

Original Article

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The Effect of Resistance and Power Exercise Types on Maximum Strength and Muscular Endurance in University Students

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ABSTRACT

Background: This study aimed to compare and analyze the effects of two training modalities—resistance training and power training—on maximal strength (one-repetition maximum, 1RM) and repetition-based muscular endurance in university students.

Methods: Fifty-seven university students (34 males and 23 females) participated in a 12-week training intervention. The program was divided into two phases: phase 1 (first 6 weeks) involved resistance training with a controlled 3-second concentric-eccentric tempo, while phase 2 (last 6 weeks) incorporated power training with 20-second maximal repetition sets. A total of 12 exercises were included, comprising eight 1RM-based and four repetition-based exercises. Measurements were conducted at three time points—T1 (pre), T2 (mid), and T3 (post)—and included assessments of body composition and exercise performance. Data were analyzed using repeated measures ANOVA and paired t-tests.

Results: Significant improvements ($P<0.001$) were observed across most 1RM-based exercises, particularly during the power training phase. Repetition-based exercises also showed positive trends, although performance declines were noted in the kettlebell exercise for some participants. In terms of body composition, skeletal muscle mass significantly increased across all participants, while male participants exhibited a slight decrease in body fat percentage.

Conclusions: These findings suggest that power training is highly effective in improving maximal strength within a short period and that the effectiveness of exercise interventions may differ depending on contraction velocity and training modality. Based on a practical training design for general university students, this study offers foundational insights for developing efficient physical training programs.

Keywords: Resistance training, Power training, Maximal strength, Muscular endurance, 1 Repetition maximal

INTRODUCTION

In modern society, the issue of insufficient physical activity among university students is becoming increasingly serious [1]. This lack of activity has been associated with a heightened risk

of decreased physical fitness, obesity, and musculoskeletal disorders [2]. Particularly, many students experience a significant decline in physical activity upon entering university, which can lead directly to deteriorating health and a reduced quality of life in the long term [3]. Against this backdrop, the importance of

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strength training has been emphasized [4]. Resistance training enhances muscle hypertrophy and maximal strength [5-7], while power training, performed at high velocity with low resistance, improves neuromuscular efficiency and fast-twitch fiber recruitment [8,9]. As these modalities differ in stimulus, their effects on maximal strength also differ. Maximal strength, commonly measured via one-repetition maximum (1RM) [10-12], is a key indicator of performance. Therefore, this study aims to compare the effects of resistance and power training on university students' maximal strength.

A unique aspect of this study is the use of identical exercises across two phases. Phase 1 applied the "3-second rule" for controlled repetitions, while phase 2 focused on high-speed repetitions within 20 seconds. Muscle strength and body composition were measured pre-, mid-, and post-intervention to assess training effects.

METHODS

This study involved 57 male and female students from Sogang University (mean age, 22.04 years). This study was approved by the Institutional Review Board at Sogang University (SGUIRB-A-1808-44) and all participants signed an informed consent form. Body composition (height, weight, muscle mass, %body fat) was measured using InBody (InBody Co.) at three time points (Table 1).

Experimental design and procedure

A 12-week repeated-measures design was used, with 24 sessions held twice weekly. The first 6 weeks focused on resistance training with controlled concentric and eccentric phases ("3-second rule"), and the last 6 weeks on power training with explosive movements.

Participants were assessed at:

- T1 (pre): 1RM/repetition test+InBody
- T2 (mid): post-resistance training
- T3 (post): post-power training

Exercise program structure

Twelve exercises were used:

- 1RM-based (8): leg press, leg curl, leg extension, shoulder press, chest press, fly, lat pull down, seated row
- Repetition-based (4): leg raise, sit-up, back extension, kettlebell

In phase 1, 1RM exercises followed the 3-second tempo, and repetitions were counted over 1 minute. Repetition-based exercises were done at a self-paced max effort for 1 minute. In phase 2, all exercises were performed as fast as possible for 20 seconds using the same load. Sessions included warm-up and cooldown, supervised by exercise specialists.

