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A Preliminary Analysis of Creatine and Glycogen Loading on Strength, Hypertrophy, and Adiposity on Human Body

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Keywords: glycogen loading; creatine supplementation; resistance training; muscle hypertrophy; adiposity; muscular strength

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An Analysis of Creatine and Glycogen Loading on Strength, Hypertrophy, and Adiposity on Human Body

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Abstract

Objective: This study aims to evaluate the effects of creatine supplementation and glycogen loading on strength development, muscle hypertrophy, and adiposity in collegiate students. Methods: Twelve male students from the Central University of Punjab, Bathinda, were randomly assigned to three groups: creatine supplementation, glycogen loading, or control. Each group participated in a 6-week structured weight training program to assess its impact on strength, muscle hypertrophy, and adiposity. Results: One-way ANOVA revealed that the glycogen loading group exhibited significantly greater upper body strength gains compared to the creatine supplementation and control groups. Conversely, the creatine supplementation group demonstrated superior lower body strength improvements compared to the glycogen loading and control groups. No significant differences were observed in muscle hypertrophy or adiposity across the groups. Conclusion: Glycogen loading enhances upper body strength, while creatine supplementation improves lower body strength. Further research with a larger sample size or additional variables is warranted to validate these findings.

Keywords: glycogen loading; creatine supplementation; resistance training; muscle hypertrophy; adiposity; muscular strength

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Introduction

Physical fitness is vital for human well-being and survival (Kumar et al., 2024). It offers numerous benefits, including enhanced physical and mental health, stronger immunity, improved metabolism, and greater stamina (Albrecht et al., 2023; Mr. Dinesh et al., 2024). Various physical activities and training can enhance fitness components (Mr. Dinesh et al., 2024; Physical Education and Sports, Hellenic Naval Academy, 2023). Nutritional health, reflected in physical appearance, depends on essential nutrients that protect against illness (Akhter Ali et al., 2017). Exercise and nutrition are critical for building fitness and strength. Weight training, which uses resistance to strengthen muscles, is a key method for improving overall fitness and health (Dinesh et al., 2024). It involves free weights, machines, or body weight to increase muscle strength, size, and endurance (Desai et al., 2024b; Tinôco et al., 2023). Carbohydrate loading, a strategy used by athletes, boosts muscle glycogen stores for energy during intense or prolonged exercise by consuming a diet high in carbohydrates (>80% of calories) (Forbes et al., 2023; Desai et al., 2024). Creatine supplementation, popular among athletes, supports performance by increasing ATP availability, enhancing muscle power, reducing fatigue, improving recovery, and boosting training capacity (Barranco-Gil et al., 2024; Deminice et al., 2013; Desai et al., 2024; Forbes et al., 2023).

Materials and Methods

Subjects in the Study

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Twelve healthy male participants (age: 23.91 ± 0.41 years, weight: 70.16 ± 1.42 kg, height: 174.97 ± 1.41 cm) from the Central University of Punjab, Bathinda, India, were randomly selected for the study. None were engaged in regular physical activity. All participants provided written informed consent prior to inclusion.

Experimental Design

A pre-test and post-test randomized group design was used.

Procedure of Data Collection

The selected subjects was randomly assigned (using the online research randomizer tool available at http://www.random.org) to different groups, i.e., creatine monohydrate supplementation (CRE; n=4), a glycogen loading group (GLY; n=4), and a control group (CON; n=4). All three groups went through a 6-week structured weight training program along with interventions. During the training period, all 12 subjects (N=12) underwent a training period of 5 days a week, training for 6 weeks. The subjects were tested on selected variables before the commencement of the training program baseline at (0 weeks), and post-intervention (6 weeks).To measure the maximum strength of upper body muscle groups, a 1RM bench press is taken using a bench with safety, and to measure the maximum strength of lower body muscle groups 1RM squat is taken using a Squat rack with safety. The subjects were asked to do an adequate warm-up on their own. Under the supervision of the tester, subjects performed the maximum no. of repetitions until failure with the selected sub-maximum weight. The weight and number of repetitions performed by subjects were recorded, and scoring was done using Brzycki's equation 1RM (Weight)÷ (102.78 - (2.78 *x Reps).*

