

Impact of Cognitive and Psychophysiological Factors on the Performance Enhancement and Management of Indian Shooters

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ABSTRACT

Background: Shooting sport performance depends on the integration of technical skill, physical conditioning, and mental readiness, yet the psychophysiological determinants of performance are usually studied in isolation. Despite substantial infrastructural and financial investment, Indian shooters have underperformed relative to expectations at recent Olympic Games, prompting the question of which cognitive and psychophysiological factors most strongly differentiate performance.

Purpose: This study investigated the combined role of cognitive factors (alertness, reaction time, time/movement anticipation, and personality traits) and psychophysiological factors (electromyographic muscle activity, respiration rate, motility, and electroencephalographic brain activity) in the performance of Indian shooters, with the aim of proposing a standard assessment model for talent identification and performance enhancement.

Methods: Forty shooters (20 individual competitors and 20 shooters affiliated with a shooting academy), each with more than two years of professional training, were selected using simple random sampling. Cognitive functions were assessed using the Vienna Test System (Reaction Test, Alertness Test, Time/Movement Anticipation Test, and the Eysenck/Big-Five Personality Profiler), and psychophysiological functions were assessed using the Schuffried Biofeedback Xpert and Neuromaster EEG systems (EMG, respiration, motility, and EEG). Descriptive statistics (means and standard deviations) were computed overall and separately for six shooting disciplines: Air Rifle, 3-Position, Air Pistol, Rapid Fire, Trap, and Skeet.

Results: Cognitive and psychophysiological scores fell predominantly in the average-to-above-average range relative to normative benchmarks, with emotional stability, EMG muscle activity, and respiration rate showing above-average scores. Performance profiles varied meaningfully across disciplines: Skeet and Air Pistol shooters showed the highest alertness scores, Trap shooters the highest reaction-time and time-anticipation scores, and Rapid Fire and Air Pistol shooters showed the greatest dispersion (variability) in their psychophysiological profiles.

Conclusion: Cognitive and psychophysiological factors jointly and measurably influence shooting performance, and their relative importance differs by discipline. Insufficient attention to these factors, rather than a lack of technical training or infrastructure, may be an important contributor to the underperformance of Indian shooters at international events. A standardized, discipline-specific cognitive-psychophysiological assessment battery is proposed as a tool for talent scouting and targeted intervention.

Keywords: Sport Psychology, Shooting Performance, Cognitive Factors, Psychophysiology, Eeg, Emg, Talent Identification, Olympic Shooting

Introduction

Shooting is a precision sport that depends on the integration of technical training, physical fitness, and mental strength [1]. A growing body of research indicates that psychological readiness, rather than technical proficiency alone, distinguishes elite performers from other competitors. Pre-competitive stress has been identified as a major determinant of reduced performance among elite shooters, verbal-memory performance has been found

to be significantly worse among sport shooters than controls, and a persistent gap in psychological support, assessment, and training has been documented among elite shooters [1-3]. Neuropsychological rehabilitation has also been shown to improve accuracy- and attention-related cognitive function in shooters under competitive-anxiety conditions, and self-paced neuro-cognitive (EEG) activity has been linked to performance differences between marksmen and novices [4,5].

Despite high-quality infrastructure, financial support, and rigorous technical training, India has secured only four Olympic medals in shooting to date, and for the first time since 2000 no

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Indian Army shooter qualified for the 2023 Olympic cycle [6]. This pattern suggests that factors beyond technical training and infrastructure limit performance. Prior research has generally examined cognitive or psychophysiological factors separately, and predominantly among international (non-Indian) shooters. Given the influence of environmental, socio-economic, and cultural context on athlete development, the combined role of cognitive and psychophysiological factors among Indian shooters specifically warrants direct investigation.

This study addresses that gap by jointly assessing eight cognitive and psychophysiological dimensions alertness, reaction time, time/movement anticipation, personality traits, EMG muscle activity, respiration rate, motility, and EEG brain activity among Indian shooters, with the goal of identifying a standard model for performance enhancement and management. The study was guided by three research questions: (1) Do cognitive and psychophysiological factors play a vital role in shooters' performance? (2) If so, how do these factors impact performance? (3) What is the key factor limiting Indian shooters at the international level?

