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Research paper

Meal Timing Jetlag is associated with anxiety, depressive and insomnia symptoms in a French-speaking online cohort: A cross-sectional analysis of ALIMENTAL 2

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ABSTRACT

Background: Chrono-nutrition – when, not only what, one eats relative to circadian timing – is an emerging determinant of mental health. We tested whether Meal Timing Jetlag (MTJL), the workday-to-free-day discordance in eating schedules, is associated with anxiety (primary outcome) and with depressive and insomnia symptoms (secondary), independently of sleep-based circadian misalignment.

Methods: Cross-sectional analysis of the ALIMENTAL 2 French-speaking online cohort (n = 2945). Sleep timing was assessed with the Munich Chronotype Questionnaire and meal timing with a Food Timing Screener. Outcomes were the GAD-7 (anxiety), CES-D (depression) and ISI (insomnia). Multivariable models adjusted for age, sex, BMI, unemployment, financial difficulty and shift work, with dose–response, logistic and BMI-stratified sensitivity analyses.

Results: In the primary model (n = 2817), MTJL was independently associated with anxiety (β = +0.47/h, 95% CI [0.14, 0.79], $p = 0.005$). The relationship was J-shaped (non-linearity $p = 0.020$; slope above 1 h + 1.03/h, $p < 0.001$). MTJL was also associated with depressive symptoms (β = +1.81, 95% CI [1.00, 2.61], $p < 0.001$) and insomnia severity (β = +0.90, 95% CI [0.47, 1.33], $p < 0.001$). Sleep-based circadian phase and sleep social jetlag were not. The per-hour anxiety effect is modest (≈12% of the GAD-7 minimal clinically important difference).

Limitations: The cross-sectional design cannot establish causality; reverse causation cannot be excluded. The cohort was online and 80% female, limiting generalisability.

Conclusions: Meal-timing regularity may be a candidate behavioural correlate of anxiety, depression and insomnia, warranting longitudinal and interventional confirmation before any clinical recommendation.

1. Introduction

Circadian rhythms orchestrate virtually all biological processes, including metabolism, immune function and mood regulation (Dibner et al., 2010). Disruption of these rhythms – through shift work, social jetlag or irregular eating – has been linked to metabolic syndrome, obesity and mental-health disorders (Depner et al., 2014; Roenneberg et al., 2012; Wittmann et al., 2006). Social jetlag (SJL), the discordance between the endogenous circadian clock (estimated from free-day sleep timing) and the socially imposed schedule on workdays, has been associated with depressive symptoms, fatigue and reduced well-being (Levandovski et al., 2011), a pattern recently confirmed by a meta-analysis of over 164,000 individuals showing that high SJL (≥2 h) is associated with elevated odds of depression (Gao et al., 2025), a pattern echoed in a separate meta-analysis among young people (Sun et al., 2025).

In parallel, the field of chrono-nutrition proposes that not only what and how much one eats, but also when one eats, influences metabolic and psychological health (Chaix et al., 2019; Pot, 2018). Animal studies show that time-restricted feeding can reset peripheral circadian clocks independently of the suprachiasmatic nucleus (Damiola et al., 2000), and in humans late eating is associated with higher obesity risk and more severe depressive and anxious symptoms (Garaulet et al., 2013). A web-based survey of 4490 Japanese workers found that irregular meal timing was independently associated with higher psychological distress after adjustment for sleep and lifestyle (Tahara et al., 2021). However, most studies have examined either sleep-based circadian misalignment or meal timing in isolation and have rarely quantified the concordance between meal timing and individual circadian phase (Chaput et al., 2020; Taillard et al., 2021).

We define Meal Timing Jetlag (MTJL) as the discordance between eating schedules on workdays versus free days — directly analogous to sleep SJL but applied to meals. This construct is closely related to the "eating jetlag" described by Gong et al. (2025) and Ciobanu et al. (2024); we deliberately reserve the term "social jetlag" for the sleep-midpoint measure and use "Meal Timing Jetlag" for the eating-timing measure. Because peripheral clocks in digestive organs are largely entrained by feeding cues (Froy, 2010), systematic desynchronisation of meal timing could plausibly affect mood regulation, gut–brain signalling and inflammatory pathways implicated in anxiety and depression (Cryan et al., 2019). A controlled experimental study has shown that restricting food intake to daytime hours prevented the mood and anxiety deterioration otherwise induced by circadian misalignment under simulated night-shift conditions (Qian et al., 2022), providing experimental support for meal timing as an independent modulator of emotional well-being.

