Wearable-derived sleep features predict relapse in Major Depressive Disorder.

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# Abstract

**Background:** Consumer-grade wearable devices can identify sleep patterns that are predictive of relapse in people with Major Depressive Disorder (MDD). We used FitBit data from individuals with recurrent MDD to describe longitudinal associations of sleep duration, quality, and regularity with subsequent depressive relapse and depression severity.

**Methods:** Data were collected as part of a longitudinal remote measurement technologies (RMT) study in people with recurrent MDD. A total of 623 people with MDD wore a FitBit and completed regular outcome assessments via email for a median follow-up of 541 days. Multivariable regression models tested for associations between sleep features and depression outcomes. We considered two samples of people with at least one assessment of relapse (n=213) or at least one assessment of depression severity (n=390).

**Outcomes:** Increased intra-individual variability in total sleep time, greater sleep fragmentation, and later sleep mid-points were associated with worse depression outcomes. Adjusted Population Attributable Fractions (PAFs) suggested that an intervention to increase sleep consistency in adults with MDD could reduce the population risk for depression by up to 18-37%.

**Interpretation:** We found consistent associations between wearable-derived sleep features and the probability of depressive relapse and increased depressive symptom severity. Disordered sleep is prevalent and disruptive, and challenging to capture longitudinally via conventional laboratory sleep assessments. Our study demonstrates a role for consumer-grade activity trackers to predict relapse risk and depression severity in people with recurrent MDD.

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# Introduction

Major Depressive Disorder (MDD) affects 30-40% of people at some point in their lifetime, is associated with poorer social and occupational functioning, increased risk of physical comorbidity and premature mortality,1 and is the leading mental health contributor to the global burden of disease.2 MDD follows a persistent, relapsing-remitting course in 55% of patients3 and is a heterogenous, complex condition with multiple associated biopsychosocial factors. A 2022 *Lancet* Commissioncalled for the identification and targeting of clinical features which prevent and pre-empt relapse to promote sustained remission and recovery.1

Mutual, overlapping mechanisms have been implicated in both sleep-circadian function and emotional regulation. Many pharmacological treatments for depression have been shown to influence the pathophysiology of sleep4 and there are a range of genetic and neurotransmitter systems shown to influence the co-occurrence of MDD and sleep impairment.5 Environmental factors such as light intensity and season can affect melatonin production; crucial for both the maintenance of a healthy circadian rhythm and mood.6 Whilst the relationship between sleep and depression is likely to be one of bidirectionality and co-occurrence, 40% of people with depressive disorder report the occurrence of sleep disturbances prior to a depression onset, and 22% at the same time.7

Changes in sleep and circadian function are leading candidate markers for early relapse identification in MDD. Disruptions in continuity and timing, or excessive sleep are core diagnostic features of depression. Approximately 90% of MDD patients report problems with sleep.5 Insomnia, poor sleep quality, and evening chronotype are robust risk factors for the development of depression, and correlate with depression severity, while morning diurnal preference has been causally associated with lower depression risk.5,8 Short sleep duration has been associated increased risk of depression recurrence.9 Sleep regularity is also critical with higher variability in sleep-wake timing; discrepancies in sleep duration between work and free days (social jetlag) are associated with lower mood.10

Remote Measurement Technologies (RMT), including consumer wearable and smartphone devices, have attracted increasing interest as tools for remote and real-time examination of dynamic changes in mood state and sleep variables.11,12 They circumvent many of the limitations associated with conventional objective sleep measures: actigraphy lacks wireless capability and is rarely acceptable for extended use over timescales that are necessary to capture clinical transitions over phases of depression, whereas polysomnography is expensive, time-consuming and only suitable for cross-sectional measurement, typically in laboratory settings. In small validation studies in generally healthy adults (no sleep disorder, mental disorder, or somatic illness), several consumer-grade devices have been shown to reliably identify sleep-wakefulness with accuracy equal to, if not slightly higher than, research-grade actigraphy devices with high sensitivity for sleep and moderate specificity for identifying wakefulness.13 Currently available consumer wearables are therefore a promising alternative in situations where research-grade actigraphy has previously been employed. RMT hold considerable potential for the development of Just-In-Time Adaptive Interventions, using dynamic individualised data to personalise the timing and content of sleep interventions.

