DOI: 10.7860/JCDR/2026/89843.24441

Original Article

Physiotherapy Section

Effect of Cervical TheraBand Exercises and Lower-limb Balance Training on Shooting Performance and Perceptual Parameters in Air Rifle Shooters: A Randomised Controlled Trial

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ABSTRACT

Introduction: Air rifle shooting is a precision-based sport in which competitive performance depends critically upon neuromuscular stability of the entire axial skeleton. The cervical musculature, richly innervated with muscle spindles, governs head stabilisation and spatial orientation via proprioceptive reflexes. Simultaneously, lower-limb balance provides the postural base from which proximal control propagates. Cervical proprioceptive impairment and lower-limb postural instability have each been independently shown to degrade performance, yet their combined training effects remain unexamined in the literature.

Aim: To evaluate and compare the independent and combined effects of cervical TheraBand exercises and lower-limb balance training on shooting performance, perceived postural stability, and perceived exertion in competitive air rifle shooters over a six-week period.

Materials and Methods: A prospective, three-arm parallel-group randomised controlled trial was conducted from April 2025 to January 2026, with 105 competitive 10 m air rifle shooters from Tapasya Shooting Academy and Royal Rifle Academy, Delhi NCR, India after getting approval from the Waves Women Empowerment Trust Independent Ethics Committee. All the subjects were, equally distributed into Group 1 (combined cervical and balance training, n=35), Group 2 (cervical TheraBand exercises only, n=35), and Group 3 (lower-limb balance training only, n=35). Randomisation was performed using a computer-generated sequence with sealed opaque envelope allocation concealment; outcome assessors were blinded to group assignment. All interventions were delivered three times per week for six weeks with progressive overload. Outcomes assessed at baseline, three weeks, and six weeks comprised: shooting score via electronic target system; Perceived Sense of Postural Sway and Instability (PSPSI, 0-8 scale); and Borg's Rating of Perceived Exertion Category-Ratio 10 (RPE CR-10). Repeated Measures Analysis of Variance (RM-ANOVA) with Bonferroni post-hoc correction and One-way ANOVA with Tukey's HSD were applied.

Results: The mean age of participants was 20.86±2.20 years; 80 males, 25 females). All three groups showed significant within-group improvements across all outcomes (p-value <0.001). Group 1 achieved the greatest shooting score gain (+10.20 points), the largest PSPSI reduction (–3.63 points), and the greatest decrease in perceived exertion (-3.17 points) from baseline to six weeks. Intergroup F-values at six weeks (absolute scores) showed significant improvement (p-value <0.001). Post-hoc analysis confirmed Group 1 significantly outperformed both Groups 2 and 3; no significant difference was observed between Groups 2 and 3.

Conclusion: A combined cervical TheraBand and lower-limb balance training programme produced superior and additive improvements in shooting performance, perceived sense of postural sway or instability, and perceived exertion compared with either training programme administered independently. Integrated multisegmental training is recommended for inclusion in the conditioning programmes of competitive air rifle shooters.

Keywords: Borg's rating of perceived exertion, Exercise therapy, Motor skills, Perceived sense of postural sway and instability, Postural balance, Proprioception, Sports

INTRODUCTION

Air rifle shooting is a precision-based Olympic discipline in which competitive success demands a stable body posture during prolonged aiming and trigger-release sequences. Even minor oscillations in body sway translate directly into rifle barrel displacement at the target, critically determining scoring outcomes [1,2]. Postural control in this sport depends upon the integrated processing of visual, vestibular, and somatosensory signals, and both cervical proprioception and lower-limb balance have been identified as key physiological determinants of performance [3,4].

