

Is Chronic Low Back Pain Related to Sleep Disturbances? A Self-Organizing Maps for Unsupervised Machine Learning-Based Patient Phenotyping.

Giorgia Petrucci¹, Fabrizio Russo^{1,2}, Simone Russo³, Gianluca Vadalà^{1,2}, Rocco Papalia^{1,2}, Vincenzo Denaro^{1,2}

¹ Operative Research Unit of Orthopaedic and Trauma Surgery, Fondazione Policlinico Universitario Campus Bio-Medico, 00128 Rome, Italy.

² Research Unit of Orthopaedic and Trauma Surgery, Departmental Faculty of Medicine and Surgery, Università Campus Bio-Medico di Roma, 00128 Rome, Italy.

³ Department of Occupational and Environmental Medicine, Epidemiology and Hygiene, Italian Workers' Compensation Authority (INAIL), Via Fontana Candida 1, Monte Porzio Catone, 00078 Rome, Italy.

Presenting author: Giorgia Petrucci
e-mail: giorgia.petrucci93@gmail.com

AUTHOR DISCLOSURES

Giorgia Petrucci (N), Fabrizio Russo (N), Simone Russo (N), Gianluca Vadalà (N), Rocco Papalia (N), Vincenzo Denaro (N).
(N = No disclosures / no conflicts of interest)

ABSTRACT INTRODUCTION: Chronic low back pain (CLBP) is a multifactorial condition and a leading cause of disability worldwide (1). Among the various contributors to symptom persistence, sleep quality has emerged as a critical yet underexplored factor (2). Evidence suggests a bidirectional relationship between poor sleep and pain intensity, disability, and psychological distress in individuals with CLBP (3). To explore the relationship between sleep quality and CLBP using machine learning techniques, specifically the Self-Organizing Map (SOM) algorithm, while accounting for demographic, clinical, psychosocial, and occupational factors.

METHODS: This was a cross-sectional study conducted at Campus Bio-Medico Hospital Foundation in Rome, Italy, between July 2024 and January 2025. The study included 279 adult working patients (aged 18-65) with a clinical diagnosis of CLBP due to degenerative causes, all of whom were candidates for conservative treatment. Patients with cancer, trauma, spinal deformities, or infections were excluded. Validated questionnaires and anthropometric data were collected. Pain intensity was assessed using the Visual Analog Scale (VAS), while sleep quality was measured with the Pittsburgh Sleep Quality Index (PSQI), a validated tool capturing various dimensions of sleep disturbance. Disability related to low back pain was evaluated using the Oswestry Disability Index (ODI). Depressive symptoms were identified using the Patient Health Questionnaire-2 (PHQ-2). Functional outcomes included assessment of work capacity through the Work Ability Index (WAI) and activity limitations via the Nordic Musculoskeletal Questionnaire, focusing on how often back pain interfered with usual daily activities. SOM, an unsupervised machine learning algorithm, was applied to detect clusters based on multidimensional patient data. Subsequent k-means clustering was used to define patient subgroups. Statistical comparisons between clusters were performed using Kruskal-Wallis and chi-squared tests. Multiple imputation addressed missing data.

RESULTS SECTION: Four distinct patient clusters were identified. Cluster 1 included physically active individuals with moderate pain and no depression. Cluster 2 consisted of highly educated women with sedentary jobs and minimal disability. Cluster 3 showed the worst outcomes: high pain intensity, severe disability, depression, and the poorest sleep quality. Cluster 4, composed entirely of men, showed high work ability, good sleep, low pain, and no depressive symptoms. Poor sleep quality correlated strongly with depressive symptoms, high pain, disability, and reduced work capacity. These associations persisted even when sleep was excluded from clustering inputs, confirming its predictive linkage.

DISCUSSION: This study explored the complex relationship between chronic low back pain (CLBP) and sleep quality using Self-Organizing Map (SOM) machine learning. Four patient clusters were identified, revealing how demographic, clinical, psychosocial, and occupational factors influence pain perception and sleep disturbances. Poor sleep quality was associated with greater pain intensity, disability, depressive symptoms, and reduced work capacity, while better sleep aligned with improved functional and psychological outcomes. These findings support a bidirectional link between CLBP and sleep, suggesting that interventions targeting sleep may help improve recovery. However, the cross-sectional design limits causal inference, and convenience sampling from a single hospital may affect generalizability. Future longitudinal research is needed to clarify causal pathways. Overall, the results emphasize the importance of a multidisciplinary approach to CLBP management, with attention to sleep quality as a modifiable factor to enhance patient outcomes.

SIGNIFICANCE/CLINICAL RELEVANCE: This study highlights the importance of a multidisciplinary approach to treating chronic low back pain, given the strong link between sleep, pain, function, and psychosocial health. Involving various healthcare professionals can improve early diagnosis, patient education, and treatment adherence, reducing the risk of chronicity.

REFERENCES

1. Vos T, Lim SS, Abbafati C, Abbas KM, Abbasi M, Abbasifard M, et al. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *The Lancet*. ottobre 2020;396(10258):1204–22.
2. Sun Y, Laksono I, Selvanathan J, Saripella A, Nagappa M, Pham C, et al. Prevalence of sleep disturbances in patients with chronic non-cancer pain: A systematic review and meta-analysis. *Sleep Medicine Reviews*. giugno 2021;57:101467.
3. Finan PH, Goodin BR, Smith MT. The association of sleep and pain: an update and a path forward. *J Pain*. dicembre 2013;14(12):1539–52.