The ALIMENTAL 2 study provides a rare opportunity to address this gap, building on the ALIMENTAL 1 cohort that examined dietary patterns and major depression in 15,262 participants (Achour et al., 2025). It is a large international French-speaking cohort of community-dwelling adults that collected detailed data on sleep timing (Munich Chronotype Questionnaire, MCTQ (Roenneberg et al., 2003)), daily meal timing on both workdays and free days, and validated mental-health outcomes (GAD-7, CES-D and ISI), enabling simultaneous estimation of sleep SJL, circadian phase and MTJL in relation to mental health.

Our primary aim was to test whether MTJL is independently associated, cross-sectionally, with anxiety (GAD-7, primary outcome), and secondarily with depressive symptoms (CES-D) and insomnia severity (ISI), after adjusting for sleep-based circadian phase, sleep SJL and sociodemographic confounders. We hypothesised that higher MTJL would be associated with worse symptoms across domains, independently of sleep-based circadian measures.

2. Methods

2.1. Study design and participants

ALIMENTAL 2 is the second phase of an international French-speaking cohort study of dietary habits, lifestyle and mental health. Participants were recruited online, via social media and health- and nutrition-related communities, between April 2024 and January 2025. Most resided in France (95.2%), with additional participants from Belgium, Switzerland, Algeria, French overseas territories and other French-speaking countries. Inclusion criteria were age ≥ 16 years and ability to complete an online questionnaire in French. The present analysis is cross-sectional, using the baseline questionnaire. Of 2945 participants, those with complete data on the MCTQ, Food Timing Screener, covariates and at least one outcome were included. The study received ethics approval (Est 1 N°SI 20.12.07.50145#1 — IDRCB 2020-A03336-331 for France and Germany; CÉRUL Santé 2021-463 for Canada); all participants provided electronic informed consent. Reporting follows the STROBE guidelines.

2.2. Circadian sleep parameters (MCTQ)

Sleep timing was assessed with the validated French version of the MCTQ (Coelho et al., 2024; Roenneberg et al., 2003). Sleep onset on a given day type was taken as the reported time of being ready to fall asleep; sleep duration was the interval to final wake time (durations <3 h or >14 h were treated as implausible and set to missing). Sleep midpoints on free (MSF) and work (MSW) days were computed as sleep onset plus half the sleep duration. Chronotype was indexed by the sleep-corrected free-day midpoint, MSFsc = MSF − (SD_free − SD_week) / 2 (applied only when free-day sleep exceeded the weekly mean), with lower values indicating morning types. Sleep social jetlag was the absolute difference between free- and work-day midpoints (circular correction applied), with SJL ≥ 1 h taken as the conventional threshold. Values beyond the 0.5th/99.5th percentile were trimmed.

2.3. Meal timing and Meal Timing Jetlag (Food Timing Screener)

Meal timing was assessed with a Food Timing Screener (Chakradeo et al., 2021) adapted from the MCTQ framework, recording habitual breakfast, lunch and dinner times on workdays and free days; the breakfast item captured the first food intake regardless of clock time. The eating window was dinner minus breakfast time. Meal Timing Jetlag (MTJL) was computed as the mean of the absolute breakfast and dinner differences between free and work days: MTJL = (|BT_free − BT_work| + |DT_free − DT_work|) / 2. Implausible entries (breakfast outside 04:00–13:00, dinner outside 16:00–24:00, eating window <6 h or >16 h, MTJL > 6 h) were set to missing.

2.4. Mental-health outcomes

Anxiety (primary outcome) was measured with the 7-item GAD-7 (0–21; ≥10 indicating moderate-to-severe anxiety) (Spitzer et al., 2006). Depressive symptoms were measured with the 20-item CES-D (0–60; ≥16 indicating probable depression) (Radloff, 1977) and insomnia with the 7-item ISI (0–28; ≥10 indicating clinical insomnia) (Morin et al., 2011); these were analysed as secondary outcomes. All three instruments were administered to the full cohort; the CES-D was complete for 2943 participants, with a score distribution typical of a community sample (mean 16.0, median 14).

