Unveiling Sleep Dysregulation in Chronic Fatigue Syndrome with and without Fibromyalgia

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Background

Chronic Fatigue Syndrome (CFS) and Fibromyalgia (FM):

- Often co-occur; more prevalent in females; clinical differentiation difficult.
- Shared symptoms: fatigue, pain, and poor sleep.

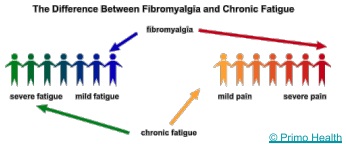
Polysomnography (PSG) = clinical sleep study:

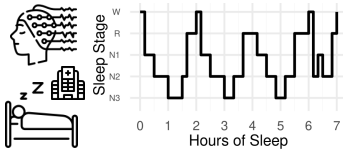
- Overnight measurement of biosignals (EEG, EOG,...).
- Each 30-second scored into five states: Wake (W), Rapid-Eye-Movement (REM), and non-REM (light: N1-2, deep: N3).

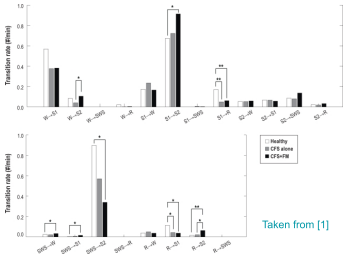
Prior work showed altered sleep-stage transitions (lag = 1) via simple statistical tests [1].

Need for more advanced modelling of sleep-stage dynamics:

- Optimal lag in {0, 1, 2, 3, ...}.
- Effects of CFS and FM → physiological interpretation.
- Compensatory alterations ($\uparrow p_{ij}$ implies $\downarrow p_{ik}$, for some $k \neq j$).







Taken from [1]

Data

Primary cohort [1]:

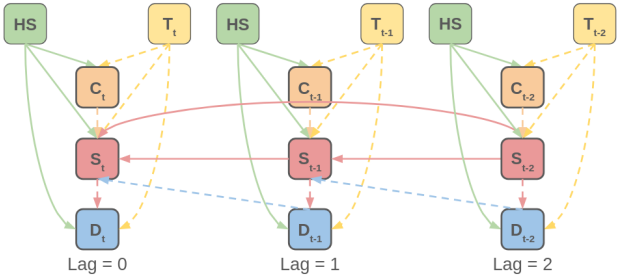
- PSG from N = 52 women: 26 Healthy (H), 14 CFS, 12 CFS+FM.
- Minimised confounding: age-matched (38 ± 8); excluded sleep/psychiatric disorders; no alcohol, caffeine, exertion; menstrual phase standardized; etc.
- 44,581 of sleep-stages → 7,254 bouts → dynamics modelling.

Out-of-domain validation cohorts, females aged 20-60:

- Sleep Heart Health Study, N = 1227, broad population.
- Berner Sleep-Wake Registry, N = 834, clinical population.

Bayesian Network:

- Discretised variables (nodes):
  - HS: Health Status (Healthy, CFS, CFS+FM).
  - T_t: Time since sleep onset.
  - C_t: Cumulative restorative (REM+N3) sleep.
  - S_t: stage-identifier (W, N1-3, REM).
  - D_t: duration.



- Expert-guided dependencies (edges); mandatory ones are solid.
- BN-lag (0-4) and variable inclusion tested experimentally using 5-fold CV monitoring next-stage prediction (Acc., F1-score) and HS-identification (AUROC).

Results: Predictive Performance & Effect Quantification

Final Bayesian Network:

- Optimality of lag = 2; confirmed findings of [2] to clinical cohort [1].
- Included health status (HS), stages, and their durations.

Subject-wise performance:

- Next-stage F1-score:
  - 69.2 (2.7)% in primary cohort using CV.
  - 70.94 (9.1)% in BSWR; 59.83 (11.6)% in SHHS.
  - Robust generalization of our “small-data” BN, as SOTA reports 62.2% in-domain test accuracy using big data [2].
- HS-identification: AUROC = 75.36 (8.3)%.

Understanding the impact of CFS/FM via simulated interventions:

- Fix HS to desired level (H, CFS, CFS+FM)] → MCMC sampling → 95% Credible Intervals.