Remote Assessment of Disease and Relapse – Major Depressive Disorder (RADAR-MDD11) is an international, multicentre cohort study in people with recurrent MDD that leverages data from smartphones and wearable devices. RADAR-MDD is the largest remote measurement study in depression conducted to-date. We have previously reported short-term associations of sleep features with depressive symptomology measured using the Patient Health Questionnaire 8-item (PHQ-814).12 Here, we extended that work to consider longer-term associations over several months and clinically-assessed relapse in addition to depression severity. We aimed to describe longitudinal associations between depression outcomes and previous assessments of (1) sleep duration, (2) sleep quality, and (3) sleep regularity.

# Methods

## Study Design and Participants

This paper presents a secondary analysis of the RADAR-MDD dataset,[13](https://www.zotero.org/google-docs/?oIuBQ1) a dataset following people with recurrent MDD for a median of 541 days (interquartile range (IQR): 401-730 days).15 Participants were recruited from the UK, Netherlands and Spain, with ethical approvals from the Camberwell St Giles Research Ethics Committee in London (reference: 17/LO/1154), from CEIC Fundacio Sant Joan de Deu in Barcelona (CI: PIC-128-17) and from the Medische Ethische Toetsingscommissie VUmc in Amsterdam (METcVUmc registratienummer 2018·012 – NL63557·029·17).

To be eligible for inclusion, individuals needed to: have had at least two episodes of MDD with their most recent episode within the previous two years; be able to complete self-reported questionnaires via a smartphone; be fluent in English, Dutch, Catalan or Spanish; be willing and able to give informed consent; be an Android user or willing to switch to an Android phone for the duration of the study and be over 18 years. Individuals were excluded if they had a history of bipolar disorder, schizoaffective disorder, schizophrenia, MDD with psychotic features, dementia, recent drug or alcohol misuse or a major medical illness (requiring long periods of hospitalisation). Recruitment took place between November 2017 and June 2020, and follow-up ceased on 30th April 2021. As this paper is a secondary analysis of an existing dataset, no sample size calculation was conducted.

## Patient and Public Involvement

RADAR-MDD was co-developed with service users in our Patient Advisory Board (PAB). They were involved in the choice of measures, the timing and issues of engagement, and development of the analysis plan. Representatives of the PAB were invited to be authors of this paper and critically review it.

## Procedure

This study was a secondary analysis of the RADAR-MDD dataset.11 Participants were asked to wear a wrist-worn Fitbit device and complete regular questionnaires throughout follow-up, administered via email using the Research Electronic Data Capture (REDCap) platform. Questionnaires assessed sociodemographic factors, medical and psychiatric history, service and medication use, health behaviours and clinical characteristics questionnaires (questionnaires are presented in Supplementary Material 1).

## Depression outcomes

We considered two outcomes that were assessed repeatedly every three months during follow-up:

**1) MDD relapse,** defined as (i) meeting the World Health Organisation Diagnostic Interview – Short Form (CIDI-SF16) criteria for MDD; *and* (ii) scoring >25 on the IDS-SR (Inventory for Depressive Symptomatology – Self Report17) indicating at least moderate symptom severity; *and* (iii) having been in a state of remission within the past six months; *and* (iv) after meeting the above criteria, being confirmed as relapsed following a telephone assessment with a trained research worker. The CIDI-SF criteria for MDD requires the individual to have endorsed at least 5 out of the 9 symptoms of MDD, one of which must be a core symptom of low mood or anhedonia. The CIDI-SF has demonstrated excellent sensitivity and specificity to identify current MDD state and is used extensively on web-based platforms.16 Participants not meeting the CIDI-SF criteria but scoring >25 on the IDS-SR (indicating with chronically severe depression symptoms) were excluded from this outcome to ensure the comparison group (‘Non-relapse’) represented only those with low depression severity.

**2) Depressive symptom severity**, assessed based on total scores on the IDS-SR, with scores ranging from 0-80 and higher scores indicating increased depression severity.

