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Impact of Hand Grip and Shoulder Muscle Strengthening Programme on Performance in Air Rifle Shooters

[1]**Revanth Gowda M C**
[*2]**Purusotham Chippala**

ABSTRACT

Background: Air rifle shooting is a precision sport requiring stability, muscle endurance, and fine motor control. Hand grip strength and shoulder muscle stability are critical for accuracy and consistency. Limited research has examined the direct impact of strength training on shooting performance. This study aimed to evaluate the impact of a hand-grip and shoulder muscle-strengthening programme on the performance of air rifle shooters.

Methods: A pre- & post-experimental study was conducted with 15 air rifle shooters (aged 11–17 years) in the Mangalore Rifle club. Participants underwent a six-week strength training intervention using hand grippers, therabands, and therapeutic putty. Pre- and post-intervention analyses included hand grip strength, shoulder muscle strength (measured with a handheld dynamometer), and shooting performance (scored out of 600 points according to ISSF guidelines). Statistical analysis performed used paired t-tests ($p < 0.05$).

Results: Significant improvements ($p = 0.001$) were observed in hand grip strength (15.33% right, 16.47% left), shoulder flexors (19.33% right, 15.24% left), abductors (19.96% right, 17.80% left), external rotators (20.34% right, 23.01% left), and internal rotators (22.56% right, 22.22% left). Shooting performance increased 7.14%, from a mean score of 511.53 to 548.07 out of 600 points ($p = 0.001$), reflecting statistically significant improvement and reduced variability.

Conclusion: Targeted hand grip and shoulder muscle strength training significantly enhance shooting performance in air rifle shooters. Strengthening programs focused on hand grip and shoulder stability should be integrated into training regimens to optimize shooting accuracy and consistency.

Trial Registration: CTRI/2024/07/070236.

Keywords: Air rifle shooting, hand grip strength, shoulder strength, shooting performance, strength training.

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CORRESPONDING AUTHOR

[*2]**Purusotham Chippala**

[1]Nitte (Deemed to be University),
Nitte Institute of Physiotherapy (NIPT), Mangalore,
Karnataka, India 575018.
Email address: revanthgowdamc@gmail.com

Nitte (Deemed to be University),
Nitte Institute of Physiotherapy (NIPT),
Mangalore, Karnataka, India 575018.
Email address: chippala_puru@nitte.edu.in

INTRODUCTION

Rifle shooting is a precision sport that demands complete control over body movements [1]. A shooter's ability to stabilize the gun is essential for performance and is thought to correlate with muscle strength. Maintaining gun stability by managing the body's kinetic lines is also crucial for accuracy and consistency [1]. Competitors in air rifle shooting aim at a target 10 meters away, according to ISSF rules [2]. Stability of hold is a key factor influencing shooting performance, and static balance is a significant determinant [2]. Adequate grip strength is essential for shooting performance, leading to firm and stable shoulders, a firm shooting stance, and efficient recoil management [2,3]. Grip strength depends on upper body characteristics like height, weight, forearm circumference, and hand length [3]. Shooters with stronger grips can pull triggers more smoothly, preserving sight alignment and potentially enhancing performance [3]. Rifle shooting skill is also influenced by motor coordination factors such as trigger timing and aiming accuracy [4].

A shooter can use an air rifle weighing not more than 5.5 kg (12.13 lbs), provided the shooter wears clothing that enhances his stance, stability, and balance and guards against chronic back injuries. This can result from the unevenly distributed load on the spine when the shooter holds the rifle in position. Starting from the ground, the legs and feet support the body, provide a directional slope to the overall posture, and allow for balance. The hip modifies the rifle's height and provides a stable surface for the left elbow to rest on. It also balances and assists in directing the position. The primary function of the shoulders is to fix the rifle to the body and to maintain relaxation. The right arm and hand stabilised the gun and managed the trigger [5].

While technical skills, physical abilities, and psychological aspects are known performance predictors in shooting, limited research has directly linked strength training to shooting performance in air rifle shooters [6]. Stability exercises are, therefore, paramount for shooting performance, with posture, grip, and control being crucial [6]. Injury surveillance in shooting athletes reported that the prevalence of injuries ranged from as low as 0.78% to as high as 6.90%, indicating common issues in the neck, shoulder, and lower back [7]. This study aimed to investigate the direct impact of a hand-grip and shoulder muscle-strengthening programme on the performance of air rifle shooters.

