

# Absolute Readiness Score (ARS) — Framework Library (v3)

**Definition:** ARS is a 0–100 score reflecting a nurse's *physiological and behavioral recovery state* relative to personal baseline (no shift-context ceiling applied yet).

Snapshots: **Morning (post-wake)** and **Pre-shift (T–60 to T–15)**.

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## 0) Shared Notation

- $z(x)$  = per-user z-score vs 14–21d rolling baseline (median + MAD).
  - Clamp ARS  $\in [0, 100]$ .
  - Fallback: ECG > heartbeat-series > SDNN (else neutral).
  - Slider:  $s \in [0, 100]$ , centered scale  $\hat{c} = (s - 50) / 50 \in [-1, +1]$ .
  - **Slider calibration:** see Section 10.
  - Swipes: binary yes/no toggles.
  - Confidence weights: high=1.0, medium=0.85, low=0.70.
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## 1) Autonomic Recovery Framework

**Inputs:** RMSSD, SDNN, RHR. Slider: *Recovered?*.

**Formula:**

```
Recovery_raw = 50
+ 15*w_rmssd*z(RMSSD)
+ 10*w_sdnz*z(SDNN)
- 10*w_rhr*z(RHR)
```

Weights: ECG={0.70,0.20,0.10}, HB={0.50,0.30,0.20}, None={0.00,0.60,0.40}.

**Slider calibration integration:** - Calibrated latent value  $L_{rec} = \alpha + \beta \tanh(\gamma \hat{c}_{rec})$  - Weight tilt:  $w_{rmssd}' = w_{rmssd}(1 + 0.1L_{rec})$  - Bias:  $\Delta_{rec\_subj} = \text{clip}(3 * L_{rec}, -3, +3)$

**Output:**  $\text{RecoveryScore} = \text{clamp}(0, 100, \text{Recovery\_raw} + \Delta_{rec\_subj})$

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## 2) Sleep Framework

**Inputs (objective):** TST, efficiency, WASO, SOL, SpO<sub>2</sub> (median/min, ODI3, time<90%), RR (sleep), temp (morning & amplitude), HR dipping, sleep midpoint SD, REM/Deep %.

**Inputs (user):** slider *Rested?*; swipes *Uninterrupted rest?*, *Napped today?*.

**Functions: - Debt penalty:**

```
if debt<0.5h → 0
0.5-2h → -3/h
>2h → -3*1.5 -5*(debt-2.0) cap -25
```

- **Quality penalties (cap -15):** eff<85, WASO>45m, SOL>40m, SpO<sub>2</sub> median<94, ODI3, RR z, temp z, HR dip, midpoint SD, REM%/Deep%. Stepwise thresholds defined in v2. - **Slider:** latent  →  $\Delta = \text{clip}(3L_{\text{rest}}, -3, +3)$ , added to quality subtotal. - **Swipes:** \* Uninterrupted=no → ×1.2 multiplier; Nap=yes → debt-0.15h & RMSSD z+0.15.

**Output:**

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## 3) Circadian Framework

**Inputs (objective):** mismatch hours M, temp amplitude z, sleep midpoint SD.

**Inputs (user):** slider *Alert?*; swipe *Bright light done?*.

**Functions:** - Mismatch:  $-3 \min(M, 3) -4 \max(0, M-3)$ , cap -20 - Stability: amplitude  $z \leq -1 = -3$ ; midpoint SD>120m=-2 (cap -5) - Alert slider: latent  scales penalty:  (×0.8-1.2) - Bright light swipe (timed) → -1

**Output:**

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## 4) Load & Strain Framework

**Inputs (objective):** ACR, shift duration H, turnaround R, workouts.

**Inputs (user):** sliders *Physical drain?*, *Mental drain?*; swipes *Break taken?*, *Ate food?*.

**Functions:** - ACR penalties (stepwise -3, -6, -10) - Shift duration penalties (-2/h for 9-10h, -3/h for 11-12h, cap -10) - Turnaround (<12h = -8 to -12) - Workout <12h pre-shift → -2 - Break=no -2; Ate=no (if H≥10h) -1 - Slider calibration:  ,  → ±3 each

**Output:**

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## 5) Safety / Illness Framework

**Inputs (objective):** SpO<sub>2</sub> min, temp z, RR z, HR z.

**Inputs (user):** swipes *Unwell?*, *Fever/chills?*.

**Rules:** - SpO<sub>2</sub><90% & temp z≥+0.5 → safety\_flag, cap=60 - Unwell=yes → cap=70 - Fever/chills=yes → cap=60 - Extra strain: RR z>+2 & HR z>+1 → -3 penalty

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## 6) Resilience Framework

**Inputs:** VO<sub>2</sub> Max; swipe *Exercising this week?*.

**Function:**

```
scale = clamp(0.7,1.3, vo2_ref/VO2_current)
ResiliencePenaltyAdj = (scale-1.0)*TotalPenalty
```

If exercise=yes → bump vo2\_ref upward slightly for 48h.

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## 7) Fusion (ARS)

```
ARS = clamp(0,100,
  50
+ 0.35*RecoveryScore*conf_weight
+ SleepContribution
+ CircadianContribution
+ LoadContribution
+ PhysioStrainExtra
)

neg = min(0, ARS-50)
ARS += (scale-1.0)*neg    # resilience scaling

if safety_flag: ARS=min(ARS,safety_cap)
```

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## 8) Self-report Integration Rules

- **Calibration:** per-user  $\alpha, \beta, \gamma$  learned weekly against objective anchors (ECG-RMSSD, sleep debt, ACR, circ mismatch). Initialized at 0,1,1.

- **Smoothing:** EMA for morning sliders; raw for pre-shift alertness.
- **Caps:**  $\pm 3$  per framework.
- **Reliability gating:** if slider-objective concordance  $< \text{threshold}$   $\rightarrow$  halve weight for 7d.
- **Quantile bootstrap:** map first 10 slider uses into normalized scale via percentiles.

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## 9) Worked Example

(Same as v2, showing ARS=26.8 with recovery, sleep, circadian, load contributions, resilience scaling, safety cap.)

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## 10) Slider Calibration & Reliability

Latent model per slider/user:

$$L_u = \alpha_u + \beta_u * \tanh(\gamma_u * (s-50)/50)$$

-  $\alpha$  = bias (optimist vs pessimist) -  $\beta$  = sensitivity (volatile vs flat) -  $\gamma$  = curvature (all-or-nothing)

**Learning:** fit weekly via regression of slider vs anchors. Robust loss. Keep priors near neutral.

**Usage:** - Recovery slider  $\rightarrow$  anchors: ECG-RMSSD z, RHR z, prior sleep. - Alertness slider  $\rightarrow$  anchors: mismatch, sleep debt, naps/light. - Phys/Ment drain  $\rightarrow$  anchors: ACR, shift length, consecutive nights.

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## 11) Algorithm Integration Map

- **NeuroKit2 (MIT):** feeds Autonomic framework (RMSSD, SDNN, pNN50, LF/HF, DFA).
- **HypnosPy (GPL, server-side):** actigraphy + sleep/wake + circadian patterns.
- **CircadiPy (MIT):** cosinor analysis for acrophase, amplitude, mesor,  $r^2$ .
- **Fallback:** manual cosinor regression on steps/HR hourly averages.

Outputs plug directly into Circadian framework (mismatch hours, rhythm stability) and Sleep framework (sleep/wake windows).

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