

# Study Protocol

**Title:** Effects of Virtual Reality Motor Imagery (VRMI) Training on Shooting Performance and Executive Function in 10-Meter Air Pistol Athletes

**Protocol ID:** VRMI-2026-01

**Date:** April 2, 2026

## 1. Background

Precision sports such as 10-meter air pistol shooting require high-level motor control, attention, and executive function. Virtual Reality Motor Imagery (VRMI) training has been shown to enhance motor imagery ability, optimize eye movement patterns, improve prefrontal cortex activation, and increase neurotransmitter levels associated with motor and cognitive performance. Traditional exercise training provides physical practice but lacks immersive cognitive simulation. This study investigates the effects of VRMI compared to traditional training and a control condition on shooting performance, executive function, visual attention, and neurophysiological indicators in elite shooters.

## 2. Objectives

### Primary Objective:

- To examine the effect of 12-week VRMI training on 10-meter air pistol shooting performance compared to traditional training and a control condition.

### Secondary Objectives:

- To assess the impact of VRMI on executive function as measured by the Stroop test.
- To evaluate eye movement behavior (average fixation count and duration) during shooting tasks.
- To measure changes in prefrontal cortex oxygenation using functional near-infrared spectroscopy (fNIRS).
- To quantify salivary neurotransmitter levels (dopamine, serotonin, acetylcholine, GABA) before and after intervention.

## 3. Study Design

- **Design:** Randomized, parallel-group, controlled trial
- **Arms/Groups:**
  1. VRMI Training (Experimental)
  2. Traditional Exercise Training (Experimental)
  3. Health Education Videos (Control)
- **Duration:** 12 weeks, 3 sessions per week, 25 minutes per session
- **Participants:** 134 healthy volunteers (20–26 years), right-handed, normal or corrected vision, no neurological, psychiatric, or musculoskeletal disorders affecting motor performance

## 4. Inclusion and Exclusion Criteria

### Inclusion Criteria:

1. Age 20–26 years
2. Right-handed participants
3. Normal or corrected vision
4. No neurological, psychiatric, or musculoskeletal conditions affecting motor control
5. Ability to comply with 12-week intervention protocol

### Exclusion Criteria:

1. Upper limb injury or impaired fine motor skills
2. Sleep disorders or irregular sleep patterns
3. Participation in other structured shooting or motor imagery training
4. Attendance below 80% of training sessions
5. Use of medications affecting cognition or motor function

## 5. Interventions

### Arm 1 – VRMI Training:

- VR-based training with progressive muscle relaxation, 3D demonstration, guided motor imagery, and physical practice.

### Arm 2 – Traditional Exercise:

- Traditional training including progressive muscle relaxation, 2D video demonstration, guided motor imagery, and physical practice.

### Arm 3 – Control:

- Health education videos covering nutrition and lifestyle. No physical practice included.

## 6. Outcome Measures

### Primary Outcome:

- **Title:** Change from Baseline in Mean Shooting Score at 12 Weeks
- **Description:** Change in mean score of 24 shots per session in VR-based 10-meter air pistol competition, evaluating precision and consistency.
- **Time Frame:** Baseline and 12 weeks

### Secondary Outcomes:

- Change in Stroop Test reaction time and error rate (executive function)
- Change in eye movement metrics (average fixation count and duration)
- Change in prefrontal cortex O<sub>2</sub>Hb levels measured by fNIRS
- Change in salivary neurotransmitters (DA, 5-HT, ACh, GABA)

## 7. Experimental Procedure

1. **Warm-Up:** 5-min steady-state cycling, baseline eye-tracking calibration
2. **Training Intervention:** 12 weeks of assigned intervention per arm
3. **Assessments:** Pre- and post-intervention measurements of shooting performance, eye-tracking, Stroop test, fNIRS, and salivary neurotransmitters
4. **Data Collection:** Standardized procedures for all outcome measures

## 8. Statistical Analysis Plan

- **Software:** SPSS 27.0
- **Normality Test:** Shapiro-Wilk
- **Primary Analysis:** Repeated measures ANOVA (group  $\times$  time) for shooting performance
- **Secondary Analysis:**
  - Paired t-tests for pre-post comparisons within groups
  - ANOVA for group differences in Stroop test, eye-tracking metrics, fNIRS data, and neurotransmitter levels
- **Significance Level:**  $P < 0.05$

## 9. Ethics and Safety

- Written informed consent will be obtained from all participants
- No adverse events are anticipated as interventions are non-invasive
- Data confidentiality maintained; individual participant data will not be shared