2.5. Covariates

Models adjusted for age (years), biological sex, body mass index (kg/m^2), unemployment, perceived financial difficulty (5-point ordinal) and habitual shift work including night work (3-level ordinal).

2.6. Statistical analysis

Multivariable ordinary least squares (OLS) regression used a sequential strategy: Model 1 (MSFsc + covariates), Model 2 (SJL + covariates) and the primary Model 3 (MSFsc + SJL + workday breakfast time + workday eating window + MTJL + covariates). Heteroscedasticity-consistent (HC3) errors and variance inflation factors (all <2.5) confirmed robustness and absence of problematic collinearity. To characterise the dose–response shape we fitted a restricted cubic spline (knots at the 5th/35th/65th/95th percentiles) and a piecewise-linear model with a knot at 1 h, testing departure from linearity by partial F-test. To complement the continuous models we fitted binary logistic regressions at clinical thresholds (GAD-7 ≥ 10, ISI ≥ 10, CES-D ≥ 16) and a quartile specification of MTJL. Effect modification by adiposity was examined through BMI-stratified models and an MTJL × BMI interaction. Sensitivity analyses excluded participants with a diagnosed depressive or anxiety disorder, removed BMI from the covariate set, and refitted the censored anxiety model by Tobit regression. Analyses used Python 3.10 (statsmodels). Significance was set at α = 0.05 (two-tailed).

3. Results

3.1. Sample characteristics

The primary analytic sample comprised 2817 participants. It was 80% female, with a mean age of 41.6 ± 14.2 years and a mean BMI of 24.1 ± 4.9 kg/m^2 (20.4% overweight, 11.5% obese). 13% were unemployed and 21% reported shift or night work. Mean MSFsc was 3.6 ± 1 h and mean sleep social jetlag 1 ± 0.7 h (49.9% ≥ 1 h). Mean MTJL was 0.93 ± 0.7 h (median 0.75 h); 49.2% had ≥1 h and 9.4% had ≥2 h. Mean GAD-7 was 5.33 ± 4.48 (16.5% ≥ 10); mean ISI 7.79 ± 5.83 (36% ≥ 10); mean CES-D 15.77 ± 11.43 (43% ≥ 16). Full descriptives are in Table 1.

3.2. Bivariate associations

In bivariate analyses, MTJL showed a small but significant positive correlation with GAD-7 ($r \approx 0.04$, $p < 0.05$); later circadian phase (MSFsc) was weakly correlated with anxiety, while sleep SJL was not. These associations were further examined in the fully adjusted Model 3 (below).

3.3. Anxiety (GAD-7, primary outcome) and dose–response shape

In the primary model (Model 3, n = 2817, $R^2 = 0.102$), MTJL was the only chrono-nutrition variable independently associated with anxiety (β = +0.465/h, 95% CI [0.142, 0.789], $p = 0.0049$). Circadian phase (β = −0.06, $p = 0.5699$) and sleep social jetlag (β = −0.294, $p = 0.0684$) were not independently associated with GAD-7 (Table 2). The strongest predictors were financial difficulty, unemployment and female sex.

A restricted cubic spline showed significant departure from linearity ($p = 0.0202$). The relationship was J-shaped: a piecewise-linear model with a knot at 1 h gave a non-significant slope below 1 h (β = −0.352/h, $p = 0.2155$) and a steep, significant slope above 1 h (β = +1.03/h, $p < 0.001$; Fig. 1). A complementary quartile logistic regression of GAD-7 ≥ 10 reproduced an apparent U-shape (Q2 OR 0.698, Q3 OR 0.743, Q4 OR 0.919; linear-trend $p = 0.3476$). This U-shape on the dichotomised outcome is an artefact of thresholding combined with 30-min time

Table 1
Descriptive characteristics of the analytic sample (n = 2817).