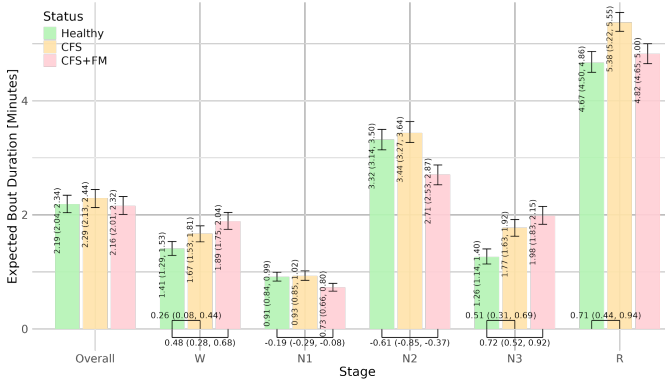
Results: Sleep-Stage Bout Duration

Shared:

- ↑W → decreased sleep efficiency.
- ↑N3 → increased physical restoration needs.

CFS: ↑REM → increased cognitive restoration needs.

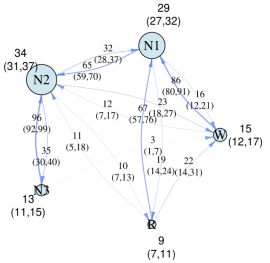
CFS+FM: ↓{N1, N2} → compensation for marked ↑N3



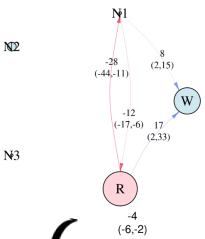
Results: Sleep-Stage Dynamics, Lag = 1

Shared: Disrupted REM sleep {↓REM, ↓REM ⇄ N1}:
➡ less sleep cycles + reduced cognitive restoration

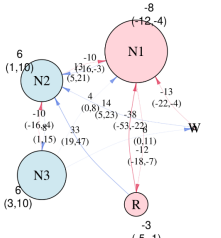
a: H (S_t | S_{t-1})



b: CFS - H (S_t | S_{t-1})



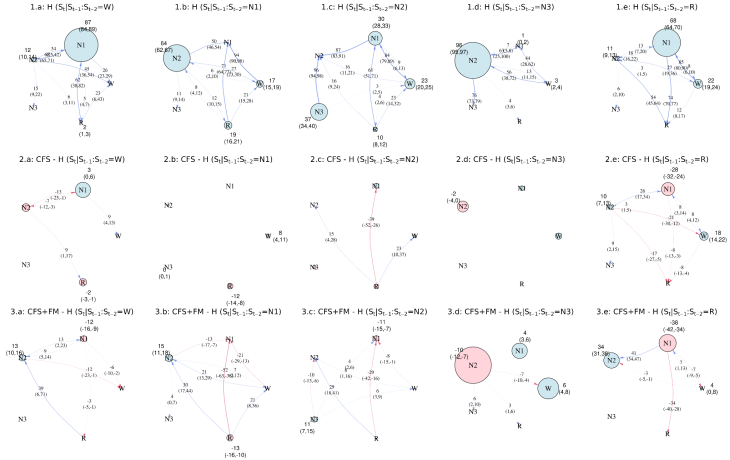
c: CFS+FM - H (S_t | S_{t-1})



CFS: More REM and N1 awakenings
➡ compensating disrupted REM ⇄ N1 dynamics

CFS+FM: Increased need for physical recovery from FM-related pain
➡ Deeper state (N2-3) dominance: {↑N2-3, ↓N1}
➡ Increased homeostatic pressure {↑(W, N1, REM) →N2}

Results: Sleep-Stage Dynamics, Lag = 2



Transition triplets from different starting states $S_t \mid S_{t-1}, S_{t-2} = s$.

- Deeper physiological insights.
- Drivers of diagnostic discrimination.
- Interpretation planned within a follow-up clinical journal publication.

Conclusions

- Extended findings by Kishi et al. (2011).
- Sleep-stage dynamics as a second-order process even in clinical population, extending Yetton et al. (2018).
- Robust next-stage predictive power despite training on small data: sleep-dynamics can serve as a diagnostic marker (AUROC = 75.4%).
- Results support clinical differentiation of CFS and CFS+FM.
- Opens path to personalised treatment interventions (e.g., CFS/FM sleep-management therapies).

That's all!

Happy to discuss in more detail.

References I

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