RoboREHAB: AI-Assisted Bilateral Gait Retraining for Musculoskeletal Injury Recovery and Return-to-Duty Assessment

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1. BACKGROUND

- **Musculoskeletal injuries (MSKI)** threaten military readiness and require objective recovery assessment.
- **Gait rehabilitation** needs measurable bilateral metrics to track functional recovery.
- **Temporal and spatial gait asymmetries** can reveal distinct dimensions of impairment.
- **Healthy speed-aware references** provide targets for personalized robotic gait retraining.
- **RoboREHAB** links recovery metrics, robotic assistance, and future AI-guided adaptation.

2. LEARNING OBJECTIVES

- **Assess** MSKI recovery using bilateral temporal and spatial gait metrics.
- **Use** healthy speed-aware references to guide robotic gait retraining.
- **Explore** adaptive assistance strategies for bilateral robotic rehabilitation.

3. MATERIALS AND METHODS

- Analyzed a **public asymmetric gait dataset** to quantify bilateral temporal and spatial recovery metrics.
- Focused on **stance-related temporal asymmetry** and **step-length-related spatial asymmetry**.
- Generated **healthy speed-aware walking references** for stride length, step width, and cadence.
- Applied **subject-level quality checks** for event ordering and marker-axis consistency.
- Extended with **STS/STSi transition analysis** and **phase-aware assistance scheduling**.

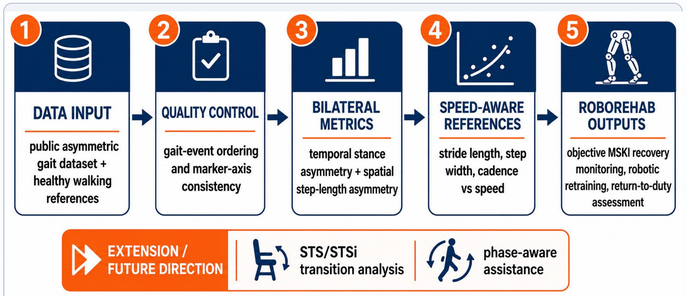

Fig. 1. Workflow for bilateral gait analysis and RoboREHAB-based recovery assessment.