## Sleep features

Participants were asked to wear a Fitbit Charge wearable device while participating in the study. The Fitbit Charge tracks sleep using accelerometer and photoplethysmography sensors. Participants were asked to wear the device continuously, removing it only to charge the battery and showering/swimming. The device has comparable performance to research-grade actigraphy devices in estimating sleep duration, sleep efficiency and sleep onset latency.3

Fitbit data were gathered continuously and summarised as daily indicators (e.g., “Total hours of sleep”). For each day, we focused on the primary sleep event, defined as the largest continuous period of sleep, thereby excluding shorter sleep events such as napping. We considered 13 sleep features split into three domains: (1) duration, (2) quality, and (3) regularity (Table 1). For each feature, we summarised the daily measures over the four weeks prior to each 3-monthly outcome assessment. For some features, we additionally considered the change over time (i.e., four weeks prior to the previous 3-monthly assessment versus the current 3-monthly assessment). The four-week reference period for sleep follows past studies showing deteriorations in sleep quality in the four18 weeks prior to relapse, suggesting four weeks is a reasonable window in which to observe prodromal symptoms of sleep disturbance prior to relapse.

We excluded weekend sleep events (except for ‘social jetlag’) to avoid conflating weekday and weekend assessments, which tend to differ. Within each four-week period, we included participants providing sleep information on at least 8 weekdays. We chose a minimum of 8 weekdays to derive reliable summaries whist minimising selection bias (participants wearing their FitBit for more than eight days tended to have lower depressive symptoms and more stable sleep patterns).

**Table 1. Sleep features measured in the four weeks prior to outcome assessment, derived from daily summaries of continuously-collected Fitbit indicators. continuous FitBit.**

|  |  |  |
| --- | --- | --- |
| **Domain** | **Feature** | **Definition** |
| **Sleep duration** | Total sleep time† | Median daily hours spent asleep. |
| Change in total sleep time‡ | Difference in median daily hours spent asleep over the four weeks before the current outcome assessment (T2) versus the four weeks before to the previous outcome assessment three months ago (T1). |
| Total sleep time, variance† | Intra-individual variance in median daily hours spent asleep. |
| Change in total sleep time, variance‡ | Difference in intra-individual variance in median daily hours asleep from T2 to T1. |
| **Sleep quality** | Sleep efficiency† | Median hours spent asleep as a proportion of hours spent in bed per day. |
| Sleep fragmentation index† | Median daily number of awakenings per hour of sleep. |
| Sleep onset latency† | Median time between last recorded step taken and Fitbit-derived sleep onset each day. |
| Sleep onset latency variance† | Intra-individual variance in median sleep onset. |
| **Sleep regularity** | Sleep midpoint† | Median midpoint between sleep onset and sleep offset. |
| Sleep midpoint, variance† | Intra-individual variance in median sleep midpoint. |
| Change in sleep midpoint‡ | Difference in median sleep midpoint from T2 to T1. |
| Change in sleep midpoint variance‡ | Difference in intra-individual variance in median sleep midpoint from T2 to T1. |
| Social jet lag† | Absolute difference between weekday and weekend sleep midpoints. |
| † Measured over the four weeks prior to each outcome assessment.  ‡ Measured as the change between the four weeks before the current outcome assessment (T2) and the four weeks before the previous outcome assessment three months ago (T1) | | |

## Covariates

We considered covariates previously shown to affect sleep and depression19, including variables measured at enrolment: age, gender, years of education (a proxy indicator of socioeconomic status, and partnership status; as well as variables measured at each 3-monthly outcome assessment: atypical depression subtype, current medication use, alcohol use, and hours of daylight in the month before each assessment, a proxy for seasonal effects. Atypical depression is characterised by hypersomnia and increased appetite and has markedly different sleep phenotypes compared to other subtypes.20 Atypical depression subtype was defined as: mood reactivity between 0-2 and at least two symptoms from leaden paralysis, weight gain, increased appetite, hypersomnia, and interpersonal sensitivity.21 Medication use was measured using three binary variables capturing medications related to depression (antidepressants, antipsychotics, anticonvulsant, stimulating antidepressant), sleep (benzodiazepine, hypnotic) or ‘other’. Alcohol use and behaviour was measured based on the Alcohol Use Disorders Identification Test (AUDIT22) total score (see Methodological Supplement for more details).

## Statistical Analyses

First, we described outcomes and covariates using appropriate summary statistics (e.g., median/IQR for continuous variables; frequencies and percentages for categorical variables).