Literature Review

Sport-psychology research on shooting has converged on several recurring themes. First, stress and anxiety regulation is central: mindfulness-based interventions reduce physiological and cognitive markers of pre-competitive stress and offer shooters new strategies for reframing high-pressure situations [1]. Second, cognitive function particularly memory, attention, and reaction speed has repeatedly been linked to shooting accuracy; sport shooters show measurable differences on verbal-memory tasks relative to non-shooters and cognitive training and cognitive workload management have been shown to influence shoot/don't-shoot decision accuracy in live-fire exercises [3-7]. Third, psychophysiological regulation including EEG-indexed brain activity, EMG-indexed muscle steadiness, and respiratory control is consistently associated with performance; neurofeedback training has produced measurable improvements in rifle-shooting performance and self-paced visuospatial EEG activity differentiates marksmen from novices [5-8].

Personality has also been implicated: stress tolerance and coping ability have been reported to predict success or failure at the international level with near-total accuracy in some samples and the cognitive-cascade hypothesis proposes that discrete cognitive abilities map onto discrete steps of the firing sequence [9,10]. Physical and biomechanical factors interact with these psychological variables for example, footwear has been shown to improve postural stability and aiming accuracy in rifle shooting and hold stability, trigger cleanliness, and aiming accuracy are the strongest technical predictors of elite air-rifle performance [11,12].

A structural gap in the literature is that psychological support for shooters is often inconsistent or absent altogether, and shooters themselves report that earlier access to professional psychological support would likely have accelerated their results [2]. Most existing studies isolate either the cognitive or the psychophysiological dimension, and few examine both concurrently within a single, discipline-differentiated sample. The present study was designed to close this gap by evaluating cognitive and psychophysiological

factors together, across six shooting disciplines, within an Indian sample.

Methods

Research Design: This study used a quantitative, cross-sectional design. Cognitive and psychophysiological functions relevant to shooting performance were assessed using validated, computerized test batteries, and descriptive statistics were used to characterize the sample overall and by shooting discipline (Air Rifle, 3-Position, Air Pistol, Rapid Fire, Trap, and Skeet).

Participants: Forty shooters (N=40) based in India were recruited using simple random sampling: 20 individual competitive shooters and 20 shooters affiliated with a shooting academy (Gun for Glory) and an Army Marksmanship Unit. All participants had more than two years of professional shooting-specific training. Sixty percent of participants were aged 20–30 years and 40% were aged 31–40 years; 76% held a bachelor's degree and 24% held a postgraduate degree. Sixty-five percent had received 2–4 years of professional training, 25% had received 0–2 years, and 10% had received four or more years. Written informed consent was obtained from all participants prior to testing.

Instruments: Cognitive functions were assessed with the Vienna Test System (VTS), a validated computerized battery used in sport-psychology assessment: the Reaction Test (RT; Cronbach's $\alpha = 0.83-0.98$), the Time/Movement Anticipation Test (ZBA; internal consistency 0.94–0.99), the Alertness Test/WAFA ($\alpha = 0.86-0.98$), and the Eysenck/Big-Five Personality Profiler (EPP6; $\alpha = 0.70-0.97$). Psychophysiological functions were assessed using the Schuhfried Biofeedback Xpert wireless system (EMG for hand and shoulder muscle activity, BFRESP for respiration rate, and MULTI-P for motility/hand steadiness) and the Neuromaster EEG neurofeedback system (delta, theta, low/high alpha, low/high beta, low/high gamma, meditation, and attention indices).

Table 1: Instrumentation Overview

Dimension	Instrument	Reliability
Reaction time	Vienna Test System — Reaction Test (RT)	$\alpha = 0.83-0.98$ (RT); 0.84–0.95 (motor time)
Time anticipation	Vienna Test System — ZBA	Internal consistency 0.94–0.99
Personality	Vienna Test System — EPP6 (Big Five)	$\alpha = 0.70-0.97$ by subscale
Alertness	Vienna Test System — WAFA	$r = 0.86-0.98$
Muscle activity (EMG)	Schuhfried Biofeedback Xpert — BFEMG	State-of-the-art wireless biofeedback
Respiration rate	Schuhfried Biofeedback Xpert — BFRESP	State-of-the-art wireless biofeedback
Motility	Schuhfried Biofeedback Xpert — MULTI-P	State-of-the-art wireless biofeedback
Brain activity (EEG)	Neuromaster Neurofeedback	State-of-the-art wireless neurofeedback

Procedure: Participants were contacted in advance to solicit consent, and those who agreed received an informed-consent form and were scheduled for testing at a time and location convenient to them. Testing sessions were conducted individually in a controlled setting. Each participant completed the full cognitive battery (VTS) followed by the psychophysiological battery (Biofeedback Xpert and EEG), administered according to each instrument's standardized protocol.

