STRIDE — Product Requirements Document v1

Version: 1.0
Date: 11/3/2025
Project Title: Smartwatch-Based Locomotive Therapy System for Post-Stroke Rehabilitation
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1) Introduction

1.1 Problem

Stroke survivors and other neurologic populations (e.g., Parkinson's disease) often present with gait asymmetry, reduced cadence, and poor coordination. Existing home-use tools either lack adaptive feedback, are not accessible, or fail to integrate therapist oversight. Patients need a reliable, simple, multimodal cadence-cueing tool that adapts in real time and logs outcomes for remote review.

1.2 Innovation & Core Technical Advance

- On-watch adaptive metronome powered by real-time IMU step detection and cadence estimation.
- Multimodal feedback (audio, haptic, visual) with accessibility-first UI for low vision and limited dexterity.
- Offline-first data logging with optional secure cloud sync to therapist dashboard.
- Therapist-tunable adaptive logic (tolerance bands, step stability gates, ramp rates) to maintain engagement without frustration.

1.3 Background & Strategic Fit

- Wear OS devices are increasingly available with adequate sensors, battery, and I/O.
- Clinicians already use rhythmic auditory stimulation (RAS) for gait rehab; STRIDE operationalizes RAS at home and in clinic, with consistent telemetry for longitudinal tracking.
- Fits a broader strategy of low-friction digital rehab that augments—not replaces—clinical care.

1.4 Assumptions

- Patients wear the watch correctly; environments may be noisy/bright; network may be unavailable.
- Must sustain ≥2 hours training per charge with continuous IMU and cueing.
- Privacy-preserving by default: all data local; cloud sync is opt-in.

2) System Architecture Overview

2.1 High-Level Diagram (updated for companion app)

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None
Wear OS Watch (STRIDE)
├── Sensor Data Subsystem (Accel/Gyro) → Filtering → Step Detection → Cadence
├── Adaptive Control (tolerance windows, ramp rates)
├── Cue Generation (Audio | Haptic | Visual)
├── Session Management (FSM: Idle/Running/Paused/Ended)
├── Local Storage (SQLite via Room)
├── BT/Network Sync Layer (BLE + HTTPS)
└── Optional Cloud Sync (Firebase/REST)

Companion App (Android/iOS)
├── Patient Mode: history, summaries, calibration wizard, accessibility controls
├── Caregiver Mode: notifications, adherence view, share/export (CSV/PDF)
├── Therapist Mode (light): quick review, target updates, notes (if enabled)
├── Pairing & Device Mgmt: BLE pairing, permissions, battery/connection status
└── Account/Auth: opt-in cloud sign-in (Firebase Auth, OIDC compatible)

Cloud (Optional)
├── Auth & RBAC (patient/caregiver/therapist roles)
├── Data API + Storage (Firestore or Postgres + S3)
└── Dashboard (web) for deeper analysis
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2.2 Key Components

- Sensor Data Subsystem (watch): IMU streaming; 5-sample moving average cadence; ≥90% step detection accuracy in controlled walking.
- Adaptive Control (watch): re-evaluates every 10 s; adjusts BPM ±1–5; smooth tempo ramp (≤1 BPM/s); clinician-tunable thresholds.

- Cue Generation (watch): stable metronome 40–120 BPM with <1% drift; modality switchable/combos.
- Session Management (watch): start/pause/resume/end via buttons or voice; auto-pause >10 s; autosave on crash.
- Local Data Layer (watch): SQLite schema: timestamp, duration, steps, avg_cadence, accuracy, mode, notes.
- Sync Layer: BLE realtime (for live tiles on phone), batched HTTPS uploads (when allowed).
- Companion App (mobile): history browser, charts, calibration wizard, settings (including accessibility), share/export; lightweight therapist/caregiver views.
- Cloud & Dashboard (optional): authenticated upload; therapist reviews, sets targets, leaves notes; web UI.