METHODOLOGY

The study was conducted at the Mangalore Rifle Club, Mangaluru, Karnataka, India. Ethical clearance was obtained from the NITTE Institutional Ethics Committee. The Clinical Trials Registry-India was used, and the trial was registered under CTRI number [CTRI/2024/07/070236]. The participants and their parents provided written informed consent/assent. The study design was a pre- and post-experimental study, and the type was an experimental study. Using convenience sampling, 15 air rifle shooters aged 11-17 years were recruited from the Mangalore Rifle Club. Based on the study conducted by Daniel Mon et al. [1], assuming an effect size of 0.8 with 80% power for 2-tailed tests, the estimated sample size was 17. Considering an attrition rate of 10%, the required sample size is 15. The sample size was calculated using software G* Power 3.1.9.4. Fifteen participants who fulfilled the eligibility requirements were chosen for this study. Subjects who fulfilled the evaluation criteria were considered for inclusion: 10-meter air rifle shooters, rifle shooters in standing position, aged 11-30 years, and of male or female sex. Exclusion criteria: Pistol shooters, police and military officers, a history of acute shoulder injury, shooters in kneeling or prone positions, participants in 25m, 50m, 100m, or 300m air rifle shooting were excluded from the study.

The methodology included pre- and post-tests to evaluate outcome measures such as hand grip strength, shoulder muscle strength, and shooting performance.

Outcome Measures:

1. Hand Grip Strength: Measured using a baseline hydraulic hand dynamometer, with two trials for both hands, and the higher reading was recorded in kilograms [14].

Figure 1: Assessing the hand grip strength

2. Shoulder Muscle Strength: The isometric strength of the shoulder flexors, abductors, internal rotators, and external rotators on both the right and left sides was evaluated using a baseline push-pull hand-held dynamometer. Participants sat upright in a chair with their feet flat on the floor. For flexion testing, the shoulder was positioned at 90° flexion with the elbow straight and the palm facing downward; the dynamometer was placed just above the elbow, and the examiner applied downward resistance. During abduction testing, the arm was abducted to 90°, with the elbow bent to 90° and the palm facing downward. The dynamometer was positioned slightly above the elbow, and downward resistance was applied. In internal rotation testing, the arms were kept at the sides, elbows bent to 90°, palms facing inward; the dynamometer was placed just above the wrist on the inner forearm, with resistance applied outward. For external rotation testing, the arms remained at the sides, elbows bent to 90°, and palms facing inward; the dynamometer was positioned just above the wrist on

the outer forearm, with resistance applied inward. The examiner stabilized the trunk and shoulder to minimize compensatory movements. Each contraction was held for about 5 seconds (break test), with three trials per muscle group and a 30-second rest between trials. The average value was calculated and expressed in kilograms. Measurements were taken directly from the dynamometer display and recorded manually without the use of additional software or applications [13].

Figure 2: Assessing the shoulder strength

3. Shooting Performance: Assessed by having participants fire 60 shots at a target 10 meters away within a 75-minute time limit, following ISSF guidelines. The scores were recorded on a scale of 0 to 600. The Average Points Per Shot (APS) was used as the primary measure [12].

Figure 3: Assessing the shooting performance

Participants underwent a six-week strength-training intervention, three times per week for 45 minutes, following the ACSM guidelines [14]. The programme focused on hand grip strengthening using a hand gripper and therapeutic putty (20 repetitions each, with 5 minutes of rest between exercises) [10], as well as shoulder and scapular strengthening exercises using therabands. Shoulder exercises included full-can band exercise, shoulder abduction, scapular depression, and scapular retraction, performed for 8-12 repetitions per set, 3 sets each [16,14]. A 10-minute warm-up preceded each session.

Shoulder and Scapular Strengthening Exercises:

1. Full Can Band Exercise- Perform in the scaption position (~30° anterior to the frontal plane) with thumbs up. Adjust the band length to vary the resistance throughout the range of motion [16].
2. Shoulder Abduction- Use a ½-inch theraband, modifying resistance by adjusting hand width or doubling the band. Train through ~45° adduction to 45° abduction [16].
3. Scapular Depression- Enhance resistance to anterior-superior forces by performing weight-bearing exercises on parallel bars or benches and altering axial stress to mimic sport-specific loads [16].
4. Scapular Retraction-Strengthen retractors with a resistance band, maintaining shoulder-width grip and fully retracting the scapula for brief holds [16]

Statistical Analysis:

Statistical analysis was performed using SPSS software, version 23. Descriptive statistics (means and standard deviations for continuous variables and frequencies and percentages for categorical variables) were used to summarise the data. Paired t-tests were used to compare pre- and post-intervention measurements of handgrip strength, shoulder muscle strength, and shooting performance. A p-value, $p < 0.05$, was considered statistically significant.