Supplementation protocol

The Experimental Group 1, i.e., the creatine supplementation group, will receive a 3-gram micronised Creatine monohydrate supplement pre-workout, the second experimental group, i.e., the Glycogen (Carbohydrate) loading group, will consume 450 grams of boiled potatoes every day before dinner, and the control group will not receive any supplement and will go through weight training alone.

Variables and Tests Used

Table 2.1. Instruments used for measuring Variables along with measuring Units.

S. No	Variables	Test items	Unit of measurement
1.	Maximum Strength of upper body	1RM Bench Press	in Kg
2.	Maximum Strength of Lower Body	1RM Squat	in Kg
3.	Muscle hypertrophy	% Skeletal mass	In %
4.	Adiposity	% Body fat	In %

Statistical Analysis

The data were analyzed using SPSS version 25, the Shapiro-Wilk test was applied to test the normality assumption of the data, and Levene's test was used to test the homogeneity of variance for the dependent variables between experimental and control groups. One-way ANOVA was used to compare the adjusted mean scores of dependent variables of experimental and control groups, and the post-hoc LSD test was applied at a 0.05 level of significance.

Results

The significant F-value (*p = 0.012*) suggests that at least one group has a significantly different upper body strength compared to the others. Table 3.2 involves post hoc analysis (LSD test) to identify which group differs.

Table 3.1. Summary of One-Way Analysis of Variance (ANOVA) of Maximum Strength of Upper Body among different groups.

Source of variance	df	SS	MS	f-Value	Sig.
Between Group	2	351.167	175.583	7.616	0.012
Within Group	9	207.500	23.056		
Total	11	558.667			

Table 3.2. Post Hoc LSD statistics of the Maximum Strength of the upper body of the three groups.

Variable	Groups		Mean Difference	Std. Error	Sig.
Maximum Strength of Upper Body	Creatine supplement	Glycogen loading	9.5	3.40	.020
	Glycogen Loading	Control	12.75	3.40	.048
	Creatine Supplement	Control	3.25	3.40	.020

*Significant at 0.05 level.

The one-way ANOVA revealed a statistically significant difference in upper body strength across groups (p = 0.012). Post-hoc analysis demonstrated the following: The Creatine Supplementation group exhibited significantly lower mean maximum upper body strength compared to the Glycogen Loading group (*MD* =9.50, p =0.020). The Glycogen Loading group showed significantly higher mean maximum strength relative to the Control group (*MD* = 12.75, p = 0.048). The Creatine Supplementation group had significantly higher mean maximum strength than the Control group (*MD* = 3.25, p = 0.020).

These findings indicate a hierarchical relationship in efficacy: **Glycogen Loading > Creatine Supplementation > Control**, with both intervention groups surpassing the control in enhancing upper body strength, though Glycogen Loading yielded superior outcomes compared to Creatine.

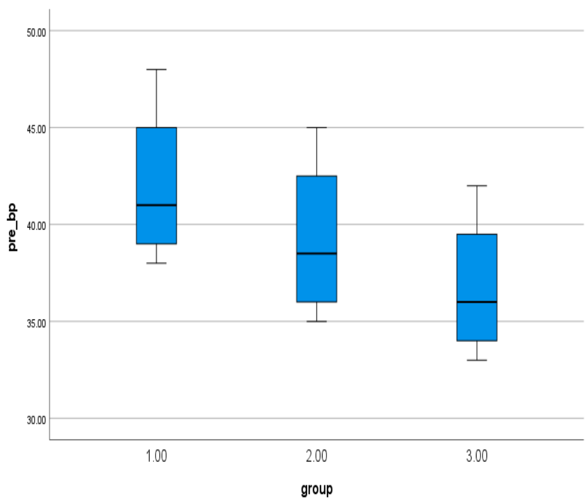

Figure 1. pre-mean scores of 1RM bench press.