The suboccipital and deep cervical musculature contains the highest density of muscle spindles in the body, providing continuous proprioceptive input for head positioning and spatial orientation [5]. The integration of these signals governs two key stabilising reflexes: the Vestibulocollic Reflex (VCR), which drives neck muscle activation in response to vestibular perturbation to stabilise the head in space; and the Cervicocollic Reflex (CCR), a stretch-feedback servo that resists passive head displacement through length-dependent contraction of the cervical extensors [6,7]. Biomechanically, this dual-reflex system functions as a continuous closed-loop controller; when the head deviates from its target alignment, the VCR and CCR generate corrective cervical torques that restore position, and these corrective forces propagate mechanically down the axial skeleton through the thoracic spine, lumbar segments, and pelvis to modulate centre-of-pressure position at the ground reaction surface. Impairment of cervical neuromuscular function, through fatigue or pain, increases postural sway, reduces proprioceptive accuracy, and disrupts the sensorimotor integration that underpins fine motor control [8-10]. Given the prolonged static postures assumed during air rifle shooting, the cervical musculature is particularly susceptible to progressive fatigue-related degradation of proprioceptive accuracy [11]. Targeted cervical strengthening is therefore expected to delay fatigue onset, preserve spindle afferent quality, and maintain CCR gain across the full duration of training and competition.

In parallel, the lower-limb musculoskeletal system provides the base of support upon which all proximal postural adjustments depend. Balance training has been shown to enhance sensory integration, improve neuromuscular coordination, and reduce postural sway-outcomes mechanistically linked to improved shooting accuracy [12,13]. Hung MH et al., reported that complex functional strength training incorporating unstable surfaces significantly improved rifle stability and shooting scores over a six-week period [14]. Kounalakis S et al., demonstrated that proprioceptive training under loaded and unstable conditions yielded superior balance and performance gains in competitive shooters [15].

Despite growing evidence for the independent contributions of cervical function and lower-limb balance to postural control, no published trial has examined their combined training effects within a single controlled design. This is a substantive gap, given that air rifle performance demands coordinated stability across the full kinetic chain from lower-limb postural anchoring to cervical alignment and head stabilisation. Furthermore, performance in precision sports is modulated by perceptual variables: elevated perceived exertion reduces attentional capacity during sustained precision tasks [16,17], while perceived postural instability increases competitive anxiety and impairs shot execution [18].

The present trial therefore aimed to determine whether the integration of cervical TheraBand resistance training and lower-limb balance training produces superior improvements in shooting performance, perceived postural sway, and perceived exertion compared with either exercise programme independently. This study is a part of a larger project in which multiple outcome measures were originally planned. The present manuscript reports three of these - shooting score, perceived exertion (Borg RPE CR-10), and PSPSI - while the remaining outcomes will be analysed and reported in subsequent publications from the same trial.

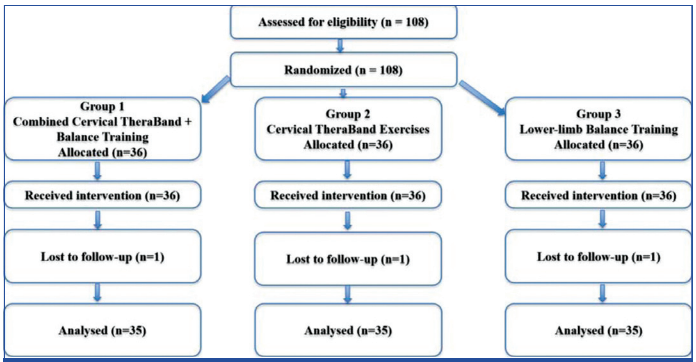
MATERIALS AND METHODS

A prospective, three-arm, parallel-group randomised controlled trial was conducted from April 2025 to January 2026 at Tapasya Shooting Academy and Royal Rifle Academy, Delhi NCR, India. Assessments were made at three time points: baseline (Week 0), mid-intervention (Week 3), and post-intervention (Week 6). The study was conducted in accordance with ethical approval from the Waves Women Empowerment Trust Independent Ethics Committee (Reference: F.1/IEC/WWE/(06)/04/2024/No. 14). CTRI registration (CTRI/2025/02/080648) was received on 17 February 2025. Written informed consent was obtained from all participants before enrolment.

Randomisation and Allocation Concealment

Eligible participants were randomly assigned to one of three groups using a chit method of random number sequence [Table/Fig-1]. Allocation was concealed using sequentially numbered, sealed opaque envelopes that were opened only after each participant had been enrolled and baseline data recorded. Outcome assessors were blinded to group assignment throughout the study period; treating physiotherapists and participants were necessarily aware of their group allocation owing to the observable nature of the exercise interventions.