RESULTS

The study included 15 air rifle shooters with a mean age of 13.6 ± 2.06 years. The sample comprised 10 males (66.7%) and five females (33.3%). The mean height, weight, and BMI were 157.00 ± 11.75 cm, 49.33 ± 5.15 kg, and 20.05 ± 1.29 kg/m², respectively.

Table 1: Demographic details of participants

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Age (years)	15	11	17	13.60	2.06
Height (cm)	15	130	168	157.00	11.75
Weight (kg)	15	38	56	49.33	5.15
BMI	15	18.87	23.67	20.05	1.29

*BMI = Body mass index

Table 2: Pre- and Post-Intervention Analysis of Grip strength of left and right-hand Parameters

					Effectiveness				
Parameter		**No. of Participants**	**Mean**	**Std. Deviation**	**Mean Difference**	**S.D. of Difference**	**Change (%)**	**t- value**	**p- value**
Grip Strength Left (Kg)	Pre	15	17.40	5.54	2.67	1.06	15.33 %	-9.71	0.001
	Post	15	20.07	5.26					
Grip Strength Right (Kg)	Pre	15	20.03	6.09	3.30	0.84	16.47 %	- 15.20	0.001
	Post	15	23.33	6.14					

This was analysed using a paired t-test to compare hand grip strength between the right and left hands. A p-value (0.001) indicates significant results.

Table 3: Pre- and Post-Intervention Analysis of Shoulder Strength of left and right, and Parameters

					Effectiveness				
Parameter		**No. of Participants**	**Mean**	**Std. Deviation**	**Mean Difference**	**S.D. of Difference**	**Change (%)**	**t- value**	**p- value**
Shoulder flexors Left (Kg)	Pre	15	9.33	1.52	1.42	0.79	15.24	-6.96	0.001
	Post	15	10.76	1.23					
Shoulder flexor Right (Kg)	Pre	15	10.58	1.78	2.04	0.74	19.33	-10.64	0.001
	Post	15	12.62	1.47					
Shoulder abductors Left (Kg)	Pre	5	9.11	1.18	1.62	0.56	17.80	-11.19	0.001
	Post	15	10.73	1.16					
Shoulder abductors Right (Kg)	Pre	15	10.80	1.67	2.16	0.63	19.96	-13.29	0.001
	Post	15	12.96	1.44					
Shoulder external rotators Left (Kg)	Pre	15	7.82	1.04	1.80	0.81	23.01	-8.56	0.001
	Post	15	9.62	0.87					
Shoulder external rotators Right (Kg)	Pre	15	9.18	1.31	1.87	0.78	20.34	-9.21	0.001
	Post	15	11.04	0.98					
Shoulder internal rotators Left (Kg)	Pre	15	7.98	0.99	1.80	0.93	22.56	-7.48	0.001
	Post	15	9.78	0.94					
Shoulder internal rotators Right (Kg)	Pre	15	9.00	1.27	2.00	0.85	22.22	-9.07	0.001
	Post	15	11.00	0.89					

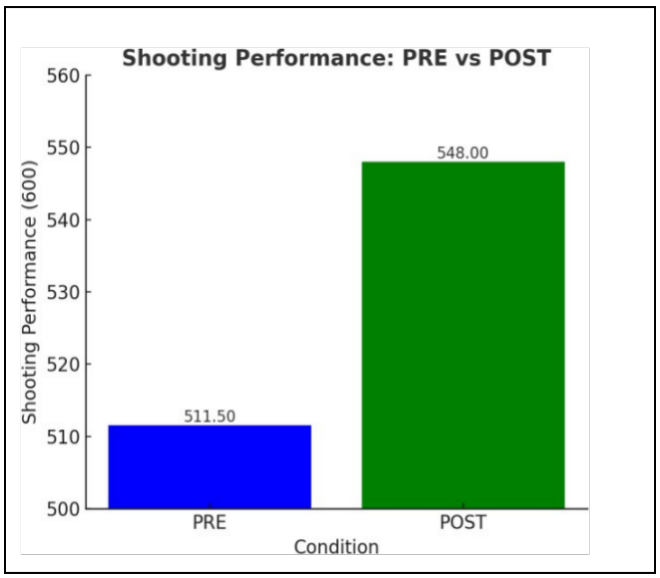
The study findings revealed a significant improvement ($p<0.001$) in shoulder strength (shoulder flexors, abductors, external rotators and internal rotators)

Table 4: Pre- and post-analysis of the effectiveness of shooting performance.

					Effectiveness				
Parameter		**No. of Partic ipants**	**Mean**	**Std. Deviation**	**Mean Difference**	**S.D. of Difference**	**Change (%)**	**t- value**	**p- value**
Shooting performance (600)	Pre	15	511.5	34.05	36.53	21.89	7.14%	-6.46	0.001
	Post	15	548.0	27.82					

The study findings revealed a significant improvement ($p<0.001$) in the shooting performance.