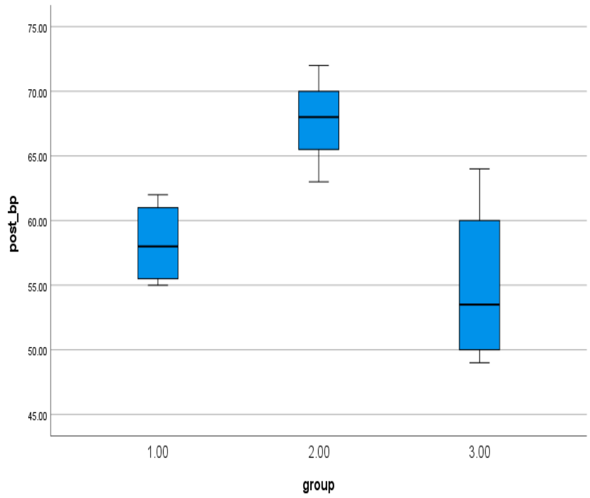

Figure 2. post-mean scores of 1RM bench pre.

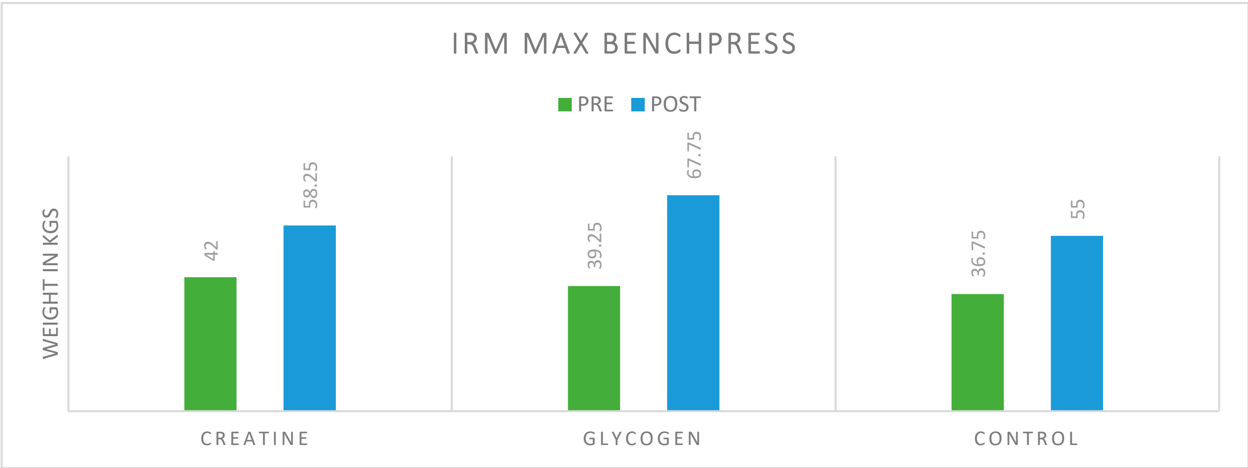

Figure 3. Comparison of pre-post performance of 1RM Bench press.

Strength of Lower Body among different group

The results of the ANOVA Table 3.3 indicate a highly significant difference in upper body strength among the three groups. Table 3.4 involves post hoc analysis (LSD test) to identify which group differs.

Table 3.3. Summary of One-Way Analysis of Variance (ANOVA) of Maximum.

Source of variance	df	SS	MS	f-Value	Sig.
Between Group	2	4056.00	2028.00	31.18	.000
Within Group	9	585.27	65.03		
Total	11	4641.27			

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Table 3.4. Post Hoc LSD Statistics of Maximum Strength of the Lower Body of three Groups.