Data Analysis: Raw scores were computer-scored according to each instrument's standard scoring procedure. Descriptive statistics (means and standard deviations) were computed for each dimension for the sample as a whole and separately by shooting discipline. Normative interpretation followed the respective test manuals, in which scores of 17–75 is classified as average, scores below 16 as below average, and scores of 76–84 as above average. Ten directional hypotheses (H1–H10) were formulated to test whether each cognitive and psychophysiological dimension, individually and by discipline, was associated with shooting performance.

Results

Overall Cognitive and Psychophysiological Profile: Table 2 summarizes the sample-wide means and standard deviations for each cognitive and psychophysiological dimension. Alertness ($M = 55.50$, $SD = 29.43$), reaction time ($M = 37.27$, $SD = 20.55$), and time anticipation ($M = 64.20$, $SD = 22.87$) fell within the average normative range. Among personality traits, emotional stability was notably higher ($M = 71.88$, $SD = 23.86$) than extroversion ($M = 24.11$), openness ($M = 27.77$), conscientiousness ($M = 25.11$), and agreeableness ($M = 32.77$), indicating that the sample was characterized more by emotional composure than by other Big Five traits. EMG muscle activity (hand: $M = 106.55$; shoulder: $M = 109.97$) and respiration rate ($M = 166.96$, $SD = 8.17$) scored above the average normative band, while motility ($M = 0.32$, $SD = 0.20$) indicated accurate hand steadiness. EEG indices showed

attention ($M = 55.24$) and meditation ($M = 48.41$) scores in the average range, consistent with a psychophysiological composed but not exceptional sample.

Table 2: Sample-Wide Cognitive and Psychophysiological Results (N = 40)

Dimension	Mean	SD
Alertness	55.50	29.43
Reaction time	37.27	20.55
Time anticipation	64.20	22.87
Personality — Extroversion	24.11	12.81
Personality — Emotional Stability	71.88	23.86
Personality — Openness	27.77	21.97
Personality — Conscientiousness	25.11	13.81
Personality — Agreeableness	32.77	26.97
EMG — Muscle activity (hand)	106.55	18.80
EMG — Muscle activity (shoulder)	109.97	24.33
Respiration rate	166.96	8.17
Motility	0.3184	0.199
EEG — Attention	55.24	3.56
EEG — Meditation	48.41	5.24

Performance Profile by Shooting Discipline: Descriptive scores diverged meaningfully across the six shooting disciplines (Table 3). Alertness was highest in Air Pistol and Skeet ($M = 81$ for each) and lowest in Air Rifle ($M = 31.8$). Reaction time was highest indicating the slowest processing in Trap ($M = 62$) and lowest in Air Pistol ($M = 21$). Time anticipation was highest in Skeet ($M = 87$) and lowest in 3-Position ($M = 74.33$ was in fact the second-highest; the lowest was Air Rifle, $M = 43.5$, excluding Air Pistol where the item was not scored). Emotional stability was highest in Rapid Fire ($M = 89.33$) and lowest in Air Pistol ($M = 57.33$), while extroversion was highest in Air Pistol ($M = 35$) and lowest in Trap ($M = 12$).

Table 3: Cognitive Dimensions by Shooting Discipline (Means)

Dimension	Air Rifle	3-Position	Air Pistol	Rapid Fire	Trap	Skeet
Alertness	31.8	56	81	50.33	58	81
Reaction time	46.4	36.33	21	25.66	62	33
Time anticipation	43.5	74.33	—	29	64.5	87
Extroversion	27	15	35	21	12	31
Emotional Stability	63	74.66	57.33	89.33	76	81.5
Openness	33.2	11.33	34.33	28.33	27	29
Conscientiousness	28	16	36	22	13	32
Agreeableness	38	16	40	34	33	34

Psychophysiological indices likewise varied by discipline (Table 4). EMG shoulder activity was highest in Trap ($M = 127.31$) and lowest in Air Pistol ($M = 78.35$). Respiration rate was highest in Trap ($M = 176.4$) and lowest in Skeet ($M = 146.6$). Motility was highest indicating relatively less steadiness in Trap ($M = 0.6$) and lowest in 3-Position ($M = 0.086$). Attention (EEG) was fairly stable across disciplines (range 53.78–57.73), while meditation showed a similarly narrow range (46.93–52.91), suggesting that arousal-regulation indices are comparatively discipline-invariant relative to the biomechanical (EMG, motility) and reactive (alertness, reaction time) measures.

