	sig.	Δ	%	sig.
G1	3.49	2.91	0.002*	2.02	12.87	0.005*	0.54	2.52	0.002*
G2	0.50	0.46		3.05	17.37		2.63	11.35	
G3	0.88	0.77		2.90	18.81		3.3	14.19	
G4	0.38	0.34		0.07	0.30		0.51	2.25	

G1 = burpee; G2 = push-up; G3 = pull-up; G4 = conventional training

*significant at $\alpha = 0.05$

The pull-up group (G3) demonstrated significant improvements in both strength ($\Delta = 2.90$, 18.81%) and endurance ($\Delta = 3.3$, 14.19%) with a shared p-value of 0.002, suggesting it was the most effective intervention for enhancing upper-body muscular endurance and strength. Meanwhile, the control group (G4) showed minimal changes across all three variables,

Discussion

The findings reveal distinct physiological adaptations resulting from different training modalities over a six-week period. The burpee group (G1) demonstrated significant improvements in muscular power and strength, a finding that aligns with the biomechanical and physiological demands of burpee exercises (Di Pietro & Puccio, 2024). Burpees are a compound, high-intensity, bodyweight movement that recruits major muscle groups including the quadriceps, glutes, hamstrings, chest, shoulders, and core in a rapid and explosive sequence (Bingley et al., 2019; Yamashita, 2023). This multi-joint activation increases neuromuscular recruitment and enhances intramuscular coordination, key mechanisms for developing muscular power and strength (Bingley, 2019). Additionally, the anaerobic component of burpees—especially during repeated, maximal efforts—stimulates fast-twitch (Type II) muscle fibers, which are crucial for power production and high-force output (D. L. Plotkin et al., 2021; Wilson et al., 2012)

The combination of strength and power gains observed in this study is also consistent with training adaptations associated with high-intensity functional training (HIFT), of which burpees are a classic example (Feito et al., 2018). HIFT has been shown to increase maximal strength and peak power output due to its emphasis on short bursts of high-load, high-speed movement, often performed with minimal rest (Greenlee et al., 2017; McWeeny et al., 2020). This contrasts with traditional resistance training, which may focus more narrowly on hypertrophy or endurance (Bernárdez-Vázquez et al., 2022), depending on the program design. Interestingly, despite the metabolic demands of burpees, the G1 group did not demonstrate significant improvements in muscular endurance. This could be attributed to the nature of the training load and progression during the intervention period. Endurance adaptations are largely dependent on volume, duration, and the oxidative stimulus applied to Type I muscle fibers (Broker, 2015), which may not be fully activated during short, high-intensity sessions unless structured for volume or longer time-under-tension (Hughes et al., 2018). Thus, while burpees are effective for inducing neuromuscular and anaerobic adaptations that enhance strength and power, they may fall short in promoting sustained muscular endurance if the training does not emphasize higher repetitions or longer work intervals.

The push-up group showed significant gains in muscular strength and endurance, consistent with the physiological demands of body-weight resistance training. Push-ups, as closed kinetic chain exercises, engage the upper body and core muscles through repeated concentric and isometric contractions, promoting hypertrophy and neuromuscular efficiency over time (Alizadeh et al., 2020; Calatayud et al., 2014). The high-volume, submaximal load characteristic of push-up routines facilitates aerobic adaptations such as increased capillarization and mitochondrial density in Type I fibres, supporting endurance improvements

(Aagaard & Andersen, 2010). However, no significant power gains were observed, likely due to the low-velocity, non-explosive nature of push-ups, which do not sufficiently stimulate the neuromuscular mechanisms required for enhancing power output. Power development typically requires high-load or high-speed movements that engage the stretch-shortening cycle and maximize force-velocity potential, such as plyometric or Olympic lifts (Cormie et al., 2011).

The pull-up group demonstrated significant improvements in power, strength, and endurance, highlighting the effectiveness of pull-ups as a comprehensive upper body exercise. Pull-ups are multi-joint, closed kinetic chain movements (Kim & Yoo, 2017; Snarr et al., 2017) that recruit several major muscle groups simultaneously, including the latissimus dorsi, biceps brachii, trapezius, and core stabilizers (J. K. Hewitt, 2018). This high level of muscle activation, especially under bodyweight resistance, promotes both neural and muscular adaptations (Hughes et al., 2018; Sale, 1988). The concentric pulling action under load enhances maximal strength (Kataoka et al., 2024), while repeated sets performed over time can increase muscular endurance by improving local muscle oxidative capacity (Wang et al., 2023). Furthermore, when performed explosively or with added resistance, pull-ups can contribute to power development by increasing the rate of force production in the upper limbs (Vigouroux & Devise, 2024).

These findings are supported by literature on climbing athletes, where pull-up-based training has been associated with improvements in all dimensions of muscular performance (Vigouroux & Devise, 2024). For instance, López-Rivera and González-Badillo (2012) found that incorporating different contraction types—such as isometric holds, concentric pulls, and eccentric lowering—during pull-up routines led to improvements in maximal strength, muscle endurance, and explosive pulling ability among climbers. This suggests that the varied muscle contractions inherent in pull-up training promote both fast- and slow-twitch fibre adaptations, enhancing overall muscular function (Golden, 2024). Additionally, the instability and control required during pull-ups may contribute to improved intermuscular coordination and motor unit recruitment, which further supports strength and power gains (Behm & Sale, 1993).

This study has several limitations that should be acknowledged. The six-week duration may not have been sufficient to observe long-term adaptations, particularly in endurance measures. Additionally, the study did not account for dietary intake, rest periods, or participants' baseline fitness levels, all of which can influence training outcomes. Future research should consider longer intervention periods, control for nutritional and recovery variables, and include a more diverse participant pool to enhance the generalizability of the findings.

Conclusion

The findings in this study highlight the differential impact of different bodyweight trainings on muscle arm performance. Pull-up exercises are the most effective in improving all three domains—power, strength, and endurance—due to the demands of multi-joints, varying types of muscle contractions, and high neuromuscular involvement. Burpee exercises (G1) significantly increase power and strength, reflecting the benefits of high-intensity full-body movements,

although they do not succeed in increasing endurance within the experimental period. Push-up (G2) exercises, on the other hand, effectively increase muscle strength and endurance but do not significantly increase power, emphasizing their usefulness for sustained submaximal workloads rather than explosive outputs. These results underscore the importance of selecting exercises based on specific training objectives and show that bodyweight training, if designed appropriately, can result in meaningful improvements in various aspects of upper arm muscle fitness.

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