Statistical analysis

SPSS ver. 25.0 (IBM Corp.) was used. Means, standard deviations, repeated measures ANOVA, and paired t-tests were applied. For statistical analysis, Friedman repeated measures ANOVA (a non-parametric test) and paired t-tests were conducted for each exercise type. Missing data were handled by listwise deletion. Significance was set at $\alpha=0.05$.

RESULTS

Analysis of one-repetition maximum-based exercises

All eight 1RM-based exercises showed statistically significant improvements across time ($P<0.001$), with paired t-tests confirming gains from T1 to T3 (Fig. 1). This supports the effectiveness of power training on maximal strength. In contrast, some repetition-based exercises (leg raise, back extension, kettlebell) showed no significant improvement, possibly due to limited neuromuscular adaptation, core-focused nature, and inconsistent protocols between phases.

Analysis of repetition-based exercises

Sit-up and leg raise improved significantly ($P<0.05$) (Fig. 2). Back extension showed marginal significance, while kettlebell showed a Friedman effect but lacked paired t-test significance. Technical difficulty and execution variability likely influenced

Table 1. Categorization of statistical methods used in the analysis

Statistical procedure	Included columns	Description
Mean and standard deviation	T1 mean, T3 mean	Summary of pre- and post-test mean values
Repeated measures ANOVA	Friedman χ^2 , P -value, N (repeated measures ANOVA)	Analysis of changes across three time points
Paired t-test	t-statistic, P -value, N (paired t-test)	Statistical comparison between T1 and T3
Missing value handling (listwise)	N (repeated measures ANOVA), N (paired t-test)	Valid sample sizes after listwise deletion of missing values

N, valid sample size; T1, pre-exercise; T3, post-exercise.

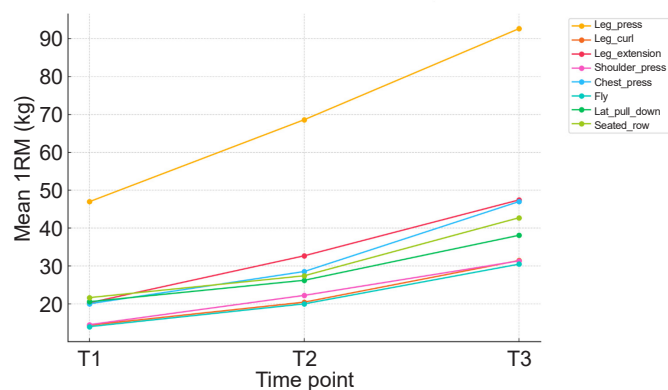


Fig. 1. Trends in mean one-repetition maximum (1RM) changes by exercise type. T1, pre-exercise; T2, mid-exercise; T3, post-exercise.

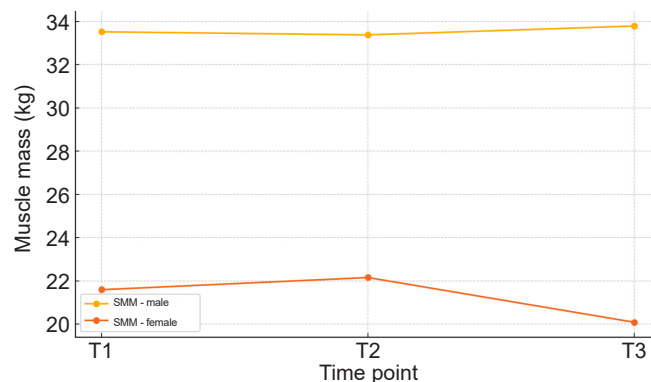


Fig. 4. Time-series changes in skeletal muscle mass (SMM) among male and female participants. T1, pre-exercise; T2, mid-exercise; T3, post-exercise.