2.3 Operating Environment

Watch: Wear OS 3.0+ (e.g., TicWatch E3).
Phone: Android 10+/iOS 15+ (Kotlin/Swift or Flutter/React Native).
Net: BLE for pairing; HTTPS for sync; offline-first throughout.

3) Requirements (Functional & Non-Functional)

3.1 Functional Requirements (FR)

ID	Requirement	Acceptance Criteria
FR-1	Metronome Cueing	Adjustable 40–120 BPM; timing drift <1%.
FR-2	Multimodal Feedback	User can select audio, vibration, visual, or combined modes.
FR-3	Step Detection	≥90% step detection accuracy in controlled conditions.
FR-4	Cadence Computation	Cadence updated every 1 s using a 5-sample moving average.
FR-5	Adaptive Adjustment	BPM adjusted by ±1–5 every 10 s based on deviation; ramp ≤1 BPM/s.
FR-6	Session Control	Start/Pause/Resume/End via UI or voice; auto-pause after >10 s inactivity.
FR-7	Data Logging	Session record includes timestamp, duration, steps, avg cadence, accuracy, mode.

FR-8	Session Summary	Summary displayed ≤3 s after session end.
FR-9	Local Storage	Data persists across restarts using SQLite.
FR-10	Cloud Sync (Opt-in)	Secure upload when connected; retries on failure.

3.2 Non-Functional Requirements (NFR)

Category	Requirement	Metric
Usability	Simple Interface	≤3 primary controls per screen; font ≥18 pt; touch targets ≥8 mm.
Accessibility	Multimodal Equivalents	All audio cues have tactile or visual equivalents; high-contrast theme.
Performance	Low Latency	Cue emission ≤100 ms from target beat.
Reliability	Offline Operation	Full functionality offline; queued sync when reconnected.
Safety	Data Privacy	AES-256 at rest; HTTPS in transit; opt-in sharing.
Battery	Power Management	≤20% battery consumed over 2 hours continuous use.
Maintainability	Modular Architecture	Subsystems independently testable; API boundaries documented.
Scalability	Cloud	Support up to 100 concurrent users (stretch) on early dashboard.
Fault Tolerance	Auto-Recovery	IMU stream loss recovers ≤3 s without app crash.

3.3 Success Metrics

- Clinical utility: ≥80% of active time within therapist-defined target band (±X BPM).
- Engagement: ≥3 sessions/week per active patient; median ≥15 min/session.
- Satisfaction: ≥80% user satisfaction on in-app survey.

4) User Interaction & Design (updated)

4.1 Primary Watch Screens

1. Home: Start Training, Settings.
2. Training: BPM readout, In-Sync/Off-Beat indicator, elapsed time, Pause/End.
3. Summary: duration, steps, avg cadence, consistency; Save/Discard.
4. Settings → Accessibility: font size, contrast, cue mode, vibration strength, voice commands.

4.2 Primary Companion-App Screens

1. Today: last session tile, quick-start, device status (battery, BLE).
2. History: list of sessions with filters; detail view with cadence vs target chart; merge/delete micro-sessions.
3. Calibration Wizard: baseline walk, result, target suggestion, clinician offset.
4. Sharing & Roles: caregiver link, therapist link, permission toggles, export (CSV/PDF).
5. Notifications: adherence reminders, post-session summaries, low-battery/pairing issues.
6. Settings: accessibility (mirrored to watch), data/privacy, account.

4.3 Accessibility Principles

- Large, high-contrast typography; minimal navigation depth; voice commands and one-tap actions.
- Redundant cueing (audio↔haptic↔visual).
- Auto-brightness bump for visual-mode cueing in bright light.

5) User Stories

US-01: Start Auditory Training Session (Watch)

Actor: Stroke survivor

Goal: Immediately begin rhythmic walking therapy from the watch home screen.