Graph 1: Represents pre- and post–analysis of shooting performance



The bar graph illustrates pre and post-intervention shooting performance, showing a significant improvement from 511.5 to 548.0. This 7.14% increase in shooting accuracy indicates improved accuracy after the intervention.

DISCUSSION

The findings of this study demonstrate that a six-week hand grip and shoulder muscle strengthening programme significantly improved both grip and shoulder strength, as well as shooting performance in young air rifle shooters. The substantial increases in grip strength (left: 15.33%; right: 16.47%) are consistent with previous research showing a positive correlation between grip strength and shooting accuracy. Brown et al. (2021) noted the importance of grip strength for achieving high scores in police pistol qualifications. In addition, he found that to achieve 85% to 90% on police pistol qualification examinations, grip strengths of 80 to 125 pounds were required [3]. Mon et al. (2015) emphasised the role of finger flexor strength in the air pistol shooting performance. The observed improvements likely resulted from enhanced neuromuscular coordination and muscle endurance, allowing for more controlled trigger pull and reduced hand fatigue [1]. Vercruyssen et al. (1989) also supported the link between resistance training and grip strength, which is necessary for precise shooting movements [17]. However, it is essential to note that excessive grip force can negatively impact accuracy, as suggested by EMG studies by Svecova et al. (2016) [8].

Significant gains in strength across all assessed shoulder muscle groups (flexors, abductors, internal and external rotators) are crucial for maintaining a stable shooting posture. These findings align with the principles outlined in shoulder stability exercises to improve shooting accuracy. The percentage changes were as follows: shoulder flexors increased by 15.24% on the left hand and 19.33% on the right; abductors improved by 17.80% and 19.96%, external rotators increased by 23.01% and 20.34%, and internal rotators increased by 22.56% and 22.22% respectively, indicating enhanced static and dynamic stability. Hung et al. (2021) also highlighted the importance of upper-body muscle endurance for shooting performance [9]. Improved shoulder stability likely contributes to reduced body sway, which Ihalainen et al. (2015) found to be associated with higher shooting scores in elite shooters [2].

While Pal & Singh et al. (2024) reported a larger percentage increase in shooting scores after a 15-day programme focusing on balance and stability, their lower baseline scores suggest a greater potential for improvement. The current study's longer duration (6 weeks) and emphasis on physical strength training provided a more thorough approach, demonstrating improvements in both strength and shooting accuracy. This suggests that while mental training can yield quicker short-term gains, physical strength training offers significant long-term benefits [6]. Spancken et al. (2021) review also supported the influence of upper-body strength on rifle stability and aiming accuracy [4]. Furthermore, Dabholkar et al. (2019) found a correlation between hand dexterity and upper extremity stability in rifle shooters, underscoring the importance of a robust shoulder complex [5].

The 7.14% improvement in shooting performance observed in this study provides direct evidence for the effectiveness of targeted strength training. This improvement, coupled with reduced score variability, indicates enhanced consistency. Mon-López et al. (2019) found that changes in competition structure had a minimal impact, reinforcing the importance of physical preparation [11]. Improved shoulder stability likely contributes to less body sway, which Dabholkar et al. (2019) identified as a significant influence on shooting performance [5]. Although Mon-López et al. (2019) noted gender-based strength inequalities in pistol shooting, the positive outcomes for both male and female participants in this study suggest the broad applicability of targeted strength training in air rifle shooting [11]. According to Ertan et al. (2003), stability is directly affected by improved forearm muscle activation patterns [15].

CONCLUSION

This study concludes that a six-week programme focusing on hand grip and shoulder muscle strengthening significantly improves shooting performance in air rifle shooters. The findings strongly suggest that integrating such strengthening programmes into the training regimens of air rifle shooters is crucial for achieving optimal shooting accuracy and consistency.

RECOMMENDATION

- Air rifle shooting training programmes should incorporate targeted exercises for hand grip and shoulder muscle strengthening.
- Coaches and researchers should utilize handheld dynamometry to monitor and track progress in grip and shoulder strength.
- Integrating psychological training with physical conditioning could offer a more holistic approach for performance enhancement in competitive shooting.

LIMITATIONS

- The sample size was relatively small (n=15).
- Long-term retention of strength gains and shooting performance improvements was not assessed.
- This study did not measure additional physiological parameters, such as heart rate variability, which could provide further insights.
- 1-RM testing was not implemented to progressively increase resistance, as the participants were not experienced strength trainers.

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