Wearable-derived metrics were associated with AIS scores and demonstrated utility in machine learning-based classification: these findings support the potential of wearable-derived metrics as digital biomarkers of insomnia in patients with RA

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INTRODUCTION

Insomnia and sleep disturbances are often prevalent in patients with rheumatoid arthritis (RA) and are associated with impaired quality of life and daily functioning[1].

The Athens Insomnia Scale (AIS) is a validated patient-reported outcome measure for assessing insomnia severity, including nighttime sleep difficulties and daytime functioning[2].

Wearable devices enable continuous, objective monitoring of physiological and behavioral parameters, offering a potential approach to better understand sleep-related symptoms in patients with RA.

OBJECTIVE

To evaluate the associations between wearable-derived physiological and behavioral metrics, including sleep-related parameters, and AIS scores in patients with RA, and to explore the potential utility of wearable-based monitoring for objectively characterizing insomnia severity in this population.

METHOD

- **Design:** prospective observational study of adult patients with RA wearing a study-provided wrist-worn device (Google Fitbit).
- **Correlation analysis:** Pearson and partial correlation adjusted for potential confounders.
- **Machine learning (ML):** models based on wearable-derived metrics classified higher vs. lower AIS scores — cutoff-based (<4 vs. ≥4, validated insomnia threshold) and quartile-based (lowest vs. highest).
- **Evaluation:** five-fold cross-validation (primary metric: AUC); SHAP analysis for influential features.

RESULTS

A total of 129 patients were enrolled, of whom 107 patients with RA completed the questionnaires and were included in the final analysis.

Table 1. The characteristics of patients

	n=107
Age	55 years (IQR 46–66)
Sex	female 84%, male 16%
Disease duration	82 months (IQR 5–162)
Medications	
Glucocorticoids	15.9%
Methotrexate	77.6%
Tumor necrosis factor inhibitors	20.1%
Interleukin-6 receptor inhibitors	29.0%
Janus kinase inhibitors	9.3%
Disease activity and QOL	
DAS28-CRP	2.5 (IQR 1.7–2.9)
CDAI	6.6 (IQR 2.3–10.7)
SDAI	6.6 (IQR 2.3–11.0)
HAQ-DI	0.8 (IQR 0.4–1.0)
AIS score	5.0 (IQR 3.0–8.0)

Table 2. Correlations between AIS score and wearable data

Variable	Correlated Parameter	r value	p value
AIS score	Sleep heart rate variability (HRV) parameter	0.49	<0.05
AIS score	Daytime mean heart rate	0.30	<0.05
AIS score	Sleep duration excluding wake periods	-0.46	<0.05

Table 3. Machine learning performance metrics of AIS classification models

	Accuracy	Precision	Recall	F1-score	AUC-ROC
Cutoff-based (AIS<4 vs. AIS≥4)	0.62	0.64	0.76	0.68	0.66
Quartile-based (lowest vs. highest quartile)	0.74	0.72	0.82	0.76	0.79

Table 4. SHAP-identified features contributing ≥10% to AIS classification

Feature	All data	Quartile
Daytime HRV parameters	●	●
Sleep HRV parameters	●	
Sleep duration excluding wake periods	●	
Total exercise time		●

SHAP analysis identified daytime HRV parameters as consistently influential features across both models.

Discussion

・Sleep and heart-rate patterns measured by a wearable device reflected how severe insomnia was in patients with RA.

・Shorter sleep and altered heart rate variability, an indicator of autonomic nervous system activity, may capture physiological aspects of insomnia that questionnaires do not.

・Passive, continuous monitoring could help identify patients who may need sleep assessment between visits, complementing the AIS.

・Limitations: This was a single time point observational study involving 107 patients, limiting the ability to infer causal relationships.

・Next step: Validation in larger cohorts with longitudinal follow-up is needed to confirm the findings and assess their generalizability over time.

CONCLUSIONS

- Wearable-derived metrics were associated with AIS scores in patients with RA.
- ML models showed moderate-to-good discrimination of insomnia severity (AUC 0.66 cutoff-based; 0.79 quartile-based).
- These findings support the potential of wearable-derived metrics as digital biomarkers of insomnia in RA.

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1. Higashida-Konishi M, Izumi K, *et al* . Association of disease activity with insomnia, depression, and fatigue in patients with rheumatoid arthritis: a multicenter prospective observational study. ACR. 2025. November 24-29. Chicago, United States.
2. J Psychosom Res. 2000 Jun;48(6):555-60. doi: 10.1016/s0022-3999(00)00095-7.Athens Insomnia Scale: validation of an instrument based on ICD-10 criteria. Soldatos CR, Dikeos DG, Paparrigopoulos TJ