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Effect of strength and flexibility training on explosive power and balance in air rifle shooters in Vadodara- an experimental study

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Abstract
Background: In order to maintain lower limb balance and stability the rifle shooters also require leg power to enhance their rifle shooting performance and improved score. Aim was to investigate the effect of strength & flexibility training exercise on explosive power and balance among Air Rifle Shooters using the Vertical jump test, Flamingo Balance Test and 10 m Shooting Performance respectively to determine the effect of Strength & flexibility training.
Methodology: 34 participants were included in the study and divided in Group A Experimental n=17 and Group B Control n=17. Patients were given intervention for 3 days/week, while control group carried on with their routine training and pre and post outcomes were observed.
Results: In Group A, significant improvements were observed in vertical jump, flamingo balance, and shooting performance compared to the control group. However, Group B showed no significant differences in the tests. Additionally, within Group A, significant differences were found in pre and post-scores for vertical jump p-value (0.0039) and flamingo balance tests p-value Right (0.0001), Left (0.0001), 10 m performance p value (0.0001) as compared to Group B. Between-group analysis confirmed these findings, showing significant improvement in Group A compared to Group B across the tests.
Conclusion: Strength and flexibility training show significant effect on balance, power and Rifle shooters Performance among 10 m rifle shooters of Vadodara.

Keywords: Flamingo balance test, vertical jump test, 10 mitre performance, bosu ball, core training

Introduction
Air rifle shooting has its roots in the 16th century, where the use of air guns initially emerged for hunting and military purposes [1]. Injury surveillance studies have found the prevalence of injury for athletes of shooting events in the Olympics to be as low as 0.78% or as high as 6.90%. Injury in specific body parts (i.e. neck, shoulder, low back). Across the events, pistol shooters tend to have more wrist injuries, shotgun shooters tend to have more shoulder injuries, and both rifle and biathlon typically have more low back injuries [2].
Strength is the muscle's capacity to generate maximum force or torque at a given velocity. This capacity differs across various muscle actions, encompassing eccentric, concentric, and isometric contractions [3].Elite shooters and gymnasts have found that improving balance can reduce reliance on posture control and muscle strength in response to external stimuli [4]. Core muscles, including those in the abdomen, lower back, and hips, are crucial for maintaining stability during shooting [5]. These muscles coordinate movements throughout the body, making movement control easier [6]. Strengthening the core and lower limbs through training interventions can enhance athletic performance [7]. Flexibility training reduces stiffness during explosive sports movements, preventing muscle strain injuries by improving muscle compliance. Its effectiveness depends on factors like muscle fiber types and specific activities. Customized training tailored to the athlete's sport is crucial, as joint range of motion may vary. Further research is needed to ascertain its benefits for specific activities or athletes, such as those in rifle sports [8].
The balance is the most important factor in air rifle shooters. The athlete's balance control is of great importance on his performance in static sports such as shooting and archery [9]. Balance can be defined as the ability to maintain the body's centre of gravity over its base of support and it reflects appropriate neuromuscular action in response to continuous visual,

vestibular, and somato-sensory [10]. Postural balance significantly impacts shooting performance, with elite air rifle shooters demonstrating superior balance compared to untrained individuals [11]. Differences in balance exist among shooters of varying skill levels, with elite shooters exhibiting smaller centre of pressure sway velocities in medial –lateral and anterior – posterior directions [12]. Additionally, elite shooters can reduce body sway before executing a shot, indicating a relationship between balance, rifle stability, and performance [13]. Postural balance is also linked to performance in air pistol shooting, where increased body sway correlates with wider sight oscillation across the target [14, 15]. Power in sports is determined by the combination of force and movement velocity. "Explosive muscular power" refers to the heightened power output achieved during a single, maximum effort muscle action[3]. Core training for air rifle shooters emphasizes strengthening local and global muscles to stabilize the spine, enhancing overall stability and improving strength in the limbs, ultimately correlating with increased power generation and enhanced athletic performance [16].

Maintaining balance in air rifle shooters necessitates isometric contractions in the hip abductors, quadriceps, and hip extensors, crucial for stabilizing the supporting leg and establishing a solid foundation for shooting movements [17]. Research indicates that heavier loads increase strength and power gains, while more repetitions and sets lead to greater muscle size. Higher intensity maximizes strength gains, while higher volume promotes muscle growth, contributing to overall strength and power development [18]. Therefore, it is essential to train the air rifle shooters with strength and flexibility training to improve their power output which will help in improving their performance.