Variable	Mean ± SD or %
Age (years)	41.6 ± 14.2
Female sex	80%
BMI (kg/m^2)	24.1 ± 4.9
Overweight (25–29.9)	20.4%
Obese (≥30)	11.5%
Unemployed	13%
Shift work (incl. night)	21%
MSFsc (chronotype, h)	3.6 ± 1
Sleep social jetlag (h)	1 ± 0.7
SJL ≥ 1 h	49.9%
Breakfast time, workdays (h)	7.7 ± 1.4
Dinner time, workdays (h)	19.8 ± 0.8
Eating window, workdays (h)	12.1 ± 1.5
Meal Timing Jetlag (h)	0.93 ± 0.7
MTJL ≥ 1 h	49.2%
MTJL ≥ 2 h	9.4%
GAD-7 (anxiety)	5.33 ± 4.48
GAD-7 ≥ 10	16.5%
ISI (insomnia)	7.79 ± 5.83
ISI ≥ 10	36%
CES-D (depression)	15.77 ± 11.43
CES-D ≥ 16	43%

The CES-D is complete for the full cohort (n = 2943) and analysed as a secondary outcome at full power.

Table 2
Multivariable OLS models for GAD-7 anxiety (Models 1–3); raw Wald *p*-values.

Predictor	M1 β (SE)	M2 β (SE)	M3 β (SE), *p*
MSFsc	0.076 (0.083)	–	−0.06 (0.106), $p = 0.5699$
Sleep social jetlag	–	−0.087 (0.115)	−0.294 (0.161), $p = 0.0684$
Breakfast time (work)	–	–	0.268 (0.128), $p = 0.0363$
Eating window (work)	–	–	−0.003 (0.11), $p = 0.9796$
Meal Timing Jetlag	–	–	0.465 (0.165), $p = 0.0049$
Age	−0.029 (0.006)	−0.032 (0.006)	−0.024 (0.006), $p < 0.001$
Female sex	0.96 (0.201)	0.941 (0.201)	0.864 (0.202), $p < 0.001$
BMI	0.041 (0.017)	0.041 (0.017)	0.035 (0.017), $p = 0.0428$
Unemployed	1.162 (0.249)	1.225 (0.249)	1.063 (0.255), $p < 0.001$
Financial difficulty	1.128 (0.089)	1.121 (0.089)	1.099 (0.09), $p < 0.001$
Shift/night work	−0.057 (0.182)	−0.024 (0.181)	−0.036 (0.185), $p = 0.8477$
R^2	0.1	0.1	0.102

discretisation rather than a protective effect of intermediate MTJL: the J-shaped continuous curve and the quartile pattern are mutually consistent (Fig. 2).

3.4. Depressive (CES-D) and insomnia (ISI) symptoms (secondary outcomes)

Analysed at full power, MTJL was independently associated with depressive symptoms (Model 3, n = 2817, $R^2 = 0.149$; β = +1.808/h, 95% CI [1.004, 2.613], $p < 0.001$) and with insomnia severity (n = 2817, $R^2 = 0.062$; β = +0.898, 95% CI [0.468, 1.329], $p < 0.001$) (Table 3, Fig. 3). The CES-D association was essentially unchanged after excluding participants with a diagnosed depressive or anxiety disorder (β = +1.844, 95% CI [1.009, 2.679], $p < 0.001$; n = 2126). As with anxiety, neither MSFsc nor sleep social jetlag was independently associated with these outcomes. Because these outcomes were pre-specified as secondary, they are interpreted as convergent support for the primary finding rather than as independent confirmatory tests.

3.5. Binary-threshold and BMI-stratified analyses

Using clinical thresholds with continuous MTJL (Table 4), the adjusted per-hour odds ratios were 1.308 for CES-D ≥ 16 (95% CI [1.11, 1.543], $p = 0.0014$) and 1.268 for ISI ≥ 10 (95% CI [1.079, 1.491], $p = 0.004$); the GAD-7 ≥ 10 odds ratio was attenuated and non-significant (1.166, $p = 0.1324$), as expected from the J-shaped relationship in which dichotomising at 10 discards the upper-tail gradient. Stratified by BMI (Table 5), the MTJL–anxiety association was strongest in normal-weight participants (β = +0.628, $p = 0.0023$) and attenuated with increasing BMI, but the MTJL × BMI interaction was non-significant (β = −0.003, $p = 0.8721$), indicating no statistical effect modification by adiposity.