Preconditions:
- Watch is powered on/unlocked; STRIDE installed; mic/sensor permissions granted.
- Baseline cadence configured via calibration or therapist setting.

Main Flow:
1. User wakes display.

2. Home shows Start Training and Settings (touch targets ≥8 mm).
3. Tap Start Training → Mode selector (Auditory / Haptic+Visual / Custom).
4. Select Auditory → 3-2-1 countdown.
5. Metronome starts at target BPM; screen shows Target BPM, Elapsed, Sync status (✔/⚠).

Alternative Flows:
- No motion >10 s → auto-pause (state retained).
- Permissions missing → toast + deep link to Settings.

Postconditions:
- Session state saved in memory (Paused or Running).

Acceptance Tests:
- Given permissions OK, when user selects Auditory, then metronome starts ≤1 s, countdown displayed.
- Given inactivity >10 s, when auto-pause triggers, then resume takes ≤1 tap with no data loss.

Priority: MUST-HAVE
Links: 🗓 Capstone Sprint Planning

US-02: Synchronize Steps to Auditory Beats (Watch)

Actor: Stroke survivor

Goal: Align steps to sound cues to retrain gait symmetry.

Preconditions: Auditory session active; speaker functional.

Main Flow:
1. IMU streams stride intervals.
2. App compares live cadence vs target each second.
3. If deviation ≥±10%, show Speed up/Slow down banner; optional tempo ramp ≤1 BPM/s.

Alternative Flows:
- Volume too low/noisy env → system adds haptic reinforcement.
- Cadence unstable → show Hold steady until stable window met.
  Postconditions: IMU summary stored (duration, avg cadence, steps, deviation%)

Acceptance Tests:
- Deviation +12% for 12 s → Slow down banner appears within 1 s and persists ≥5 s.

- p95 cue jitter <10 ms; drift <1% over 20 min bench test.

Priority: MUST-HAVE
Links: Capstone Sprint Planning

US-03: Train Using Visual & Haptic Cues (Watch)

Actor: Hearing-impaired stroke survivor

Goal: Maintain cadence via tactile/visual cues.

Preconditions: Accessibility mode enabled; vibration/display functional.

Main Flow:
1. From Start Training, choose Haptic/Visual.
2. On each beat, emit vibration + flash; increase brightness in bright light.
3. Progress circle fills with cadence accuracy.

Alternative Flows:
- User adjusts vibration intensity via crown/slider.
- Irregular stride → progress circle flashes red; message explains correction.
- No motion >10 s → auto-pause.

Postconditions: Metrics saved; preferred mode persisted.

Acceptance Tests:
- Beat-to-vibration latency ≤100 ms (bench measured).
- Visual contrast ratio meets WCAG-AA equivalent for watch UI.

Priority: MUST-HAVE
Links: Capstone Sprint Planning

US-04: Adaptive Tempo Adjustment (Watch)

Actor: Stroke survivor

Goal: Keep training challenging without frustration.

Preconditions: Adaptive Mode ON; thresholds configured.

Main Flow:

1. Start at baseline (e.g., 68 BPM).
2. Every 10 s, compare cadence vs target.
3. +3% for ≥20 s → +2 BPM; <−5% → −2 BPM; ramp ≤1 BPM/s.
4. Display toast: New Target: 70 BPM.

Alternative Flows:
- Adaptive OFF → fixed target.
- Signal unstable → wait 5 s then re-evaluate.

Postconditions: Final BPM stored as next baseline.

Acceptance Tests: Rule table covered by unit tests; hysteresis prevents oscillation (no >2 changes/min at steady state).

Priority: MUST-HAVE
Links: ⊞ Capstone Sprint Planning

US-05: Review Post-Session Summary (Watch & Phone)

Actor: Stroke survivor

Goal: Understand progress and stay motivated.

Preconditions: Session ended or auto-paused.

Main Flow (watch): Auto-navigate to Summary (duration, steps, avg cadence, consistency); Save/Discard.

