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Wearable Sensor-Based Gait Analysis in Benign Paroxysmal Positional Vertigo: Quantitative Assessment of Residual Dizziness Using the ϕ-Bonacci Framework

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Statement of the Problem: Benign Paroxysmal Positional Vertigo (BPPV) is the most common vestibular disorder. Although canalith repositioning procedures (CRPs) usually resolve positional vertigo, many patients still report imbalance or residual dizziness, which is difficult to quantify with standard clinical tests. This study evaluates the clinical usefulness of wearable sensor–based gait metrics, enhanced by the newly developed ϕ-bonacci index framework, to quantify gait changes and residual dizziness in BPPV before and after CRPs.

Methodology & Theoretical Orientation: Fifteen BPPV patients (BPPV-P) and fifteen age-matched healthy controls performed supervised straight-walking tests under eyes-open (EO, 20 m) and eyes-closed (EC, 10 m) conditions while wearing inertial measurement units (IMU; Movit System G1). From the mid-trial composite gait cycle, ϕ-bonacci components were computed: self-similarity/harmonicity (A_1), swing symmetry (A_2), and double-support consistency (A_4), to capture gait harmonicity, symmetry, and stability. Patients were assessed pre-CRP and ~2 weeks post-CRP; residual dizziness was recorded using a visual analogue scale (VAS=0 vs VAS>0).

Findings: Before treatment, BPPV-P showed significantly higher A_1 than controls under both visual conditions ($p=0.038$ EO; $p=0.011$ EC), indicating impaired gait harmonicity. After CRPs, A_1 normalized toward control levels, suggesting restoration of gait self-similarity. Visual deprivation (EC) produced marked increases in A_1 and A_4 across all groups, highlighting the stabilizing contribution of vision to balance control during locomotion. Among post-treatment patients with clinical resolution of positional nystagmus, those reporting residual dizziness displayed persistently elevated A_4—particularly under EC—suggesting incomplete sensory reweighting despite clinical recovery.

Conclusion & Significance: Wearable IMU-derived ϕ-bonacci metrics offer sensitive, objective digital biomarkers of gait abnormalities and residual dizziness in BPPV, supporting their use for diagnosis, rehabilitation monitoring, and follow-up.

Biography

Dr. Nicolò Colistra is a biomedical engineer and AI researcher at ENEA (Italy) whose work integrates machine learning, biomedical sensing and intelligent systems for healthcare diagnostics, treatment optimization and human performance assessment. His research spans AI for oncology and cardiology, predictive modeling for clinical decision-making, and multi-scale digital twin architectures. He has contributed to cardiotoxicity assessment through automated pipelines and microelectrode-array platforms, as well as to microfabrication, biosensor design and clean-room prototyping. In parallel, he develops wearable and signal-processing methods for gait analysis and rehabilitation monitoring, including the ϕ-bonacci framework for quantifying locomotor harmonicity, symmetry and stability. He has collaborated with ENEA, the Department of Electronic Enginnering of University of Rome Tor Vergata, the Italian Institute of Technology and IBM Research.