Limited scientific evidence exists regarding the effectiveness of strength and flexibility training for air rifle shooters. This study aims to assess how strength and flexibility training, combined with conventional therapy, impact the balance, power, and performance of rifle shooters. By examining the effectiveness of these training methods, especially in terms of power, which has not been directly studied before in rifle shooters, this research aims to fill this gap in the literature.

Materials and Methods

Participants and study design

An interventional study was conducted at the Manjalpur Sports Complex, a private institute, focusing on air rifle shooters. The study population comprised 34 participants selected through convenient sampling, with the study duration spanning 10-12 months following ethical approval. Inclusion criteria encompassed individuals aged 18-30, state and national professional players, both male and female, engaged in rifle shooting for at least one year. Exclusion criteria involved participants with a history of surgery or recent injury, orthopaedic deformities of upper or lower extremities, neurological disorders, or recent infections. Materials utilized included a stopwatch, measuring tape, chalk, and Swiss ball. Approval for the study was obtained from the Ethics Committee of Biomedical Health and Research [KPGU/KSPR/EC/23/03/27.9].

34 Players were selected on basis of inclusion and exclusion criteria. Pre-intervention data were gathered at the beginning. Players were randomly allotted in 1:1 ratio. The players were divided equally into two groups: Group A (n=17) received strength and flexibility exercises. At the same time, Group B (n=17) served as the control group and only received routine exercises. Both groups trained for 3 days per week over 6 weeks.

Outcome Measures

Flamingo Balance Test [1]

The Flamingo Balance Test (FBT) was employed to assess static balance in participants. Subjects stood on wooden balancing equipment measuring 50 cm in length, 4 cm in height, and 3 cm in width, aiming to maintain balance. They lifted one foot, holding it with the same-side hand and bending the knee towards the hip. Timing began as they achieved balance on one foot, striving to sustain this position for one minute. If balance was disrupted, time paused until the research group assisted in rebalancing, with the test continuing for the designated duration. Each attempt by the subject to regain balance after a fall was noted and recorded at the end of the test.

Vertical Jump Test [19, 20]

This test was utilized to assess lower limb power, employing the chalk-on-finger method. Participants performed three consecutive jumps within a 30-second timeframe, with recovery periods between trials considered in calculating the average. To initiate the test, participants stood erect beside a tall wall and extended their hands upward. Using chalk, they marked the wall at the highest point reachable by fingertip touch. Subsequently, participants executed maximal effort jumps from a flat-footed position, marking the wall again with chalk at the peak of their jump. The distance between the initial and subsequent chalk marks was then measured using a measuring tape to determine lower limb power.

Meter Air Rifle Shooting Performance [2]

Prepare the shooting range with proper safety measures and set up shooting lanes for 10-meter distances. Place targets at designated spots. Before the commencement of the event, participants are allotted time for warm-up shots to adjust to the shooting environment and fine-tune their equipment as necessary. Following this, participants are instructed to adopt their preferred shooting stance, catering to their comfort and skill level. When ready, participants aim at the target and proceed to fire a series of shots in accordance with the specific rules and regulations governing the event. Shots are typically discharged either in a predetermined sequence or within a specified time frame, depending on the competition rules in place. Subsequently, scores are recorded based on the placement of shot holes on the target, with various scoring systems possibly employed, contingent upon the specific competition rules. In the free-standing position, participants are required to fire a total of 60 shots within a duration of 75 minutes. The target, situated 10 meters away from the shooter, features a "ten" ring with a diameter of 0.5 mm, followed by lower rings spaced at intervals of 2.5 mm. Prior to the event's commencement, a safety briefing is conducted, emphasizing the correct handling of firearms and strict adherence to range safety protocols. Additionally, participants and spectators are mandated to wear appropriate eye and ear protection to mitigate the risk of injury from stray pellets or exposure to loud noises.

Intervention [21]

Baseline data was obtained. Before starting of training & at the end of the 6 weeks, Flamingo Balance Test, vertical Jump Test, 10 m Air rifle shooting Performance Test. Test was taken for each participant & recorded. Both Groups were given Intervention for 6 weeks. (3 days/week).

Group A: Participants were receiving Strength and Flexibility training, Group B: Participants doing routine training. Warm up Exercises: Stretching of muscle – Hamstring, Abductor, Calf, Hip (flexor & Extensor), Pectorals. General body warm up consist of 5 minute jogging, followed by dynamic stretching. The Dynamic Stretching for the above muscle was for 5 times and 1 set each for total of 5 minute. Cool Down: 5 minute jogging followed by dynamic starching above muscle, per 5 minute with 5 time 1 set each.