Main Flow (phone): Summary card appears on Today; tap for detailed chart and notes.

Alternative Flows: Crash/reboot → autosave; storage full → prompt to delete oldest.

Postconditions: Entry visible in History on phone; eligible for sync/share.

Acceptance Tests: Summary render ≤3 s; export CSV produces correct schema.

Priority: MUST-HAVE
Links: ⊞ Capstone Sprint Planning

US-06: Pair Watch with Companion App (Phone)

Actor: Patient or caregiver

Goal: Securely pair phone and watch to enable notifications and richer views.

Preconditions: STRIDE installed on both; BLE enabled.

Main Flow:
1. Open phone app → Pair Device.
2. App scans for watch; user confirms 6-digit code on both.
3. Permissions review (health data, notifications).
4. Connection tile shows battery, last sync time.

Alternative Flows:
- Already paired → show device status, option to re-pair.
- Pairing fails → retry with troubleshooting tips.

Postconditions: Secure channel established; background sync enabled per settings.

Acceptance Tests: Pairing success rate ≥99% across 50 trials; re-pair completes <60 s.

Priority: MUST-HAVE
Links: 🗓 Capstone Sprint Planning

US-07: Calibration Walk (Watch → Phone)

Actor: First-time user

Goal: Establish baseline cadence and suggested target.

Preconditions: Setup in phone app or watch.

Main Flow:
1. Start Calibration → walk naturally 60 s.
2. Compute baseline cadence; apply therapist offset (+5–10 BPM).
3. Show result on phone with option to accept/redo.

Alternative Flows: <20 steps → prompt redo.

Postconditions: Baseline stored; synced to watch.

Acceptance Tests: Baseline CV ≤5% across 3 runs in controlled setting.

Priority: SHOULD-HAVE
Links: 🗓 Capstone Sprint Planning

US-08: Caregiver Notifications (Phone)

Actor: Caregiver

Goal: Be notified of adherence and progress.

Preconditions: Caregiver linked; notifications allowed.

Main Flow:
1. After session save, phone receives push: "8-min session, 72 BPM, 90% in-sync."
2. Tap opens history; caregiver can leave a note.

Alternative Flows: Offline → queued until online.

Postconditions: Notification logged in app.

Acceptance Tests: Delivery p95 <5 min; opt-out respected.

Priority: COULD-HAVE
Links: 🗓 Capstone Sprint Planning

US-09: Therapist Data Review & Plan Update (Phone/Web)

Actor: Physical therapist

Goal: Review sessions and update targets remotely.

Preconditions: Patient opted into cloud; therapist invited.

Main Flow:
1. Therapist opens patient timeline; filters unreliable micro-sessions.
2. Reviews cadence-vs-target chart; adds note; sets next target BPM and tolerance.
3. Change syncs to patient watch.

Alternative Flows: No cloud → patient exports CSV/PDF to share.

Postconditions: Updated parameters stored and versioned.

Acceptance Tests: Parameter update appears on watch within 2 min of phone online.

Priority: SHOULD-HAVE
Links: 🗓 Capstone Sprint Planning

US-10: Handle Garbage/Fragmented Data (Phone)

Actor: Therapist

Goal: Identify and resolve low-quality data.

Preconditions: Multiple micro-sessions detected.

Main Flow:
1. Phone flags low-quality sessions (e.g., <60 s, frequent start/stop).
2. Therapist merges or discards; app suggests contacting patient/caregiver

Alternative Flows: Undo merge; restore from trash (7-day window).

Postconditions: Cleaned timeline; audit trail saved.

Acceptance Tests: Precision/recall of auto-flag rules ≥0.9 on labeled set.

Priority: SHOULD-HAVE

Links: 🗓 Capstone Sprint Planning

US-11: Extreme Low-Vision Workflow (Watch/Phone)

Actor: 90-year-old stroke survivor with very low vision

Goal: Operate STRIDE with minimal visual demand.

