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| **SAM Metric** | **Green Zone (Elite Readiness)** | **Yellow Zone (Monitor / Adjust)** | **Red Zone (Intervention Needed)** | **Genetic Sensitivity & Insights** | **Additional Relevant SNPs** |
| **Resting HR (RHR)** | 42–54 bpm (indicative of high parasympathetic tone & fitness) | 55–59 bpm (possible cumulative load, mild dehydration, or heat) | ≥ 60 bpm (acute fatigue, inflammation, illness) | PPARA (rs4253778) G, ACE (rs1799752) I, ACTN3 (rs1815739) C → genetically lower RHR baseline; COMT slow (Val158Met AA) → stress-linked HR spikes more easily; higher RHR post-rest indicates inflammation | ADRB1 (rs1801253), GNB3 (rs5443) – cardiac output efficiency |
| **Average HR (Day)** | 50–68 bpm | 69–74 bpm | ≥ 75 bpm | ADRB2 (rs1042713, rs1042714) → higher sympathetic tone; NOS3 (rs1799983) T → reduced vascular efficiency; monitor closely if HR climbs without load | EDN1 (rs5370) – vascular reactivity; HIF1A (rs11549465) – hypoxia adaptation |
| **SpO₂ (Night)** | ≥ 97% | 95–96% | ≤ 94% | HIF1A C, VEGFA (rs699947) C → advantage at altitude; BDNF (rs6265) Met → hypoxia worsens mental fatigue and mood | EPAS1 (rs13419896) – oxygen carrying capacity; EGLN1 (rs480902) – hypoxic tolerance |
| **Step Count / Training Load** | ≥ 100% target (adjusted to phase of season) | 85–99% | ≤ 70% | ACTN3 C + AMPD1 (rs17602729) C → fast recovery potential; drops may indicate injury risk genes COL5A1 (rs12722) T, GDF5 (rs143383) risk allele | TNMD (rs55780018) – tendon resilience; IL6 (rs1800795) – inflammation |
| **HRV (Night)** | ≥ 90 ms (elite) | 70–89 ms | < 70 ms | PPARGC1A (rs8192678) G, PPARA G → high mitochondrial efficiency; FKBP5 (rs1360780) C/T & BDNF Met → stress reduces HRV faster | CRHR1 (rs242941) – cortisol rhythm; NR3C1 (rs6189) – glucocorticoid sensitivity |
| **Deep Sleep %** | > 22% | 17–21% | < 17% | CLOCK (rs1801260) AA, PER3 VNTR (short) → reduced baseline; MAO-A slow, COMT slow → deep sleep critical for neurotransmitter reset | ADA (rs73598374) – adenosine clearance; APOE (rs429358) – brain recovery |
| **REM Sleep %** | 20–25% | 16–19% or 26–30% | < 16% or > 30% | TPH2 (rs4570625) G/T, SLC6A4 S allele → REM instability impacts serotonin regulation; excessive REM may indicate emotional stress load | HTR2A (rs6311) – sleep architecture; CHRNA4 (rs1044396) – arousal control |
| **Light Sleep %** | 35–45% | 46–50% | > 50% | GABRA6 (rs3219151) C/T, HTR1A (rs6295) C/G → fragmented sleep affects anxiety & focus | CACNA1C (rs1006737) – neural excitability; DRD2 (rs1800497) – dopamine tone |
| **Sleep Duration** | 8–9.2 h | 7–7.9 h | < 7 h | BDNF Met, DRD4 long repeats → more sensitive to cognitive decline from sleep loss; PER3 long allele → higher sleep need | MTNR1B (rs10830963) – melatonin signalling; NPAS2 (rs2305160) – circadian rhythm |
| **Respiratory Rate (Night)/Vibro** | 10–14 | 15–16 | ≥ 17 | NOS3 T, ADRB2 risk → airway reactivity; linked to asthma predisposition | CHRNA3 (rs1051730) – respiratory control; IL13 (rs20541) – airway inflammation |
| **Temperature Trend** | 36.4–36.9°C | 37.0–37.3°C | > 37.3°C or < 36.3°C | PPARG (rs1801282) C, PPARA G → efficient metabolism; rises may indicate inflammation or overtraining | UCP2 (rs659366) – thermogenesis; IL1B (rs16944) – immune activation |

**How the Predictive Layer Works**

1. **Biometric Drop Detected** → HRV, RHR, Sleep, SpO₂, Temp deviations
2. **Genetic Context Applied** → Adjust thresholds based on SNP baselines
3. **Cause Prediction**:
   * **Circadian misalignment** → late sleep onset, reduced deep sleep %, HRV dip without inflammation markers
   * **Inflammation / illness** → HRV drop + RHR/Temp rise + SpO₂ drop
   * **Nutrient deficiency** → Sustained HRV drop + stable temp/RHR but reduced deep or REM %

📌 **Example Dashboard Alert**

**ALERT**: HRV down 22% from baseline, Deep Sleep down 15%, RHR stable. **Likely Cause**: Circadian delay (PER3 long, CLOCK AA). **Recommendation**: Advance bedtime by 45 min, increase morning light exposure, add magnesium glycinate (400mg) + choline-rich meal at dinner.