Sample size: A priori power analysis was conducted using G*Power version 3.1.9.7 to determine the minimum required sample size for a repeated-measures ANOVA with between-subjects factors. The analysis assumed a medium effect size (Cohen's f=0.25),



[Table/Fig-1]: CONSORT 2010 flow diagram showing participant recruitment, randomisation, allocation, follow-up, and analysis.

a significance level of α=0.05, and a desired statistical power of 0.80. The study design included three groups and three repeated measurements, with an assumed correlation of 0.50 among repeated measures. The analysis indicated that a minimum total sample size of 108 participants (36 participants per group) would be required. Participants were recruited from Tapasya Shooting Academy and Royal Rifle Academy, Delhi NCR. However, three participants were lost to follow-up, resulting in a final sample of 105 participants included in the analysis.

Inclusion criteria:

1. Competitive 10 m air rifle shooters with active competitive participation;
2. Age ≥18 years;
3. Participants needed ≥80% of sessions to be included in the final analysis.

Exclusion criteria:

1. Any musculoskeletal, neurological, visual, or orthopaedic disorder in the preceding three months capable of impairing exercise participation or balance testing;
2. Clinically significant cervical dysfunction, pain, or positive neural provocation testing on clinical examination [19].

A total of 35 participants were included in each group.

Group 1	Combined: cervical + balance training
Group 2	Cervical TheraBand exercises only
Group 3	Lower-limb balance training only

Outcome Measures

Shooting performance: Cumulative shooting score was recorded using a calibrated electronic target system (SIUS Electronic Scale Target- Gem International sensor board and digital monitor). The cumulative shooting score obtained from the digital monitor was used for statistical analysis.

The percentage improvement was calculated using the following formula:

Percentage improvement = (Post-intervention mean - Baseline Mean)/Baseline mean × 100

Perceived postural stability: Assessed using the PSPSI questionnaire [18]. Scores range from 0 (minimal instability) to 8 (maximal instability); lower scores indicate improved perceived stability.

Perceived exertion: Measured immediately post-session using Borg's RPE CR-10 scale [20]. Lower scores indicate reduced perceived physiological strain.

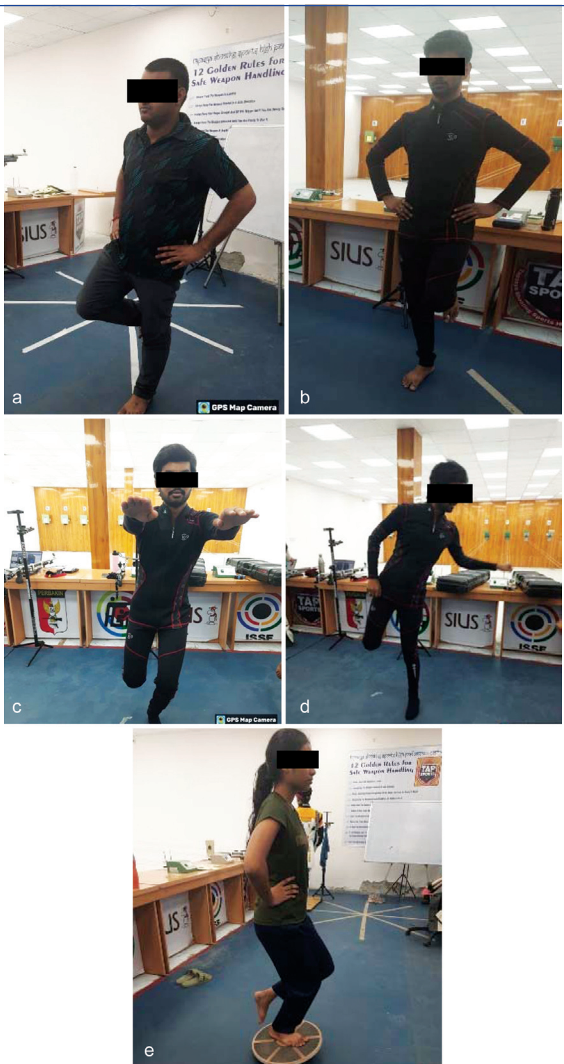
Intervention Protocol

Group 1 (Combined): Participants completed both cervical TheraBand exercises and lower-limb balance training. Cervical exercises were performed three times per week for six weeks; each session comprised 2-3 sets of 10-25 repetitions with 5-second inter-set rest, preceded and followed by five minutes of neck and shoulder stretching. The warm-up included all cervical movements, each held for six seconds and repeated three times. The programme incorporated cervical flexion, extension, bilateral lateral flexion, rotation, chin tuck, and neck shrugs [21].