Preconditions: Accessibility preset selected on phone.

Main Flow:

1. Phone pushes Ultra-Large UI + Voice-Only Start to watch.
2. Wake watch → say "Start STRIDE" to begin; single large Pause/End button only.

Alternative Flows: If voice fails → long-press side button to start/stop.

Postconditions: Session logged normally.

Acceptance Tests: All critical actions possible with voice or one large control; touch targets ≥12 mm.

Priority: MUST-HAVE
Links: 🗓 Capstone Sprint Planning

US-12: Limited Dexterity / Parkinson's Workflow (Watch/Phone)

Actor: Person with tremor/limited fine motor skills

Goal: Start/stop without precise tapping.

Preconditions: Motor-friendly mode enabled.

Main Flow:
1. Shake-to-start gesture or long-press hardware button.
2. On-screen controls have dwell-tap option (500–800 ms).

Alternative Flows: Auto-start on wrist-raise (configurable).

Postconditions: Reduced mis-taps; audit trail notes gestures used.

Acceptance Tests: Error rate ≤2% across 100 trials with tremor simulation.

Priority: SHOULD-HAVE
Links: 🗓 Capstone Sprint Planning

US-13: GPS/Context Anomaly Handling (Phone)

Actor: Patient

Goal: Correct inaccurate context data (e.g., GPS, transport).

Preconditions: Session has questionable signals.

Main Flow:
1. Phone flags potential anomalies (e.g., high speed suggests car travel).
2. User marks session as Non-Walk or edits notes.

Alternative Flows: Auto-suppress GPS entirely (privacy-first) in v1.

Postconditions: Clean metrics; anomalies labeled.

Acceptance Tests: Flagging specificity ≥0.9 on test set; user edit writes tags to record.

Priority: COULD-HAVE
Links: 🟩 Capstone Sprint Planning

US-14: Physician Telehealth Review (Phone/Web)

Actor: Physician

Goal: Pull up progress during telehealth.

Preconditions: Patient shared access.

Main Flow:
1. Physician opens Summary PDF or web view; sees trends and last note.
2. Discusses goals; optionally updates clearance for training intensity.

Alternative Flows: No account → view time-boxed share link.

Postconditions: Encounter note attached to timeline.

Acceptance Tests: PDF generated <5 s; link expires per policy.

Priority: COULD-HAVE
Links: 🟩 Capstone Sprint Planning

6) Questions (Open Issues)

1. What tolerance/offset policy do clinicians prefer for initial targets (e.g., baseline +5 vs. +10 BPM)?
2. Is voice control feasible for severe dysarthria, or should we prefer single-tap start?
3. Minimal viable dashboard: CSV export only vs. hosted Firebase app?
4. Handling inaccurate GPS or motion artifacts (e.g., wheelchair transport) — do we need a "non-walking" detector?
5. Escalation path when therapists receive "garbage data" — in-app contact, email, or clinic portal?

7) What We're NOT Doing

- No fall detection or emergency call features.
- No ML-based gait phase classification beyond cadence (future work).
- No continuous GPS tracking; location only if later justified for clinic routing.

8) System Models

- Contexts: Patient ↔ Watch App ↔ (Optional) Cloud ↔ Therapist Dashboard.
- Interactions: Start session; Adaptive tick; Auto-pause/resume; Save & Sync; Therapist target update.
- Structural: Data classes for Session, CadenceWindow, AdaptiveParams; service interfaces for SensorStream, CueScheduler, Storage.
- Behavioral: FSM states (Idle, Running, Paused, Ended) with transitions on tap/voice/inactivity.

9) Appendices — Technologies Employed

- Platform: Wear OS 3.0+; Kotlin; Coroutines; Jetpack Compose for Wear.
- Data: Room/SQLite; optional Firebase Auth/Firestore; CSV export.
- Analytics (local): simple counters and histograms; opt-in usage metrics.