Variable	Groups		Mean Difference	Std. Error	Sig.
Maximum Strength of Lower Body	Creatine Supplement	Glycogen Loading	22.28	4.31	.000
	Glycogen Loading	Control	11.14	4.31	.047
	Creatine Supplement	Control	33.42	4.31	.000

*Significant at 0.05 level.

The one-way ANOVA revealed a statistically significant difference in lower body strength across groups (p = 0.000). Post-hoc analysis demonstrated the following: The Creatine Supplementation group exhibited significantly higher mean maximum upper body strength compared to the Glycogen Loading group (*MD* = 22.28, p = 0.000). The Glycogen Loading group showed significantly higher mean maximum strength relative to the Control group (*MD* = 11.14, p = 0.047). The Creatine Supplementation group had significantly higher mean maximum strength than the Control group (*MD* = 33.42, p = 0.000). These findings indicate a hierarchical relationship in efficacy: **Creatine Supplementation > Glycogen Loading > Control**, with both intervention groups surpassing the control in enhancing upper body strength, though the creatine group yielded superior outcomes compared to glycogen loading.

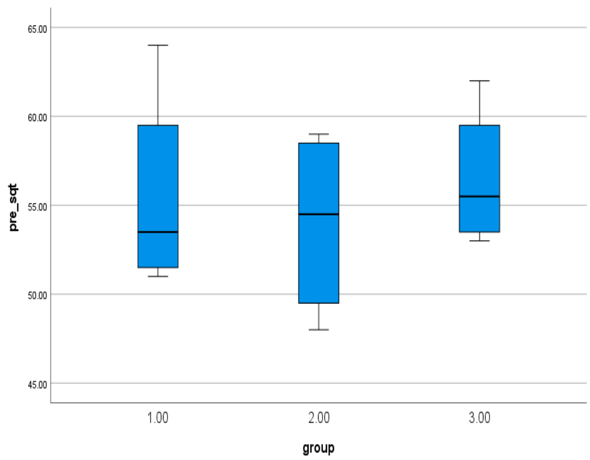

Figure 4. pre-mean scores of 1RM Squat.

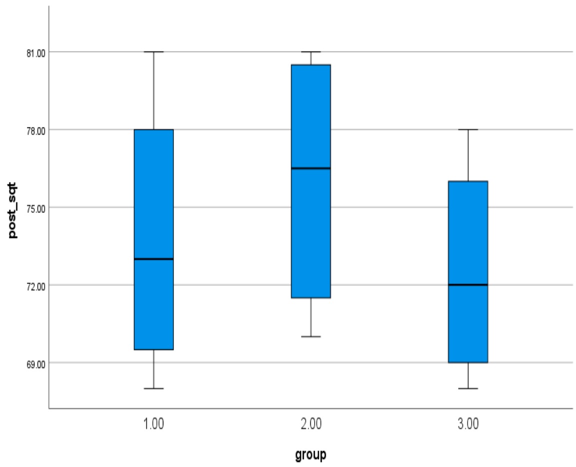

Figure 5. post-mean scores of 1RM Squat.