4. SYSTEM OVERVIEW AND KEY RESULTS

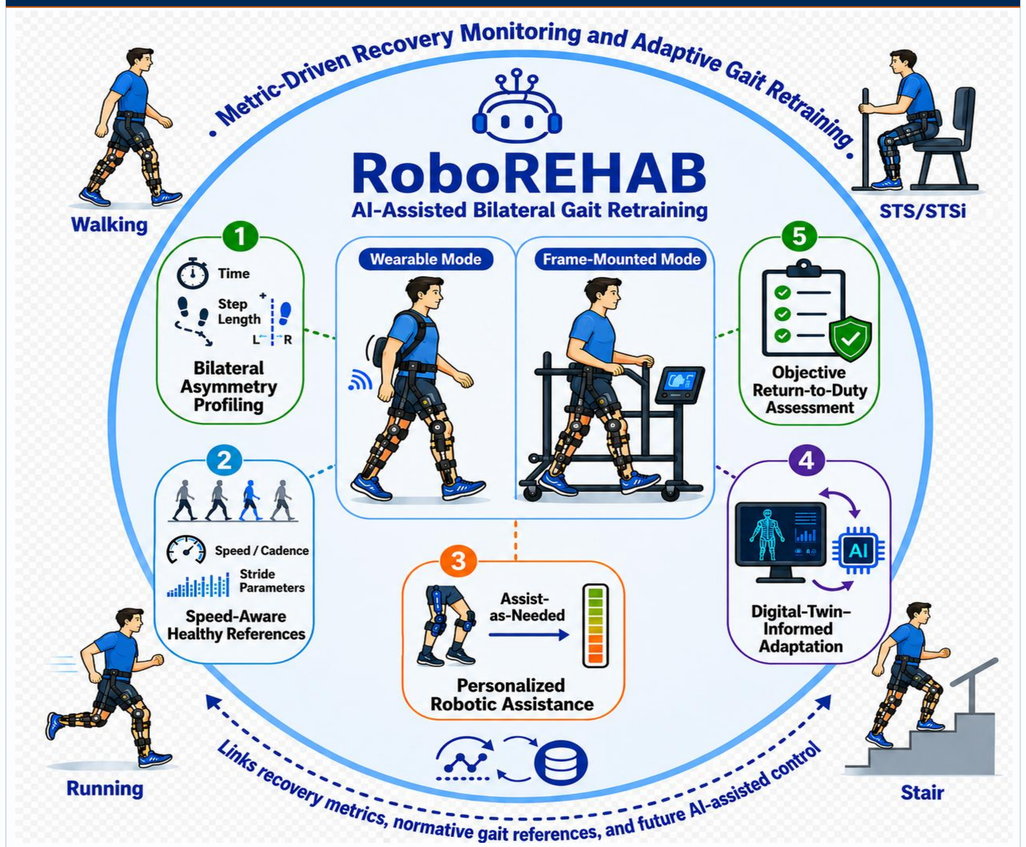

Fig. 2. RoboREHAB framework for bilateral gait retraining and recovery monitoring.

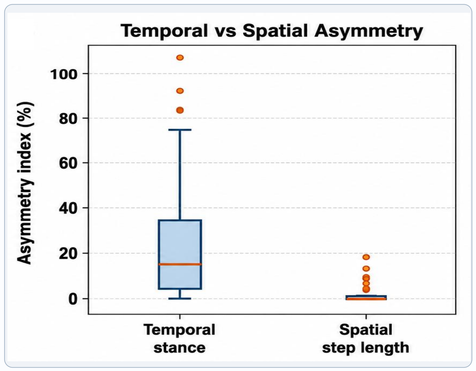

Fig. 3. Bilateral temporal and spatial gait asymmetry.

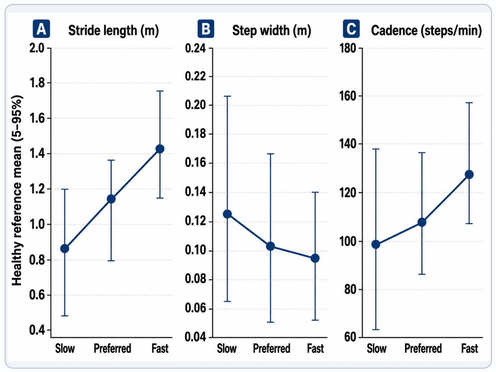

Fig. 4. Speed-aware normative gait references.

❖ **RoboREHAB** integrates **bilateral asymmetry metrics, speed-aware references, and transition analysis** to support objective MSKI recovery monitoring and future personalized robotic assistance.

5. KEY FINDINGS / DISCUSSION

- **Temporal and spatial gait asymmetries** were measurable at the subject level.
- **Temporal asymmetry** appeared more pronounced than spatial asymmetry.
- The **two asymmetry measures** did not fully align, suggesting distinct dimensions of impairment (**Fig. 3**).
- **Speed-aware healthy references** provide physiologically grounded targets for robotic gait retraining (**Fig. 4**).
- **STS/STSi analysis** suggests phase-specific assistance rather than uniform support (**Fig. 5**).

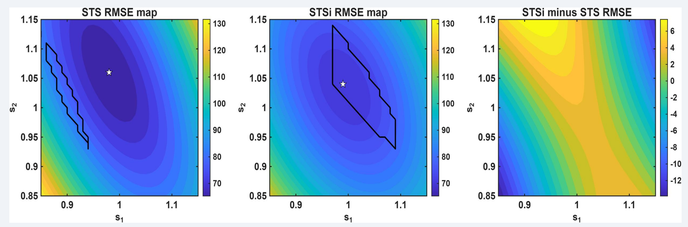

Fig. 5. Sensitivity heatmaps for STS and STSi.

6. CONCLUDING REMARKS

- RoboREHAB supports **metric-driven bilateral rehabilitation assessment** for MSKI recovery.
- Combining asymmetry profiling with healthy normative references can improve objective recovery monitoring.
- The framework provides a pathway toward **personalized robotic assistance and return-to-duty decision support.**
- **STS/STSi transition analysis** extends RoboREHAB toward broader functional mobility assessment.

7. NEXT STEPS / CONTACT

- **Next steps**:
  - **Expand validation** with larger MSKI and healthy cohorts.
  - Develop subject-specific **digital twins** and **adaptive assistance control**.

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