Table: 1 Intervention for Group A

Number of Week	Name Of Exercise	No. of set & Repetition & Hold Seconds
Week -1-2	Plank Squat Jump Swiss Ball – Sit up Romanian Deadlift	3*1 min 3*7 3*7 3*7
Week-3-4	Side Plank(R/L) Box Jump Back Bridge on Swiss Ball Forward Lunge	3*1 min 3*7 3*7 3*7
Week-5-6	Plank Dynamic Rotation Split Squat Single leg Back Bridge on Swiss ball Floor Wiper	3*10 3*7 3*10 sec 3*10

Statistical analysis

All statistical analysis was performed by using IBM SPSS Version 29.0.0 (Armonk, NY: IBM Corp).The Sample Size was calculated by using G-Power Software version 3.1.9.4. The outcome variable values flamingo balance test were before protocol Mean ± SD = 5.03 ± 2.86, after protocol mean ± SD = 1.84±1.23. Keeping the values of a error as 0.05 since (95% confidence interval) and b error as 0.2 (since power of study 80%). The calculated sample size is 34(17 in each group). Paired t test (within in group analysis) and unpaired t test (between group analysis) was used for Group A and B.

Results

Participant characteristics

The Age of the participants in this study was from 18 to 30 Years. Total 34 Participants participated in the study. The mean age of the participant's was 21. There were 17 Female & 17 Male participants. Mean age of the female was 20.44 and the mean age of male was 21.58.

As shown in given table/graph:

Table 2: Demographic data of participants

	Male	Female
Participants	17	17
Age	21.58	20.52
Height	164.29	160.35
Weight	62.35	59.52

Table 3: Within Group analysis Group A on VBT, FBT, 10 M performance test

	EG PRE Mean ± SD	EG POST Mean ± SD	T VALUE	P VALUE
VBT	2339.53±684.23	2494.29±603.3	3.37	0.0039
10 M	86.34±1.29	99.08±12.68	6.6064	0.0001
FBT RT	4.95±1.25	2.12±2.15	6.68	0.0001
FBT LT	4.41±1.62	2.18±1.33	6.83	0.0001

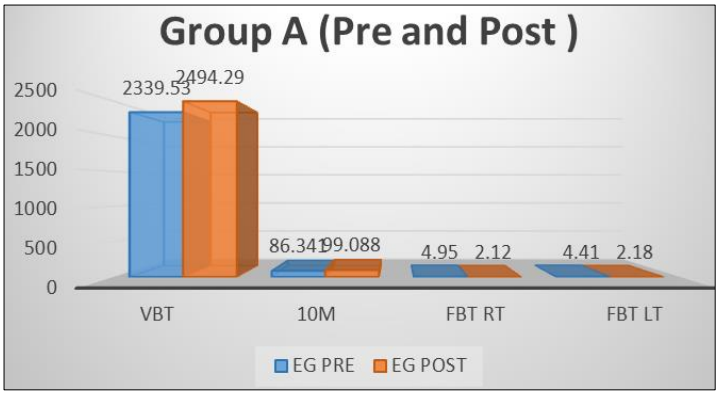

Fig 1: Within group analysis Group A on VBT, FBT, 10 m performance test

Table 4: Within Group analysis Group B on VBT, FBT, 10 M performance test

	CG PRE Mean ± SD	CG POST Mean ± SD	T VALUE	P VALUE
VJT	1995±388.58	1991.65±379.3	0.19	0.84
10 M	83.79±8.36	84.5±8.36	1.24	0.17
FBT RT	6.63±1.7	5.88±1.76	2.0210	0.0603
FBT LT	7.12±1.36	6.53±1.28	1.8983	0.0758