Balance training was conducted concurrently for 15-30 minutes per session, three times per week. Single-leg stance, single-leg squats (30-45° knee flexion), and single-leg stance with concurrent catching tasks were performed on both stable and unstable surfaces under eyes-open and eyes-closed conditions. Training progressed from floor-based exercises (Weeks 1-2) to wobble board exercises (Weeks 3-6). Each session commenced with a standardised 5-minute warm-up [Table/Fig-2,3] [22,23].

Surface	Phase	Eyes	Workout	Exercise
Floor	Phase 1 - Day 1 to 7	Open	1 set, 8 reps/leg	Single-leg stance; Single-leg squat (30°-45°); Single-leg stance with catching
	Phase 2 - Day 8 to 14	Closed	2 sets, 10 reps/leg	Single-leg stance; Single-leg squat (30°-45°); Single-leg stance with catching
Board	Phase 3 - Days 15 to 21	Open	2 sets, 12 reps/leg	Single-leg stance; Single-leg squat (30°-45°); Double-leg stance with unstable surface rotation
	Phase 4 - Days 22 to 28	Closed/Open	2 sets, 15 reps/leg	Single-leg stance (closed); Single-leg squat (open); Single-leg stance with unstable surface rotation (open)
	Phase 5 - Days 29 to 42	Closed/Open	3 sets, 15 reps/leg	Single-leg stance (closed); Single-leg squat (open); Single-leg stance with unstable surface rotation (open)

[Table/Fig-2]: Balance training protocol.
reps = repetitions¬



[Table/Fig-3]: a) Floor-single leg stance, eyes closed; b) Floor-single leg stance, eyes open; c) Floor-single leg squat, eyes open; d) Floor-single leg stance with catching; e) Board-single leg squats.

Group 2 (Cervical only): Participants completed the identical cervical TheraBand exercise protocol described for Group 1, without balance training.

The cervical TheraBand progressive overload protocol was implemented in accordance with the original colour-coded elastic band progression system described by Page PA et al., [24]. Participants commenced with the yellow TheraBand (light resistance) performing three sets of 10 repetitions per exercise. Each subsequent session added five repetitions per set, progressing toward a target of three sets of 25 repetitions. Band resistance was advanced to the next colour level (yellow → red → green → blue) when a participant successfully and consistently completed three sets of 25 repetitions across three consecutive sessions without soreness or perceived excess fatigue, with correct technique, controlled contraction tempo, and full cervical range of movement. Upon band upgrade, repetitions were reset to three sets of 10 and progressively rebuilt toward three sets of 25 before the next upgrade was considered. This high-repetition, low-to-moderate resistance approach was designed to develop muscular endurance and aerobic capacity of the cervical musculature while also providing progressive strength gains, consistent with the training rationale of Page PA et al., [24]. All sessions included a 5-minute warm-up and cool-down of cervical and shoulder stretching, with each position held for six seconds and repeated three times. Exercises were performed three days per week for six weeks. Band upgrade decisions were assessed and documented by the supervising physiotherapist at each session using individual training logs.

Group 3 (Balance only): Participants completed the identical balance training protocol described for Group 1, without cervical exercises [22,23]. Adherence was monitored through supervised exercise sessions, attendance registers, and individual exercise logs maintained by the supervising physiotherapist. Participants attending less than the prescribed intervention schedule were recorded accordingly [Table/Fig-2,3].

STATISTICAL ANALYSIS

Data were analysed using Statistical Package for the Social Sciences (SPSS) Statistics version 25.0 and are expressed as mean±Standard Deviation (SD). The normality of the data was assessed using the Shapiro-Wilk test. Within-group differences across time points were assessed by RM-ANOVA. Between-group differences at each time point were evaluated by One-way ANOVA followed by Tukey's Honestly Significant Difference (HSD) post-hoc test. Statistical significance was set at p-value <0.05.