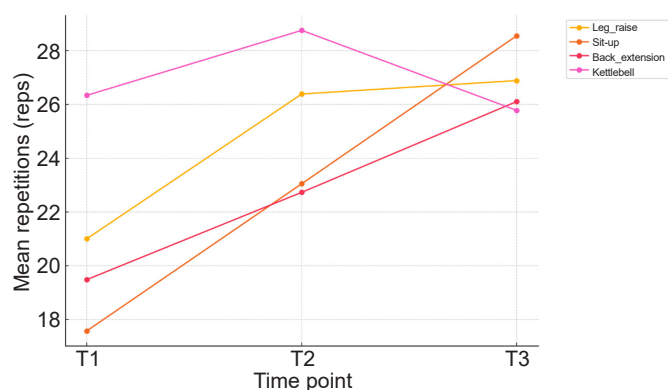


Fig. 2. Changes in performance by exercise for repetition-based movements. T1, pre-exercise; T2, mid-exercise; T3, post-exercise.

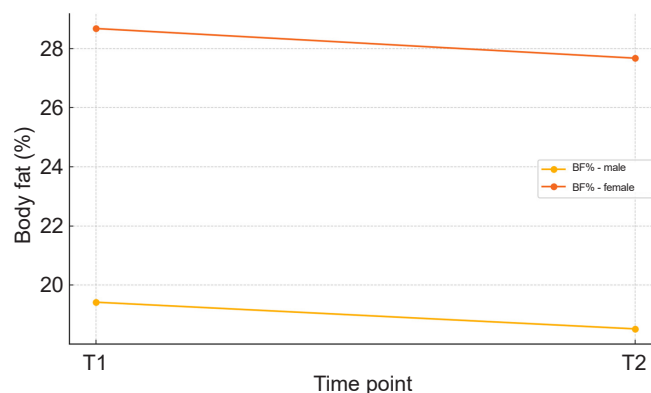


Fig. 5. Time-series changes in body fat percentage (BF%) among male and female participants. T1, pre-exercise; T2, mid-exercise.

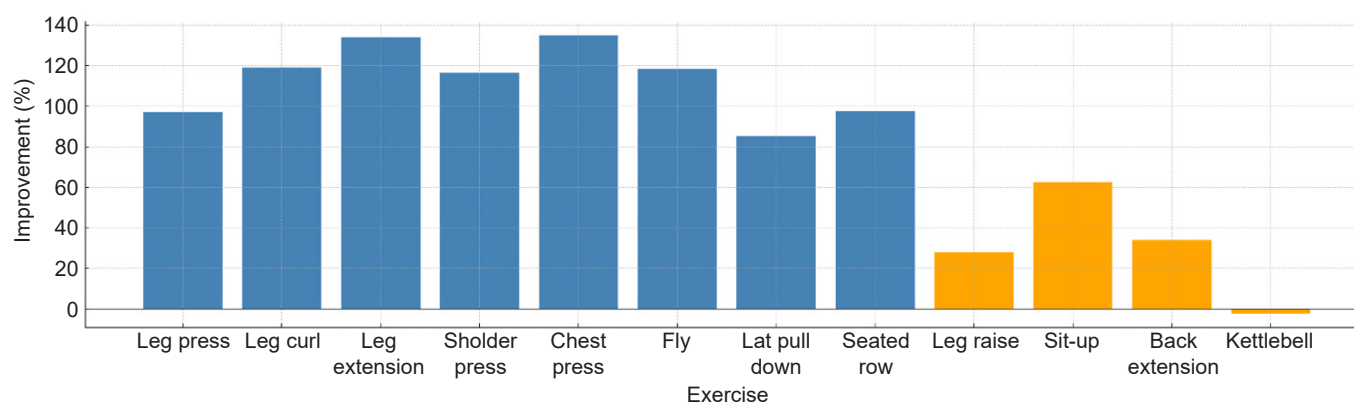


Fig. 3. Comparison of improvement rates by exercise from T1 (pre-exercise) to T3 (post-exercise).

these outcomes.