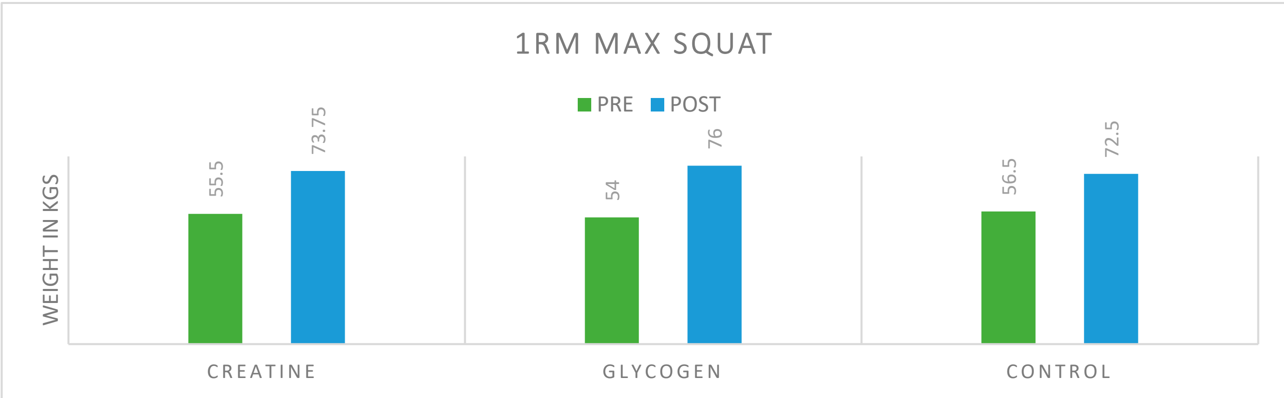

Figure 6. Comparison of pre-post performance of 1RM Squat.

Table 3.5. Summary of One-Way Analysis of Variance (ANOVA) of Skeletal Muscle Mass among different group.

Source of variance	df	SS	MS	f-Value	Sig.
Between Group	2	34.88	17.44	0.90	0.44
Within Group	9	174.16	19.35		
Total	11	209.04			

The one-way ANOVA results indicate no significant difference in the skeletal muscle mass among the different groups (F=0.90, p=0.44); since the p-value is greater than the conventional significance level of 0.05, we fail to reject the null hypothesis. This suggests that any observed variation in skeletal muscle mass between the groups is likely due to random chance rather than an actual effect.

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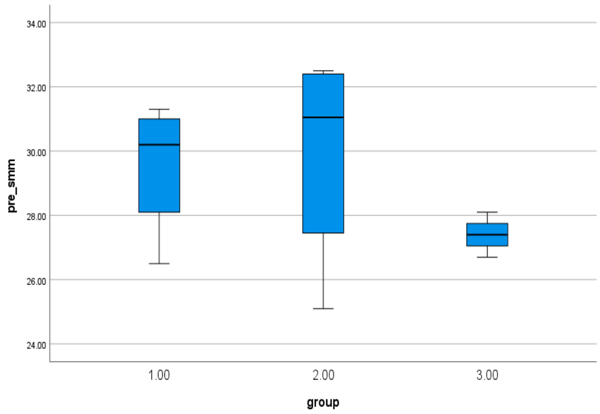

Figure 7. pre-mean scores of skeletal muscle mass.

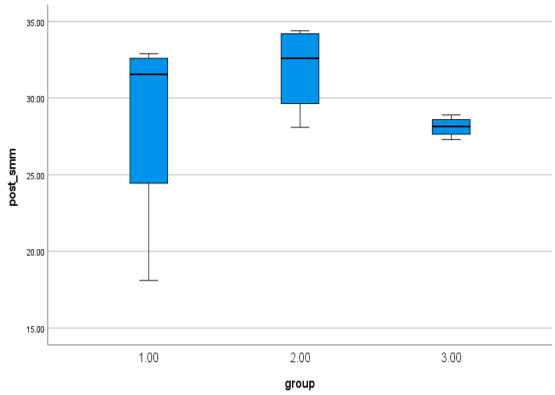

Figure 8. post-mean scores of skeletal muscle mass.