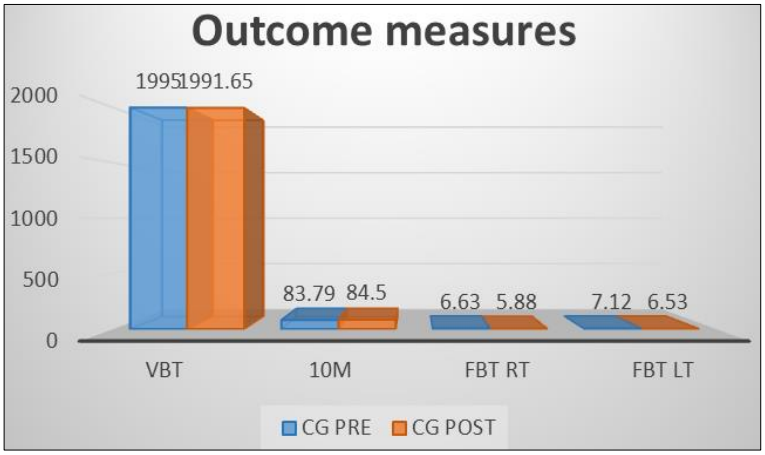

Fig 2: Within Group analysis Group A on VBT, FBT, 10 M performance test

Table 5: Within Group analysis Group A on VBT, FBT, 10 M performance test

	EG POST Mean ± SD	CG POST Mean ± SD	T VALUE	P VALUE
VBT	2759±1527.02	1991.65±379.3	2.0108	0.0528
FBT RT	2.12±2.15	5.88±1.16	5.5864	0.0001
FBT LT	2.18±1.33	6.53±1.28	9.7062	0.0001
10 M	99.18±12.72	84.5±8.83	3.9071	0.0005

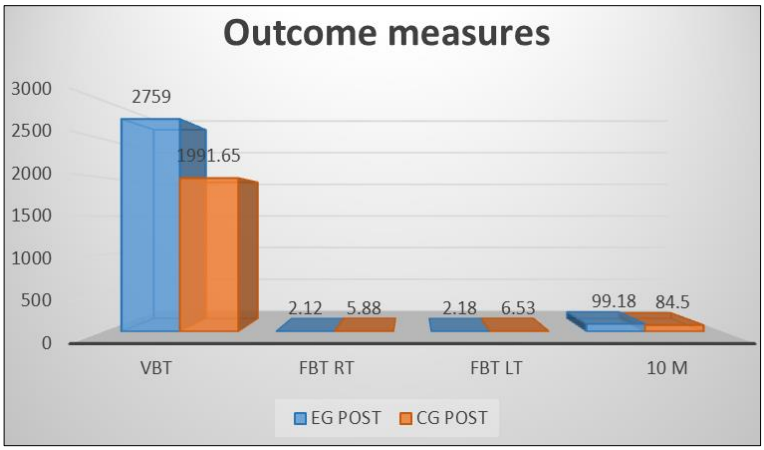

Fig 3: Within Group analysis Group A on VBT, FBT, 10 M performance test

Discussion

The study's findings of vertical jump test revealed that a six-week intervention, conducted three times a week, resulted in enhanced power among the experimental group, as assessed through the vertical jump test. Table 3, showing significant differences between pre and post intervention showing significant improvement between (group A) Experimental group. Whereas, Table 4 shows no significant difference between the pre and post values in (Group B) Control group. Erzeybek, M.S *et al*. [22] where they found that strengthening exercise had enhanced the vertical jump among the handball after 8 weeks of training 3 times a week on one group pretest post- test design. They concluded that strength exercises performed with Olympic lift and plyometric jump specific to handball were more effective than the other exercises. Similarly, Bettariga, F et al. [23] conducted a study on male soccer players were unilateral strength and power training were given for 6 week and found that unilateral strength and power training are beneficial for reducing imbalance and improve jump performance compared to soccer skill training. The enhanced power in the rifle shooters is thus explained. Adequate flexibility and stability play vital roles in reducing the risk of injuries. Key internal factors contributing to injury risk include impaired postural control and diminished muscle power. Impaired postural control is evident through delayed responses in lower

extremity muscles when compensating for unexpected disturbances. Additionally, core stability enables the simultaneous strengthening of both arm and leg muscles, representing a dynamic concept that consistently adapts to reposition the body or handle external loads. In the realm of athletic performance, higher core stability is associated with increased power output in the limbs. Therefore, enhancing body balance and core strength can improve the efficiency of movements and the generation of power. Consequently, the lower limbs and core serve as a foundational support, generating kinetic energy that is subsequently transferred through the arms. Therefore, these could be potential explanations for the improvement observed in power output among the air rifle shooters in this study. Table 5 showed a significant difference between Group A and Group B on power output as compared to control group (Group B). Likewise, Pardos-Mainer, E *et al* [24] where they found that after 10 weeks of strength training combined with power training has shown greater improvement in speed, change of direction and vertical jump than control group (soccer training alone) for 8 weeks in 36 female adolescents soccer players on using countermovement jump test, drop jump, horizontal jump tests.

