STUDY PROTOCOL AND STATISTICAL ANALYSIS PLAN

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Official Title: *The Role of Musical Stimulation Intensity on Postural Control in Athletes: A Virtual Reality-Based Posturography Study*

Document Type: Study Protocol and Statistical Analysis Plan

Ethics Approval: Malatya Turgut Özal University Health Sciences Scientific Research Ethics Committee

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1. Background and Rationale

Postural stability depends on the integration of visual, vestibular, and somatosensory inputs for equilibrium control. Auditory stimulation, particularly music, can modulate standing posture through mechanisms such as attentional modulation and stochastic resonance, which may alter proprioceptive feedback and motor strategies. The influence of different music intensity levels on balance performance in athletes remains insufficiently studied, especially using virtual reality-based posturography. This protocol evaluates how auditory intensity modulates sensory reweighting and stability indices in sport-trained individuals.

2. Objectives

Primary Objective

To investigate the effects of different musical intensity levels (low, medium, high) on postural control in athletes using VR-based posturography.

Secondary Objective

To explore whether individual noise sensitivity moderates balance performance during auditory stimulation.

3. Study Design

This experimental, cross-sectional study used a randomized crossover design. Each participant completed balance assessments under three musical intensity conditions (low ≈55 dB, medium ≈70 dB, high ≈85 dB). Conditions were presented in randomized order, and a ≥60-second washout period was provided between trials to minimize carryover effects.

4. Participants

Inclusion Criteria

- Age 18–30 years
- Active athletic training ≥5 years
- Normal hearing thresholds (≤20 dB HL)
- No vestibular, neurological, orthopedic, or psychiatric disorders
- Written informed consent

Exclusion Criteria

- Current or past vestibular disorder or vertigo
- Intolerance to auditory stimulation
- Ototoxic drug use in the last 3 months
- Abnormal tympanometry

5. Intervention Description

Auditory stimulation consisted of *Mozart's Jupiter Symphony*, delivered via standardized VR-integrated headphones (Balance VR system). All participants listened to the same musical excerpt at three intensity levels. Balance evaluations were conducted using VR-based CTSIB and Limits of Stability modules.

6. Outcome Measures

Primary Outcomes

- CTSIB composite equilibrium score
- Sensory component scores: somatosensory, visual, vestibular, and visual preference

Secondary Outcomes

- LOS metrics: reaction time, endpoint excursion, maximum excursion, mean velocity, and directional control
- Noise sensitivity measured using the Weinstein Noise Sensitivity Scale (Turkish validated version)

7. Statistical Analysis Plan

Normality was assessed using the Shapiro–Wilk test. The effects of auditory intensity and sport type were analyzed using repeated-measures ANOVA and linear mixed models. Bonferroni correction was applied for post-hoc pairwise comparisons. Pearson correlations were performed to examine the association between noise sensitivity and postural outcomes. Partial eta-squared (η^2) was used to estimate effect size. Significance level: $\mathbf{p < 0.05}$ (two-tailed).

8. Ethics and Data Handling

The study was approved by the Malatya Turgut Özal University Health Sciences Scientific Research Ethics Committee (Approval No: 2025/95) and adhered to the Declaration of Helsinki. All participants signed written informed consent. Data are anonymized and securely stored. Individual participant data will **not** be publicly shared due to institutional data protection regulations; only aggregated results may be reported.