RESULTS

Gender distribution: A total of 105 shooters meeting all criteria were enrolled. The sample comprised 80 males and 25 females with a mean age of 20.86±2.20 years. In Group 1 (Combined Exercises), 21 participants (60.0%) were male and 14 (40.0%) were female. Group 2 (Neck Exercises) comprised 28 males (80.0%) and seven females (20.0%), while Group 3 (Balance Training) consisted of 31 males (88.6%) and only four females (11.4%). Across the entire cohort, 80 participants (76.2%) were male and 25 (23.8%) were female. A chi-square test revealed a statistically significant difference in gender distribution among the three groups (χ^2=8.30, p-value=0.016), indicating that the groups were not homogeneous with respect to gender composition, a factor that was subsequently considered during interpretation of outcomes.

Shooting Score

All three groups demonstrated statistically significant within-group improvements in shooting score across the six-week intervention period (all p-value <0.001) [Table/Fig-4a]. Group 1 recorded the greatest absolute gain, improving from 608.91±8.66 at baseline to 619.11±6.66 at six weeks (total gain: 10.20 points; 1.68%

improvement; F=61.61). The percentage improvement was calculated using: Percentage Improvement = (Post-intervention Mean - Baseline Mean)/Baseline Mean × 100.

Group 2 improved from 606.19±10.00 to 613.18±7.72 (gain: 6.99 points; 1.15% improvement; F=84.89). Group 3 improved from 605.68±9.79 to 611.58±7.27 (gain: 5.90 points; 0.97% improvement; F=39.30). In competitive 10 m air rifle, a gain of approximately ten points represents a practically meaningful advance within the upper range of competitive scores. Intergroup differences were non-significant at baseline (F=1.17, p-value=0.316) but significant at three weeks (F=4.63, p-value=0.012) and highly significant at six weeks (F=10.53, p-value=0.001). Tukey post-hoc analysis [Table/Fig-4b] confirmed that by six weeks Group 1 significantly outperformed Group 2 (mean difference 5.93, p-value=0.002) and Group 3 (mean difference 7.53, p-value <0.001).

Group	Baseline Mean±SD	3 wks Mean±SD	6 wks Mean±SD	F	p-value
Group 1	608.91±8.66	614.48±8.01	619.11±6.66	61.61	<0.001*
Group 2	606.19±10.00	609.65±9.15	613.18±7.72	84.89	<0.001*
Group 3	605.68±9.79	608.85±7.92	611.58±7.27	39.30	<0.001*
Intergroup p	F=1.17, p=0.316	F=4.63, p=0.012*	F=10.53, p=0.001*		

[Table/Fig-4a]: Intragroup and intergroup comparison of shooting score (points) across time points.
*Statistically significant (p<0.05); SD: Standard deviation; wks: weeks; RM-ANOVA for within-group; One-way ANOVA for intergroup comparison

Shooting score			Baseline		After 3 wk		After 6 wk	
			Mean Diff.	p-value	Mean Diff.	p-value	Mean Diff.	p-value
Group 1	vs	Group 2	2.71	0.459	4.83	0.046	5.93	0.002
Group 1	vs	Group 3	3.23	0.334	5.63	0.016	7.53	<0.001
Group 2	vs	Group 3	0.51	0.972	0.80	0.915	1.60	0.625

[Table/Fig-4b]: Tukey post-hoc paired comparisons of shooting score between the groups.

Perceived Sense of Postural Sway and Instability (PSPSI Score)

Significant within-group reductions in PSPSI score were recorded across all groups (all p-value <0.001) [Table/Fig-5a]. Group 1 achieved the greatest reduction, declining from 6.00±0.94 at baseline to 2.37±0.77 at six weeks (total reduction 3.63 points; F=338.20). Group 2 declined from 6.03±0.89 to 3.43±0.88 (reduction 2.60 points; F=136.10). Group 3 declined from 6.26±0.66 to 3.71±0.57 (reduction 2.55 points; F=161.20). Intergroup differences were significant at six weeks (F=30.86, p-value <0.001). Tukey post-hoc analysis [Table/Fig-5b] confirmed Group 1 was superior to Group 2 (mean difference -1.06, p-value <0.001) and Group 3 (mean difference -1.34, p-value <0.001); Groups 2 and 3 did not differ significantly (p-value=0.256).