Table 4: Psychophysiological Dimensions by Shooting Discipline (Means)

Dimension	Air Rifle	3-Position	Air Pistol	Rapid Fire	Trap	Skeet
EMG (hand)	102.5	102.9	120.67	109.66	105.68	98.20

EMG (shoulder)	103.18	111.18	78.35	115.35	127.31	121.16
Respiration rate	159.45	168.93	171.8	162.06	176.4	146.6
Motility	0.15	0.086	0.29	0.346	0.6	0.525
EEG — Attention	55.83	56.45	53.78	57.37	56.74	57.73
EEG — Meditation	47.57	49.43	52.91	47.29	46.93	47.85

Variability Across Disciplines: Standard deviations were used as an index of within-discipline consistency, where a lower deviation reflects a more homogeneous (and, per the study's interpretive criterion, more favorable) performance profile. Air Pistol and Skeet shooters showed the greatest overall dispersion in their scores, while Trap and Rapid-Fire shooters showed comparatively tighter clustering around the mean on most cognitive dimensions. On psychophysiological measures, Air Pistol again showed the widest spread (e.g., respiration-rate SD = 171.8; EMG-hand SD = 46.48), suggesting greater individual variation in physiological regulation within that discipline than within Trap or Skeet.

Discussion

The results indicate that cognitive and psychophysiological factors are jointly associated with shooting performance, and that their relative importance is discipline-specific rather than uniform across shooting sport. Alertness sustained, focused attention amid competing external stimuli such as crowd noise was highest among Air Pistol and Skeet shooters, consistent with the fast-paced, reactive demands of those disciplines. Reaction time, the measurable interval between stimulus and motor response, was slowest among Trap shooters, which may reflect the discipline's longer decision window relative to faster-paced events. Time anticipation the shooter's ability to predict target movement and pre-position accordingly was strongest in Skeet, aligning with that discipline's requirement to track and intercept a moving target.

Personality results showed a sample-wide elevation in emotional stability relative to the other Big Five traits, and this elevation was most pronounced in Rapid Fire. Emotionally stable individuals report greater composure, lower reactivity to stress, and less disruption of performance under pressure; the concentration of this trait among Rapid Fire shooters, a discipline with extremely compressed decision windows, is consistent with prior findings that stress tolerance and coping ability are strong predictors of shooting success [9].

On the psychophysiological side, hand and shoulder muscle steadiness (EMG) and respiration control were above the normative average overall, and both were elevated specifically in Trap. Because postural and muscular steadiness directly affects aim, and because respiration, heart rate, and muscle tension are physiologically interconnected, the elevated EMG and respiration values among Trap shooters may reflect either the physical demands of that discipline (repeated shouldering and swinging of the shotgun) or a compensatory response to its longer aiming and tracking sequence. Brain-activity (EEG) findings were comparatively stable across disciplines, suggesting that broad attentional and relaxation states are less differentiated by shooting discipline than are motor-reactive and muscular measures a pattern consistent with neurofeedback studies showing that EEG-indexed

attention training benefits shooting performance generally rather than in a discipline-specific way [8].

These findings are consistent with, and extend, prior literature that has generally treated cognitive and psychophysiological factors separately. Cognitive-cascade accounts linking discrete abilities to discrete phases of the shot sequence, footwear and postural-stability findings in rifle shooting, and hold-stability and trigger-cleanliness findings in elite air-rifle shooting all point toward the same conclusion reached here: that performance is the product of an integrated cognitive-physiological system rather than any single factor [10,11,13]. The discipline-specific pattern observed in this study suggests that a single, undifferentiated training protocol is unlikely to be optimal, and that talent identification and intervention should be tailored to the cognitive and psychophysiological demand profile of each shooting discipline [14-17].

Conclusion and Recommendations

Cognitive and psychophysiological factors alertness, reaction time, time/movement anticipation, personality traits, EMG muscle activity, respiration rate, motility, and EEG brain activity were found to differentiate performance profiles among Indian shooters, both overall and by discipline [18]. Insufficient systematic attention to these factors, rather than a shortfall in technical training or infrastructure, may be an important and previously underexamined contributor to the underperformance of Indian shooters at international events [19]. A standardized cognitive-psychophysiological assessment battery, differentiated by shooting discipline, is proposed as a practical tool for talent scouting, athlete monitoring, and targeted intervention design [20].

This study is limited by its relatively small, cross-sectional sample ($N = 40$) and its descriptive (rather than inferential) analytic approach; causal claims about the direction of influence between cognitive/psychophysiological factors and competitive outcomes cannot be made from these data [21,22]. Future research should extend this work with inferential statistical testing, larger and more geographically diverse samples, and discipline-specific normative models, and should examine whether targeted cognitive-psychophysiological training programs produce measurable gains in competitive performance over time [23].

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