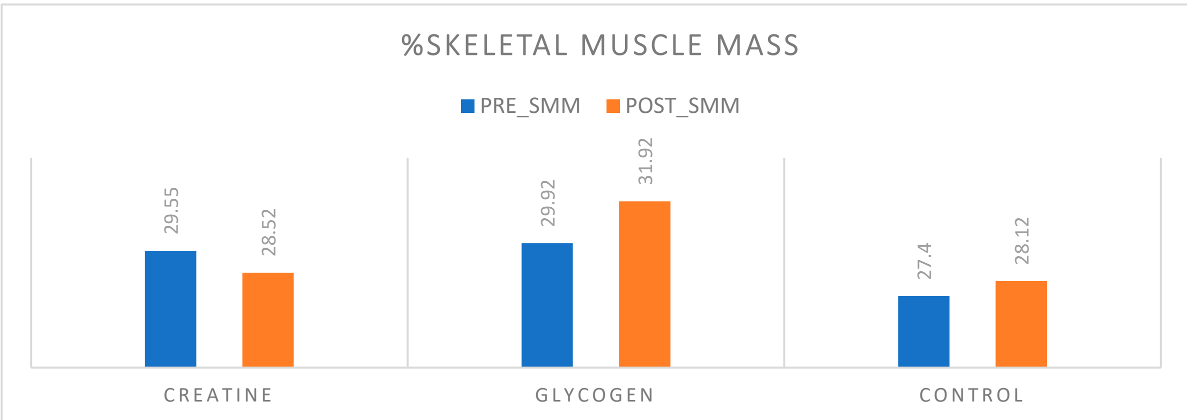

Figure 9. Comparison of pre-post performance of 1RM Bench press of all three groups.

Table 3.6. Summary of One-Way Analysis of Variance (ANOVA) of Body Fat Mass among different groups.

Source of variance	df	SS	MS	f-Value	Sig.
Between Group	2	9.252	4.626	0.90	0.44
Within Group	9	46.225	5.136		
Total	11	55.477			

The one-way ANOVA results indicate no significant difference in the skeletal muscle mass among the different groups (F=0.90, p=0.44); since the p-value is greater than the conventional significance level of 0.05, we fail to reject the null hypothesis. This suggests that any observed variation in skeletal muscle mass between the groups is likely due to random chances rather than an actual effect.

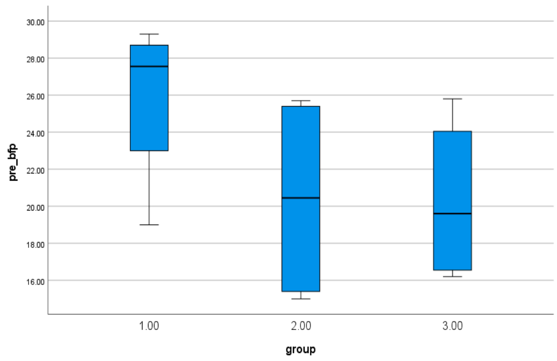

Figure 10. pre-mean scores of %body fat mass.

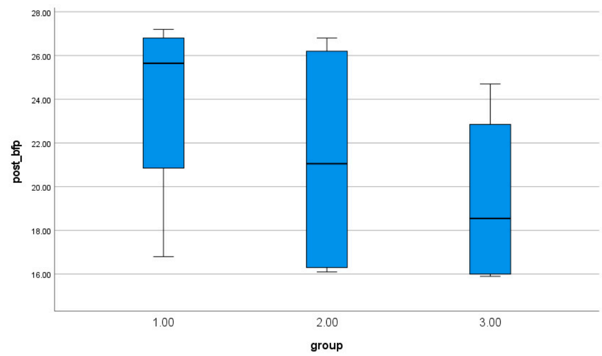

Figure 11. post-mean scores of %body fat mass.