Group	Baseline Mean±SD	3 wk Mean±SD	6 wk Mean±SD	F	p-value
Group 1	6.00±0.94	4.69±0.93	2.37±0.77	338.20	<0.001*
Group 2	6.03±0.89	5.00±0.87	3.43±0.88	136.10	<0.001*
Group 3	6.26±0.66	5.17±0.89	3.71±0.57	161.20	<0.001*
Intergroup p	F=0.99, p=0.375	F=2.63, p=0.077	F=30.86, p<0.001*		

[Table/Fig-5a]: Intragroup and intergroup comparison of Postural Sway and Instability {(PSPSI Score in (0-8 scale)}.
*Statistically significant (p<0.05); PSPSI: Perceived Sense of Postural Sway and Instability; lower scores = better stability; SD: Standard deviation

Perceived Exertion (Borg RPE CR-10 Score)

All three groups showed significant within-group reductions in perceived exertion (all p-value <0.001) [Table/Fig-6a]. Group 1 achieved the greatest absolute reduction, declining from 5.60±0.89 at baseline to 2.43±0.67 at six weeks (total reduction 3.17 points; F=189.80). Group 2 declined from 6.04±0.98 to 3.80±0.79 (reduction 2.24 points; F=126.90). Group 3 declined from 5.80±0.68 to 3.61±0.52 (reduction 2.19 points; F=217.40). Intergroup differences emerged at three weeks (F=7.26, p-value=0.001) and were highly significant at six weeks (F=43.70, p-value <0.001). Tukey post-hoc analysis [Table/Fig-6b] confirmed Group 1 significantly outperformed Group 2 (mean difference -1.37, p-value <0.001) and Group 3 (mean difference −1.19, p-value <0.001); Groups 2 and 3 did not differ significantly (p-value=0.476). [Table/Fig-7] shows the summary of mean parameter changes from baseline to six weeks.

Postural score			Baseline		After 3 wk		After 6 wk	
			Mean Diff.	p-value	Mean Diff.	p-value	Mean Diff.	p-value
Group 1	vs	Group 2	-0.03	0.989	-0.31	0.314	-1.06	<0.001
Group 1	vs	Group 3	-0.26	0.408	-0.49	0.066	-1.34	<0.001
Group 2	vs	Group 3	-0.23	0.491	-0.17	0.706	-0.29	0.256

[Table/Fig-5b]: Tukey post-hoc paired comparisons of postural sway and instability (PSPSI) score between the groups.

Group	Baseline Mean±SD	3 wk Mean±SD	6 wk Mean±SD	F	p-value
Group 1	5.60±0.89	4.39±1.12	2.43±0.67	189.80	<0.001*
Group 2	6.04±0.98	5.14±0.82	3.80±0.79	126.90	<0.001*
Group 3	5.80±0.68	4.93±0.53	3.61±0.52	217.40	<0.001*
Intergroup p	F=2.28, p=0.107	F=7.26, p=0.001*	F=43.7, p<0.001*		

[Table/Fig-6a]: Intragroup and intergroup comparison of Perceived Exertion (Borg RPE CR-10) score.
*Statistically significant (p<0.05); RPE: Rating of perceived exertion; lower scores = reduced perceived effort; SD: Standard deviation

Perception score			Baseline		After 3 wk		After 6 wk	
			Mean Diff.	p-value	Mean Diff.	p-value	Mean Diff.	p-value
Group 1	vs	Group 2	-0.44	0.088	-0.76	0.001	-1.37	<0.001
Group 1	vs	Group 3	-0.20	0.593	-0.54	0.025	-1.19	<0.001
Group 2	vs	Group 3	0.24	0.481	0.21	0.550	0.19	0.476

[Table/Fig-6b]: Tukey post-hoc paired comparisons of perceived exertion (Borg RPE CR-10) score between the groups.

