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Unveiling the Dynamics of Physical Activity and Mood in Schizophrenia Spectrum Disorders: A Bayesian Approach from the Multicentric DiAPAson Project

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INTRODUCTION

Schizophrenia spectrum disorders (SSD) affect approximately 1% of the global population [1], leading to significant quality-of-life impairments and functional disabilities. Physical inactivity is a critical modifiable risk factor in SSD, with meta-analytic evidence showing markedly reduced physical activity (PA) levels compared to the general population. While PA is a promising intervention to improve both physical and mental health outcomes, its real-time interplay with mood in SSD remains poorly understood. Despite the potential of Ecological Momentary Assessment (EMA) and accelerometry for monitoring mood and activity in natural settings, few studies have examined these variables together in SSD populations. Most traditional approaches study PA and mood separately, overlooking their bidirectional relationship. In this study, we address this gap by integrating EMA and accelerometry within a Bayesian framework to examine the dynamic interactions between PA and mood in SSD patients, capturing their complex temporal dependencies.

AIMS

This study aims to examine the bidirectional relationship between PA and mood in individuals with SSD through the use of EMA and accelerometry. By employing a Bayesian framework, we aim to model the dynamic interactions between these variables and investigate potential differences between SSD patients and healthy controls. The primary goal is to provide empirical evidence supporting the integration of PA interventions into the clinical management of SSD.

METHODS

As part of the Italian DiAPAson project, we conducted a multicenter cohort study involving 120 patients diagnosed with SSD and 113 healthy controls (HC), matched for sex and age. Over seven consecutive days, participants underwent ecological monitoring that combined smartphone-based EMA of emotional states with continuous 24-hour PA tracking using the ActiGraph GT9X Link device. The EMA protocol included seven daily prompts to assess current mood, calculated as the difference between self-reported happiness and sadness scores.

Our analytical strategy followed a two-step approach. First, we employed a generalized linear mixed-effects model (GLMM) to examine the association between daily mood and aggregated daily PA, adjusting for demographic variables and group membership. This provided insight into between-subject differences in mood–PA associations at the day level.

Moreover, we investigated the dynamic, within-day bidirectional relationship between mood and PA using a Bayesian Network approach. For each EMA evaluation, we computed the average PA level in the 30 minutes before and after the mood rating, allowing us to jointly estimate the prospective influence of PA on mood and the reciprocal effect of mood on subsequent PA. The model accounted for first-order

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autoregressive effects in both mood and PA time series, and controlled for circadian patterns using time-slot indicators. The analytical framework was formalized through a DAG (Fig. 1) and estimated via Monte Carlo Markov Chain (MCMC) sampling, enabling robust multilevel inference adapted to our high-frequency, hierarchical data structure.

RESULTS

The GLMM confirmed that SSD patients exhibited significantly lower mood levels compared to healthy controls, but revealed no significant association between daily physical activity and mood in the overall sample. However, temporal factors may play a crucial role, as both PA and mood show marked diurnal variations which daily-level analyses may fail to capture. Further analysis using a Bayesian multilevel model provided deeper insights into the bidirectional relationship between PA and mood. This model jointly estimated the prospective influence of PA on mood and the reciprocal effect of mood on subsequent PA, accounting for time-lag effects, autocorrelations, and time slots throughout the day. The posterior distribution for HC predominantly indicated a positive relationship, with most values above zero, suggesting consistent evidence for PA leading to mood improvements. For SSD patients, the posterior distribution also remained mostly positive, but with greater variability and uncertainty, indicating more individual differences in the effect of PA on mood. These findings highlight the more variable and individualized nature of the relationship between PA and mood in SSD patients, compared to the clearer pattern observed in HC individuals.

CONCLUSIONS

Our findings highlight the potential of PA as a valuable addition to psychiatric care for improving outcomes in patients with SSD. Although the impact of PA on mood was more variable in SSD compared to healthy controls, the overall trend supports the integration of structured PA programs to address functional and emotional challenges, improve adherence, and enhance long-term benefits. Personalizing PA interventions to individual needs and timing is crucial for maximizing therapeutic outcomes. Methodologically, our innovative use of Bayesian multilevel modeling represents a methodological breakthrough in understanding complex bidirectional relationships between lifestyle factors and psychological states. The framework we present offers a robust statistical foundation for investigating complex temporal dynamics across diverse biobehavioral domains, with broad implications for advancing personalized medicine beyond psychiatric contexts.

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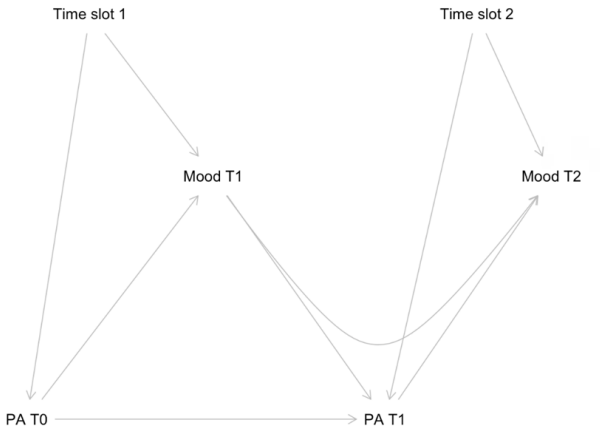

Fig. 1: DAG shows the joint effect of PA on each mood evaluation and of mood levels on following PA patterns. For each EMA evaluation, the average PA level in the previous 30 minutes was estimated

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