3.6. Sensitivity analyses

The primary MTJL–anxiety association was robust: it persisted after excluding participants with a diagnosed psychiatric disorder (β = +0.461, $p = 0.0072$; n = 2126), after removing BMI from the covariate set, and under Tobit regression accounting for the 12.1% floor at GAD-7 = 0 (Tobit β ≈ +0.53, $p < 0.01$). Subgroup analyses restricted to economically active and to day-working participants yielded comparable estimates.

4. Discussion

In a large French-speaking online cohort, Meal Timing Jetlag – the

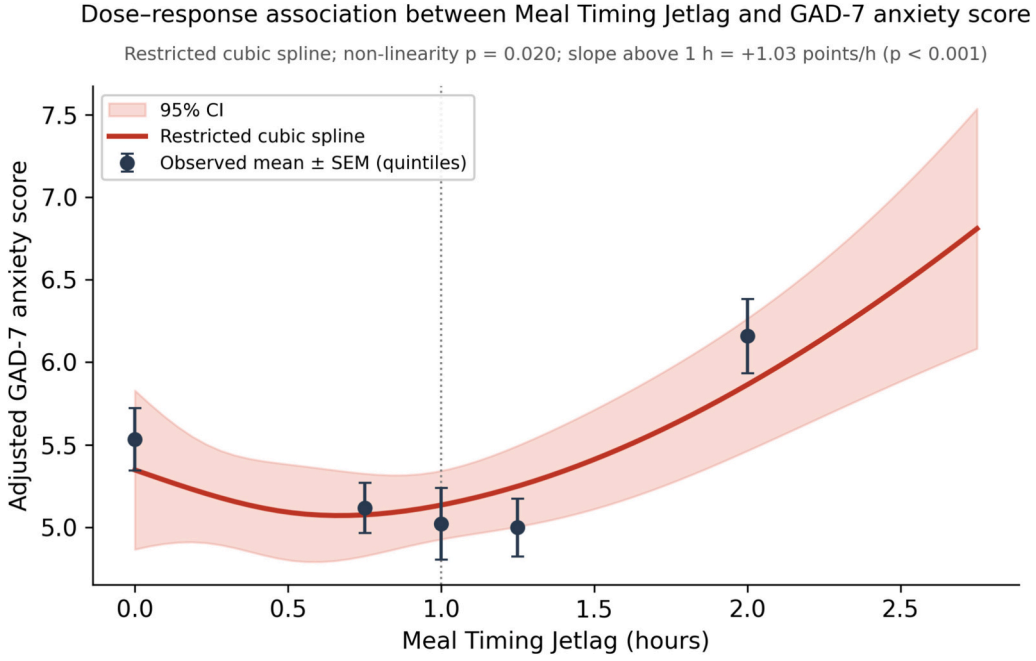


Fig. 1. Dose–response association between Meal Timing Jetlag and adjusted GAD-7 anxiety score (restricted cubic spline with 95% CI; observed quintile means ± SEM overlaid). The association is J-shaped: flat below ~1 h and rising steeply above it.

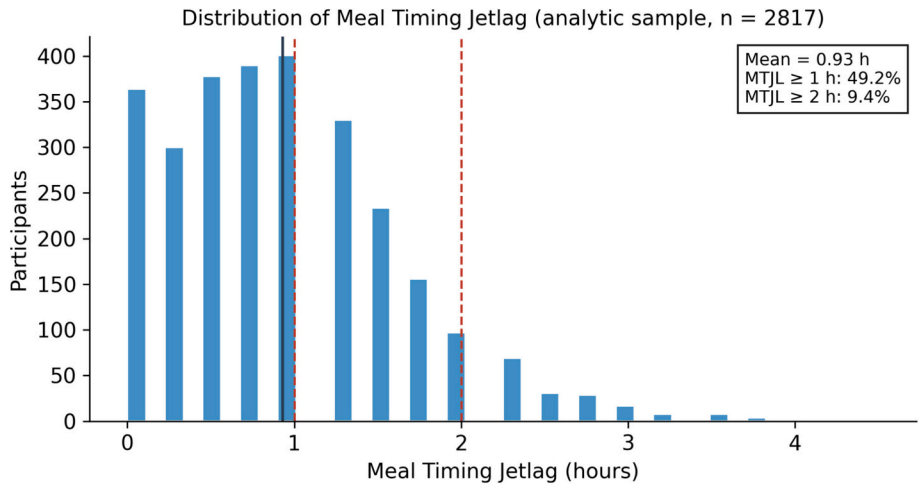


Fig. 2. Distribution of Meal Timing Jetlag in the analytic sample (n = 2817), with sample mean and the 1 h and 2 h thresholds. The clinical signal is carried by the right tail of the distribution.