Parameters	Gp 1 Mean±SD	Gp 2 Mean±SD	Gp 3 Mean±SD	F	p-value
Shooting score change	+10.20±5.92	+6.99±3.63	+5.90±3.93	8.23	<0.001*
PSPSI score change	−3.63±0.91	−2.60±1.12	−2.55±0.78	14.61	<0.001*
RPE score change	−3.17±0.81	−2.24±1.00	−2.19±0.67	15.40	<0.001*

[Table/Fig-7]: Summary of mean parameter changes from baseline to six weeks (change-score intergroup ANOVA).
*Statistically significant (p<0.05); PSPSI: Perceived Sense of Postural Sway and Instability; RPE: Rating of Perceived Exertion; negative values indicate improvement; F-values here reflect One-way ANOVA on change scores and differ from absolute six-week score ANOVAs in [Table/Fig-4a, 5a, and 6a]

DISCUSSION

The present randomised controlled trial demonstrated that all three intervention protocols significantly improved shooting performance, perceived postural stability, and perceived exertion after six weeks of training. However, participants receiving the combined cervical TheraBand and lower-limb balance training achieved significantly greater improvements than those receiving either intervention alone. These findings suggest that integrating cervical neuromuscular strengthening with balance training provides additional benefits for precision shooting performance beyond those achieved through isolated training modalities.

The improvement in shooting performance observed following the combined intervention is consistent with previous research demonstrating the importance of postural stability in precision shooting. Niinimaa V and McAvoy T first reported that increased body sway adversely affects rifle stability and shooting accuracy [1], while Ball KA et al., further demonstrated that reductions in postural sway are associated with improved aiming precision [2]. Similarly, Hung MH et al., observed significant improvements in shooting performance following functional strength and balance training, and Kounalakis S et al., reported enhanced shooting accuracy after unstable-surface balance exercises in competitive shooters [14,15]. The present findings extend these observations by demonstrating that combining cervical strengthening with lower-limb balance training produces greater improvements than either intervention performed independently. To our knowledge, this is one of the first randomised controlled trials to investigate the additive effects of these two complementary training approaches in competitive air rifle shooters.

The superior outcomes observed in the combined intervention group may be explained by the integrated role of cervical proprioception and lower-limb postural control in maintaining whole-body stability. Efficient shooting performance requires continuous integration of visual, vestibular, and somatosensory information to minimise body sway during aiming. Peterka RJ described this process as multisensory reweighting, whereby the central nervous system dynamically adjusts the contribution of different sensory inputs to maintain balance [4]. Cervical resistance training is believed to improve the function of deep cervical muscles and enhance proprioceptive feedback from muscle spindles, whereas balance training improves lower-limb sensorimotor control and postural coordination [23]. Together, these adaptations may optimise postural regulation throughout the kinetic chain, resulting in greater stability of the head, trunk, and lower extremities during shooting.

Previous experimental studies have shown that cervical muscle fatigue and neck pain impair proprioception and increase postural sway [8-10]. Progressive cervical strengthening, as implemented in the present study, may therefore improve shooting performance by reducing fatigue-related deterioration of cervical sensorimotor control. Likewise, lower-limb balance training enhances neuromuscular coordination and improves the efficiency of postural adjustments [12,13]. The combination of these adaptations is likely to provide a more stable platform for maintaining rifle alignment during prolonged shooting tasks.

An interesting finding of this study was the absence of a significant difference between the isolated cervical exercise group and the isolated balance training group, despite the distinct theoretical mechanisms underlying each intervention. Cervical resistance training is thought to act primarily through enhanced proprioceptive afferent signalling from deep neck muscle spindles, whereas lower-limb balance training is thought to act primarily through improved somatosensory and neuromuscular control at the ankle and hip. Nevertheless, both afferent pathways ultimately converge on the same central postural control process. Within Peterka RJ's multisensory reweighting framework, the central nervous system continuously redistributes reliance across visual, vestibular, and somatosensory inputs to preserve overall stability [4]. It is therefore plausible that, although the two interventions strengthen different peripheral inputs, central reweighting allowed each to be translated into a comparable net improvement in whole-body postural stability and, consequently, shooting performance. This would suggest that cervical proprioceptive training and lower-limb balance training independently contribute to postural regulation through complementary but functionally convergent sensorimotor pathways, and that shooting performance depends less on the specific origin of proprioceptive input than on the overall efficiency of the central integration process. A methodological explanation should also be considered: because both isolated interventions were active treatments rather than passive controls, detecting a difference between them required a larger sample than would be needed for an active-versus-control comparison, and the present study may have been underpowered to identify a true but modest difference between Groups 2 and 3. A ceiling effect occurring within the six-week training period is a further possibility, whereby both single-component interventions approached a similar upper limit of achievable improvement over this relatively short timeframe, potentially obscuring mechanism-specific differences that might otherwise emerge with a longer intervention or with outcome measures capable of isolating segment-specific contributions. Importantly, when the two interventions were combined, their effects appeared additive rather than redundant, supporting the broader concept that optimal shooting performance depends on coordinated neuromuscular control across multiple body segments rather than on isolated enhancement of a single sensorimotor component.