Improvement summary

Most 1RM exercises improved by over 100%, while endurance exercises had lower gains. Fig. 3 visualizes all exercise-specific improvements.

Body composition

Muscle mass increased significantly overall, with male participants showing a slight decrease in body fat (Fig. 4, 5). These trends are attributed to hormonal/metabolic responses to training.

Statistical overview

Table 2 summarizes key results for all exercises. The leg extension showed high significance ($\chi^2=49.79$, $t(30)=-8.97$, $P<0.001$). Non-parametric methods were used when normality was violated. Training phases were clearly differentiated: the first phase applied time-under-tension (3-second rule), and the second emphasized explosive 20-second bouts. Performance differences, especially in kettlebell work, suggest the importance of both neuromuscular stimulus and technical proficiency.

DISCUSSION

This study investigated the effects of resistance and power training on maximal strength (1RM), endurance performance (repetition-based), and body composition (skeletal muscle mass and body fat percentage) in a population of university students. Among the 12 exercises evaluated, 11 showed significant

improvements, with particularly notable performance gains observed in exercises such as leg extension, chest press, and sit-up. The average improvement rate for the 1RM-based exercises exceeded 100%, indicating a pronounced effect of the training intervention over a relatively short period.

Resistance training has been shown to enhance muscle hypertrophy, neuromuscular efficiency, and muscle fiber cross-sectional area [13]. In contrast, power training emphasizes explosive speed and fast-twitch fiber recruitment, aiming to maximize repetitions within a short time window. In this study, both forms of training contributed to improved strength outcomes. Given that resistance and power training were applied sequentially rather than as isolated sessions, the observed effects may be interpreted as resulting from a combined or hybrid training model.

Skeletal muscle mass changes differed by sex; male participants generally showed consistent increases, whereas female participants displayed maintenance or slight decreases after the second measurement. This pattern is likely related to hormonal differences [14] and muscle fiber distribution characteristics, aligning with previous findings that men exhibit more rapid muscular adaptations to high-load training. Body fat percentage gradually decreased in both sexes, presumably due to increased energy expenditure and enhanced metabolic efficiency.

Not all exercises showed improvement, however. The kettlebell exercise was the only activity that exhibited a decline in average repetitions, a result that was not statistically significant. This outcome may be attributed to the technical difficulty of the movement, insufficient individual proficiency, or inconsistencies in exercise intensity prescription [15]. Accumulated fatigue

Table 2. Statistical analysis results by exercise type

Exercise	Friedman χ^2 (repeated measures ANOVA)	P-value (repeated measures ANOVA)	N (repeated measures ANOVA)	T1 mean	T3 mean	t-statistic (paired t-test)	P-value (paired t-test)	N (paired t-test)
Leg press	44.486	<0.001	30	43.55	88.84	-7.114	<0.001	31
Leg curl	38.71	<0.001	31	13.23	27.19	-6.673	<0.001	31
Leg extension	49.791	<0.001	31	19.35	46.94	-8.972	<0.001	31
Shoulder press	43.521	<0.001	30	14.03	29.32	-5.84	<0.001	31
Chest press	50.643	<0.001	30	18.55	44.35	-9.628	<0.001	31
Fly	43.146	<0.001	30	13.39	27.48	-6.093	<0.001	31
Lat pull down	38.242	<0.001	29	19.5	34.8	-6.706	<0.001	30
Seated row	35.958	<0.001	28	20.52	38.1	-7.433	<0.001	29
Leg raise	8.237	0.0163	15	19.5	25.75	-2.188	0.0449	16
Sit-up	17.238	<0.001	16	14.56	27.69	-4.132	<0.001	16
Back extension	8.842	0.012	15	18.88	26.0	-3.148	0.0066	16
Kettlebell	11.828	0.0027	15	28.93	26.33	1.033	0.319	15

N, valid sample size; T1, pre-exercise; T3, post-exercise.

and reduced movement accuracy may also have influenced the decrease in performance [16]. These findings highlight the need to reassess exercise-specific responsiveness and ensure clearly defined quantification criteria during program design.