Table 3
Meal Timing Jetlag and mental health (Model 3, per hour).

Outcome	n	β (95% CI)	*p*	R^2
GAD-7 (anxiety, primary)	2817	0.465 [0.142, 0.789]	0.0049	0.102
CES-D (depression)	2817	1.808 [1.004, 2.613]	<0.001	0.149
ISI (insomnia)	2817	0.898 [0.468, 1.329]	<0.001	0.062

workday-to-free-day discordance in meal timing – was independently associated with anxiety (primary outcome) and, as secondary outcomes, with depressive and insomnia symptoms, after adjustment for circadian phase, sleep social jetlag and sociodemographic factors. To our knowledge this is among the first large-cohort demonstrations that eating-behaviour misalignment carries a mental-health signal across symptom domains, independently of sleep-based circadian measures. The anxiety association was J-shaped, driven by the upper tail of the distribution. Because the design is cross-sectional, causality cannot be inferred; the data are equally compatible with anxious or depressed individuals adopting more irregular eating schedules.

The per-hour anxiety effect is modest – about 11.6% of the GAD-7 minimal clinically important difference (≈ 4 points) (Toussaint et al., 2020) – and only the ~9.4% of participants with ≥2 h MTJL approach a clinically perceptible shift. The depression and insomnia associations are proportionally larger. Convergence across three independent instruments, and persistence after excluding diagnosed disorders, argues against the signal being an artefact of a single scale or of clinical caseness.

4.1. *Candidate mechanisms (speculative)*

Because no biological mediators were measured, the following pathways are necessarily speculative and are offered only as candidate mechanisms for future testing. Irregular meal timing may desynchronise feeding-entrained peripheral clocks from the central pacemaker, with downstream effects on glucocorticoid and inflammatory rhythms implicated in mood and anxiety; feeding-driven oscillations in the gut microbiota and tryptophan metabolism provide a second candidate route; and irregular eating may co-occur with broader lifestyle irregularity (sleep, activity) that itself affects mental health. These remain hypotheses, not findings.

Table 4
Binary logistic regression at clinical thresholds (per hour MTJL).

Outcome (threshold)	n/events	OR/h	95% CI	*p*
GAD-7 ≥ 10	2817/464	1.166	[0.955, 1.425]	0.1324
CES-D ≥ 16	2817/1210	1.308	[1.11, 1.543]	0.0014
ISI ≥ 10	2817/1014	1.268	[1.079, 1.491]	0.004

Table 5
MTJL → GAD-7 stratified by BMI (interaction $p = 0.8721$).

BMI stratum	n	β (95% CI)	*p*
Normal (<25)	1919	0.628 [0.225, 1.031]	0.0023
Overweight (25–30)	574	0.352 [−0.332, 1.035]	0.3137
Obese (≥30)	324	0.102 [−0.848, 1.051]	0.8341

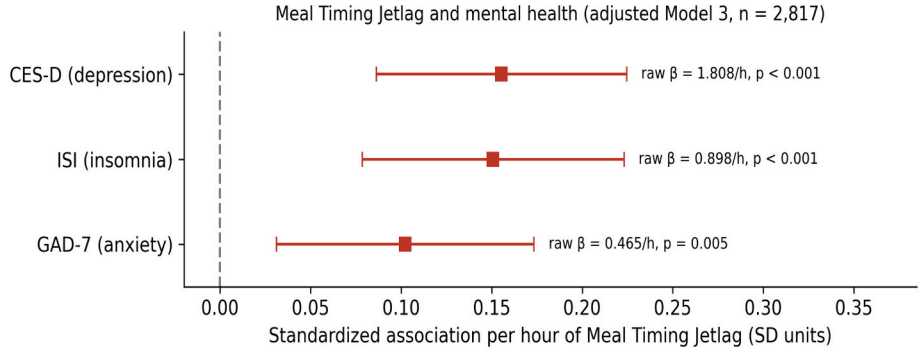


Fig. 3. Standardized associations (per hour of Meal Timing Jetlag, SD units) with each outcome in the fully adjusted Model 3; raw per-hour coefficients are annotated.