The combined intervention also produced the greatest reduction in PSPSI. Improved cervical proprioception and balance likely enhanced participants' perception of body stability during shooting, thereby reducing awareness of postural fluctuations. These findings are consistent with those of Beinert K and Taube W, who demonstrated that balance training improves cervical sensorimotor function and postural control [23]. Improved perceived stability may also contribute to greater confidence during competition, potentially facilitating more consistent shooting performance.

Similarly, all groups demonstrated reductions in Borg RPE, with the combined intervention showing the greatest improvement. Reduced perceived exertion may reflect improved neuromuscular efficiency, allowing athletes to maintain shooting posture with less muscular effort during prolonged training sessions. Previous studies have suggested that lower perceived exertion and improved self-efficacy contribute to better concentration and performance in precision sports [16,17,25-28]. Therefore, the observed reduction in perceived effort may represent both physiological adaptation and enhanced psychological readiness during shooting.

The findings of this study have practical implications for sports physiotherapists, strength and conditioning specialists, and shooting coaches. Incorporating cervical strengthening exercises alongside structured balance training may enhance postural control, reduce perceived effort, and improve shooting performance in competitive air rifle athletes. As both exercise programmes are inexpensive, easy to administer, and require minimal equipment, they can be readily integrated into routine conditioning programmes without substantial logistical constraints. However, the timing of exercise sessions should be planned appropriately to avoid temporary fatigue immediately before competition.

Overall, the present study provides evidence that a multi-component neuromuscular training programme targeting both cervical stability and lower-limb balance offers greater benefits than isolated interventions. These findings contribute to the growing body of evidence supporting integrated postural training strategies for precision sports and provide a practical framework for optimising physical conditioning in competitive air rifle shooters.

Limitation(s)

Despite these encouraging findings, the study was limited by its relatively short intervention period, recruitment from two shooting academies, and the absence of objective biomechanical and physiological outcome measures such as force-platform posturography, electromyography, and motion analysis. Future multicentre studies with longer follow-up periods and objective assessments are warranted to confirm the long-term effectiveness of the intervention and to further elucidate the mechanisms underlying improvements in shooting performance. Also, the follow-up could not be completed due to loss to follow-up and logistical constraints.

CONCLUSION(S)

This randomised controlled trial demonstrated that a six-week programme combining cervical TheraBand exercises with lower-limb balance training resulted in significantly greater improvements in shooting performance, perceived postural stability, and perceived exertion than either intervention performed independently. Although both cervical strengthening and balance training were effective when administered alone, their combination produced superior overall outcomes, suggesting complementary effects on neuromuscular control and postural regulation.

These findings support the incorporation of integrated cervical strengthening and lower-limb balance training into the conditioning programmes of competitive air rifle shooters to optimise postural control and enhance shooting performance. Given the simplicity, low cost, and ease of implementation of these exercises, the programme may be readily incorporated into routine training under appropriate supervision.

Acknowledgement

The authors acknowledge the cooperation of the shooters and coaching staff at Tapasya Shooting Academy and Royal Rifle Academy, Delhi NCR, for facilitating participant recruitment and data collection. No external funding was received for this study.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: May 09, 2026
- Manual Googling: Aug 17, 2026
- iThenticate Software: Aug 19, 2026 (3%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Apr 17, 2026**
Date of Peer Review: **Jun 04, 2026**
Date of Acceptance: **Aug 21, 2026**
Date of Publishing: **Oct 01, 2026**