The results of 10 m Rifle Shooters Performance, Flamingo Balance test from the current study indicated that engaging in strength exercises three times a week for a duration of six weeks led to enhanced balance and performance within the experimental group on assessing with the flamingo balance test and 10 m rifle performance. Table 3 and 4, showing significant differences between pre and post intervention in balance and performance in group A (Experimental group). The findings revealed that there was no notable difference in balance and performance between the pre and post-intervention assessments within group B. These outcome are supported by the Aydin, A.S, Revan, S[1].The study, conducted over a 12-week period with interventions administered 3 times a week, involved both experimental and control groups continuing their shooting training regimen. The findings indicated that balance training enhanced both static and dynamic balance and improved the postural and shooting performance of the participants. The study concluded that balance positively influenced shooter performance by reducing barrel movement, highlighting the significance of balance training in enhancing static balance and shooting proficiency. Akınoğlu, B, Acar, H.Y [25]. They concluded that static balance ability of female athletes was significantly better than male athletes, The HUR Smart Balance measurement device (BT4, HUR Labs Oy, Tampere, Finland) was used to evaluate the static and dynamic balance of the athletes and Romberg & functional reach test were assessed 4 times for 30 seconds each 76 Male and female each. The potential explanations for the improvements observed in the balance and performance of air rifle shooters in this research lie in the brain's continual adjustments of the body's position, relying on various cues. Key sources of information include visual feedback from the eyes and proprioceptive feedback from muscles and nerves. These cues are particularly vital for shooters, providing information about the positioning of the head and body in relation to the surroundings, all while maintaining focus on the target. Moreover, feedback on muscle tension aids the brain in discerning the body's orientation, whether it tilts left, right, forward, or backward. Moreover, the extent of body sway observed in pistol shooters is directly linked to the movement of their sight across the target. A greater degree of body sway corresponds to a wider range of sight oscillation. Consequently, it is essential for pistol shooters to comprehend and address body sway, as specific exercises targeting improved postural stability can help reduce the extent of body sway during shooting performance. Factors such as Body Mass Index and back muscle strength play a role in this context. Achieving an enhanced sense of balance often comes from years of dedicated sports practice. Therefore, individuals who are beginners or those not meeting performance expectations in shooting can gain significant advantages by participating in training programs that focus on enhancing postural stability. Such training aims to decrease the degree of body sway exhibited during the shooting stance. Shooters, whether lacking access to comprehensive facilities or aiming for further performance improvement, can benefit from specialized postural stability and balance training that goes beyond traditional pistol training routines. It is noted that as fatigue sets in, the body's ability to regulate postural muscles decreases, leading to a reduction in control over muscle tension and an increase in body sway. Conversely, Nurten Dinç1, Esin Ergin [16] Chu SKW, Jayabalan P, Kibler WB, Press JM [17]. The kinetic chain revisited: new concepts on throwing mechanics and injury. The experimental group exhibited higher post-test results compared to the control group after the 8-week intervention. Core strength training, conducted three times a week for 8 weeks, had no impact on athletes' balance but demonstrated a positive influence on long jump and agility. Table 5 indicates enhancement in balance and performance among air rifle shooters in Group A in comparison to Group B Hung, MH, Lin, KC [7] they found that the Whole-body vibration and unstable surface training method using bosu ball on 6 weeks of strength training effectively improved body sway and shooting performance in eight rifle shooters.

Conclusion

The present study showed that 6 weeks of strength training and Flexibility Training in the experimental group (Group-A) was beneficial in improving Balance, Explosive Power and 10 m Performance of rifle shooters than the Control group (Group- B) regular training. Through the Strength and flexibility training static balance of the shooters was improved resulting in sustaining and maintaining the static posture for a prolonged period of time with greater explosive power generation which simultaneously helps them to focus on targeted aiming performance.

Limitations

The limitations of the study are unequal distribution of male and female participants. Sample size is small to extrapolate the entire population. Samples taken were only from Vadodara district.

Future Scope

The present study acknowledge that future studies will require for better understanding of the effect of strength and flexibility training on balance, power and air rifle shooting performance among shooters players. Large sample size and follow–up may give a more précised result for efficacy of the intervention protocol. Apply strength and flexibility training (upper and lower limb) to improve stability, balance and performance in other static sports.

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