Furthermore, among the repetition-based exercises, both leg raise and back extension did not exhibit statistically significant changes. This may be attributed to the inherent difficulty in providing a uniform training stimulus across participants. Specifically, the leg raise exercise involves lower abdominal activation without upper body stabilization, making performance highly dependent on individual core strength levels [17]. In the case of the back extension, variations in range of motion and the degree of bodyweight support across individuals hinder precise quantification of repetitions [18]. These factors likely contributed to the lack of statistical significance, suggesting the need for more refined intensity control methods for such exercises in future studies.

The results of this study show that resistance exercise effectively enhances muscular strength [19]. Furthermore, incorporating aerobic components into the training program appears to promote broader functional improvements [20]. This study provides empirical evidence that short-term, high-intensity interventions can significantly enhance maximal strength even in healthy college populations.

Nonetheless, several limitations should be acknowledged. First, the use of voluntary participants may limit the generalizability of the findings. Second, the independent effects of resistance and power training could not be fully isolated due to the sequential design of the intervention. Third, potential confounding variables such as prior training experience and physical activity levels outside the study were not controlled. Additionally, missing data were present for certain exercises and were addressed using listwise deletion.

Despite these limitations, the study presents a practical exercise program model aimed at improving maximal strength and endurance in a general college student population. The circuit-style intervention—incorporating a mix of strength- and repetition-based exercises—is suitable even for beginners and can be adapted for personalized programming based on sex and body composition.

A key strength of the study lies in its unique experimental design, which applied different training modalities to the same set of exercises. In the first phase, resistance training was conducted using the “3-second rule,” with each repetition performed over 1 minute at a controlled tempo (1.5 seconds concentric+1.5 sec-

onds eccentric). In the second phase, the same exercises were performed for 20 seconds using a power training format aimed at maximal repetition. By distinguishing between 1RM-measurable exercises (8 types) and repetition-based exercises (4 types), the study was able to comprehensively evaluate both strength and muscular endurance. This approach enabled a clear investigation into the combined effects of movement speed, duration, and repetition count on muscle development. It also provided a basis for examining the interaction between maximal strength and muscular endurance. Such a distinction is expected to serve as a meaningful framework not only for understanding improvements in muscular strength, but also for identifying neuromuscular and metabolic responses that differ according to training modality. Ultimately, the experimental framework suggests that a hybrid training program—combining resistance and power components—may yield superior outcomes compared to using either approach in isolation.

Practical implications and recommendations

Based on the findings of this study, the following practical recommendations are proposed:

- 1) A combined circuit training program incorporating both resistance and power exercises is effective for improving physical fitness in university students.
- 2) Individualization of training variables such as intensity and repetitions is essential, taking into account sex and baseline fitness levels.
- 3) Technically demanding exercises (e.g., kettlebell movements) should be accompanied by proper instruction and repeated practice to ensure safety and efficacy.
- 4) Future studies should control for external factors such as training cycle, intensity modulation, dietary habits, and psychological motivation.
- 5) Longitudinal research is needed to assess the sustainability and long-term maintenance of training effects.

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AUTHOR CONTRIBUTIONS

Dr. Daihyuk CHOI had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors reviewed this manuscript and agreed to individual contributions.

Conceptualization: JWK and DC. Data curation: JWK, HJ, and KAC. Formal analysis: JWK. Investigation: JWK. Methodology: JWK. Project Administration: JWK and DC. Resources: DC, HJ, and KAC. Supervision: DC. Validation: JWK, HJ, and KAC. Visualization: JWK. Writing—original draft: JWK. Writing—review & editing: DC, HJ, and KAC.

CONFLICTS OF INTEREST

No existing or potential conflict of interest relevant to this article was reported.

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DATA AVAILABILITY

The data presented in this study are available upon reasonable request from the corresponding author.

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