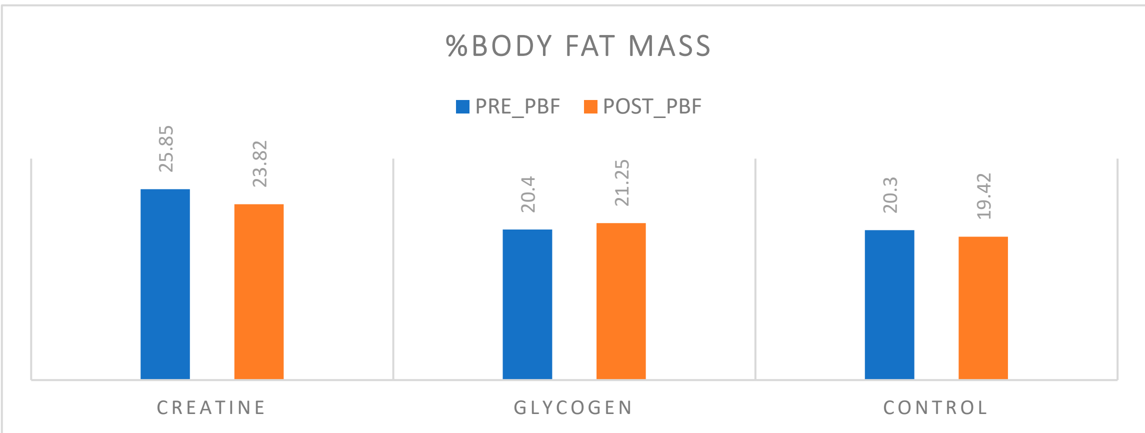

Figure 12. Comparison of pre-post performance of % body fat mass.

Discussion

The study investigated the effect of glycogen loading and creatine supplementation on maximal strength development in the upper and lower body. Participants (N=12) were stratified into three groups: creatine monohydrate supplementation (CRE; n=4), a glycogen loading group (GLY; n=4), and a control group (CON; n=4). All groups completed a six-week progressive resistance training program. Maximal strength outcomes were assessed via one-repetition maximum (1RM) testing pre- and post-intervention.

Statistical analysis using one-way ANOVA revealed significant improvements in both upper and lower body maximal strength in the GLY group compared to CRE and CON ($p<0.05$). Glycogen loading will likely support upper body strength by super-compensating muscle glycogen stores. Glycogen serves as a primary fuel for glycolytic energy systems, which are essential for sustaining performance during moderate-load, higher-repetition upper body exercises (e.g., bench press, pull-ups). Upper body muscles, which may rely more on Type I (slow-twitch) fibers or mixed fiber types, benefit from glycogen's role in delaying fatigue and supporting recovery between sets, thereby enabling greater training volume and hypertrophy over time (Burke et al., 2017; Robergs et al., 1991). This outcome may be attributed to glycogen's role as the primary substrate for adenosine triphosphate (ATP) generation during high-intensity anaerobic exercise, thereby enhancing work capacity and neuromuscular performance during repeated bouts of resistance training (Escalante et al., 2021). In contrast, the creatine group showed significant improvement in lower body maximum strength compared to the GLY and CON group at the 0.05 level of significance. Creatine supplementation likely enhanced lower body strength due to its role in rapidly regenerating adenosine triphosphate (ATP) during high-intensity, short-duration activities, which are critical for lower body movements like squats and deadlifts. These exercises heavily recruit large muscle groups (e.g., quadriceps, glutes) dominated by Type II (fast-twitch) fibers, which benefit most from creatine's ability to buffer ATP and promote cell volumization, leading to greater hypertrophy and power output (Cooke et al., 2009; Rawson & Volek, 2003).

No significant difference between muscle hypertrophy and adiposity has been observed due to several factors, including the small sample size (Button et al., 2013). Six weeks of resistance training may not be sufficient time, as muscle growth and fat loss are gradual processes that often require more protracted intervention (Schoenfeld et al., 2016, 2017). Training alone without a calorie deficit may not lead to significant changes in adiposity, which could also be a possible reason (Willis et al., 2012). Dietary intake was also not controlled or monitored; differences in caloric intake or micronutrient distribution could have influenced the results (Morton et al., 2018).

Conclusions

The conclusions were derived based on the findings and within the study's limitations. The one-way ANOVA indicated that the Glycogen Loading Group significantly improved the upper body maximum strength compared to the creatine supplement and control group, whereas the creatine group showed greater lower body strength development compared to the Glycogen loading and control groups. No significant difference between the groups has been observed regarding muscle hypertrophy and adiposity. Further investigation with the large sample size or additional factors may be needed to confirm these findings.

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Conflict of Interest: The authors declare no conflict of interest.

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