4.2. Limitations

Several limitations bound these conclusions. The cross-sectional design precludes causal and directional inference. Participants were recruited online, largely through health- and nutrition-oriented channels; the sample was 80% female and 95.2% resident in France, and is therefore not a general-population sample, with limited external validity to men and to offline populations. Meal timing was self-reported on a brief screener and is subject to recall and social-desirability bias, with 30-min response resolution coarsening the measure. Because we administered the standard MCTQ rather than the MCTQ-Shift (Juda et al., 2013), sleep social jetlag cannot be validly estimated in the 21% of participants doing shift or night work, so the null sleep-SJL association should be read with caution rather than as evidence of no association. Because circadian phase is already adjusted for via MSFsc, residual confounding more plausibly arises from light exposure, dietary quality, work constraints, medication use, or unmeasured psychiatric severity, which cannot be excluded.

4.3. Clinical and public-health implications

These cross-sectional findings do not, on their own, justify public-health recommendations. If corroborated by longitudinal and experimental studies, maintaining consistent meal timing between workdays and free days could be explored as a low-cost behavioural candidate for mental-health prevention, alongside existing lifestyle approaches, and would be particularly worth testing in shift workers. Our data also underscore the overriding importance of socioeconomic determinants (financial hardship, unemployment) as correlates of anxiety.

5. Conclusions

Meal Timing Jetlag may be associated with anxiety, depressive and insomnia symptoms, independently of sleep-based circadian misalignment, in a J-shaped manner for anxiety. These findings identify meal-timing regularity as a candidate behavioural correlate of mental health that warrants prospective and interventional study, time-stamped dietary records, and replication in more representative samples before any public-health recommendation is made.

CRediT authorship contribution statement

Guillaume Fond: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Julien Coelho:** Writing – review & editing, Conceptualization. **Brendon Stubbs:** Writing – review & editing. **Dong Keon Yon:** Writing – review & editing. **Yannis Achour:** Writing – review & editing, Data curation, Conceptualization. **Tasnime Akbaraly:** Writing – review & editing. **Bruno Aouizerate:** Writing – review & editing. **Lou Boulot:** Investigation, Conceptualization. **Francesco P. Cappuccio:** Writing – review & editing. **Lucile Capuron:** Writing – review & editing. **Sylvain Iceta:** Writing – review & editing, Conceptualization. **Guillaume Lucas:** Writing – review & editing, Investigation, Conceptualization. **Roberto Manfredini:** Writing – review & editing. **Wolfgang Marx:** Writing – review & editing. **Jean-Arthur Micoulaud-Franchi:** Writing – review & editing. **Filippo Pigazzani:** Writing – review & editing. **Masoud Rahmati:** Writing – review & editing. **Bach Xuan Tran:** Writing – review & editing. **Laurent Boyer:** Writing – review & editing. **Jacques Taillard:** Writing – review & editing, Writing – original draft, Conceptualization. **Michael Berk:** Writing – review & editing, Writing – original draft.

Ethics

Approved in France and Germany (Est 1 N°SI 20.12.07.50145#1 — IDRCB 2020-A03336-331) and Canada (CÉRUL Santé 2021-463); electronic informed consent obtained from all participants; conducted per the Declaration of Helsinki.

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Declaration of competing interest

G.F. is the owner of Dr. Guillaume Fond SARL, Marseille, France. F.P. reports recent election as Chair of the GIS-CRONO Executive Board (French Scientific Interest Group on Chronobiology, https://gis-crono.com) and declares no other competing interest. All remaining authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2026.122229.

Data availability

De-identified data are available from the corresponding author on reasonable request, subject to applicable data-protection regulations (GDPR).

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