🧬 **Genetic × Biometric × Recovery Cause Mapping**

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| **SAM Metric** | **Green Zone** | **Yellow Zone** | **Red Zone** | **Circadian Rhythm SNPs (impact on metric)** | **Nutritional Genomics SNPs (impact on metric)** | **Predictive Flag for Drop** |
| **Resting HR** | 42–54 bpm | 55–59 bpm | ≥ 60 bpm | CLOCK (rs1801260), PER3 VNTR → baseline circadian RHR | MTHFR C677T (folate), NOS3 G894T (NO synthesis) → vascular recovery | Elevated RHR + poor sleep metrics → circadian misalignment; RHR + ↑ temp → inflammation |
| **Average HR (Day)** | 50–68 bpm | 69–74 bpm | ≥ 75 bpm | RORA (rs12912233) → stress tolerance cycles | FADS1 (rs174550) → omega-3 status; ADRB2 A16G → catecholamine sensitivity | Sustained ↑ avg HR + normal HRV → nutrient gap (iron, omega-3) |
| **SpO₂ (Night)** | ≥ 97% | 95–96% | ≤ 94% | PER2 (rs934945) → night oxygen dips with phase delay | GSTM1 null → oxidative stress risk; HIF1A (rs11549465) → hypoxia resilience | Low SpO₂ + ↑ REM proportion → airway restriction; low SpO₂ + ↑ HRV drop → inflammation |
| **HRV (Night)** | ≥ 90 ms | 70–89 ms | < 70 ms | BMAL1 (rs7950226) → HRV circadian amplitude | COMT (rs4680) slow → stress response; MTRR A66G → B12 demand for ANS regulation | Drop with stable sleep → overtraining; drop with reduced REM → circadian issue |
| **Deep Sleep %** | > 22% | 17–21% | < 17% | PER3 long allele → deep sleep need; CRY1 (rs8192440) → reduced slow-wave | PEMT (rs7946) → choline status; APOE E4 → brain repair | Low deep sleep + ↑ temp → inflammation; low deep sleep + late sleep onset → circadian misalignment |
| **REM Sleep %** | 20–25% | 16–19% / 26–30% | < 16% / > 30% | PER2 & PER3 → REM timing shifts | TPH2 (rs4570625) → serotonin production; MAO-A (rs6323) → REM stability | Excess REM + high HRV drop → mental/emotional fatigue |
| **Light Sleep %** | 35–45% | 46–50% | > 50% | CLOCK, CRY2 → light sleep duration tendencies | GABRA6 (rs3219151) → GABA function; HTR1A (rs6295) → serotonin balance | High light sleep + low deep sleep → magnesium or GABA deficiency |
| **Sleep Duration** | 8–9.2 h | 7–7.9 h | < 7 h | NPAS2 (rs2305160) → total sleep need | VDR Taq1 (rs731236) → vitamin D regulation impacting sleep quality | Short sleep + late bedtime → circadian misalignment; short sleep + ↑ RHR → illness load |
| **Respiratory Rate** | 10–14 | 15–16 | ≥ 17 | RORA (circadian lung function rhythm) | IL13 (rs20541) → airway inflammation; GSTP1 (rs1695) → oxidative airway stress | Elevated RR + low SpO₂ → airway inflammation; elevated RR only at night → circadian-driven |
| **Temperature Trend** | 36.4–36.9°C | 37.0–37.3°C | > 37.3°C or < 36.3°C | BMAL1 → temp circadian amplitude | UCP2 (rs659366) → metabolic thermogenesis; IL6 (-174 G/C) → inflammatory response | Temp rise + RHR rise → inflammation; temp drop + poor HRV → nutrient depletion (thyroid, iron) |
| **Training Load** | On target | 85–99% | ≤ 70% | PER3 → activity readiness timing | ACTN3 R577X → recovery speed; AMPD1 → muscle fatigue | Drop in load + high HRV → mental fatigue; drop + low HRV → inflammation |

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