Second, we tested associations between each sleep feature and outcome by fitting a series of multivariable regression models. We used binary logistic models for MDD relapse and linear models for depression severity (IDS-SR total score). All models included a participant random intercept (to account for the clustering of repeated three-monthly outcome assessments) and the covariates listed above. Sleep features were standardised (mean=0, standard deviation=1) and some were log-transformed (see Methodological Supplement). Each sleep feature was tested in a separate model. All models included quadratic terms for the sleep feature to allow for non-linear effects on depression. Linear models for depression severity included the previous value of the outcome (at the previous three-monthly assessment) as both a linear and quadratic term, recognising that prior severity may have non-linear effects on current severity.23

The effect of each sleep feature on depression was summarised using average marginal effects and adjusted predictions. A marginal effect is the partial derivative of the regression equation with respect to each variable in the model for each unit in the data. The average marginal effect (AME) is the mean of these partial derivatives over the sample. For relapse, the AME represents the percentage points increase in the probability of relapse per standard deviation difference in the sleep feature; for depression severity, the increase in IDS-SR total score (compared to three months ago) per standard deviation difference in the sleep feature. For selected sleep features, we additionally plotted adjusted predictions. These represent the model-predicted outcome across a range of values for each sleep feature (from -2 SD to +2 SD), holding other variables to their median values.

These models were estimated in a Bayesian framework using Stan via the brms package for R.24 All models were sampled for 40,000 iterations and thinned by retaining every 10th sample. Weakly informative priors were used, centred on zero, to constrain coefficients to plausible values (see Methodological Supplement). No corrections were made for multiple testing.25 Posterior draws for AMEs were summarised as the median and 50% and 89% credible intervals. We retained all available outcome assessments under the missing at random assumption.

Third, to illustrate the potential for future interventions targeting sleep in an MDD cohort, we calculated adjusted population attributable fractions (PAFs) for selected sleep features and relapse. PAFs represent the relative reduction in the risk of relapse in the population under a counterfactual scenario where a specific risk factor is removed in this case, poor quality sleep. We derived a binary variable (0/1) for selected sleep features indicating participants in the upper quartile. We fitted binary logistic regression models for relapse. Each model included the dichotomised sleep feature and covariates listed above. From these models, we estimated adjusted PAFs with cluster robust 95% confidence intervals to account for clustering of repeated outcome assessments. Models were estimated using the glm and AFglm functions in R.

## Sensitivity analyses

We conducted two sensitivity analyses. First, we investigated whether the effect of sleep differed for participants with atypical depression by comparing models with and without an interaction term (sleep × atypical depression subtype). Models were compared using leave-one-out cross-validation (LOO) where a difference of ≥4 in the expected log pointwise predictive density utility score (ELPD) was considered significant.26 Second, we repeated the models for depression severity after removing four sleep items from the IDS-SR to ensure that any associations were not the result of overlapping measures.

# Results

Of 623 participants (3777 observations) in the RADAR sample, we excluded 224 participants without any information recorded on sleep and one participant with missing covariate information. Excluded participants were similar to those analysed in terms of age, gender, partnership status, and years of education (Supplementary Table 2.1). We derived two overlapping analytical samples. Sample 1 (n=213) included participants with at least one assessment of the MDD relapse outcome (either ‘relapse’ or ‘no relapse’). Sample 2 (n=390) included participants with at least one assessment of the IDS-SR depression outcome.

Table 2 presents participant characteristics at enrolment. In both samples, participants had a median age of 50 years and one quarter were male. Around half were living with a partner and two-thirds were taking an antidepressant medication. From 603 observations during follow-up, there were 38 relapse events (6·3%). There were 1,355 assessments of depression severity, with median IDS-SR scores of 17 (IQR: 12, 21) and 30 (19, 38) in Samples 1 and 2, respectively.

Figure 1 presents average marginal effects for each outcome for a one standard deviation (SD) difference in each sleep measure (see also Supplementary Table 2.2). For relapse, these represent the percentage points increase in the probability of relapse; for IDS-SR, the increase in depression severity.

**Table 2: Characteristics of the analytical samples**

|  | Sample 1*\** | Sample 2*\** |
| --- | --- | --- |
| n=213 individuals | n=390 individuals |
| **Participant characteristics at enrolment** | | |
| Age*†* | 52·0 (34·0, 58·4) | 48·5 (32·0, 57·0) |
| Years of education*†* | 17·0 (14·0, 19·0) | 16·0 (13·0, 18·0) |
| AUDIT total score*†* | 3·0 (1·0, 5·0) | 2·0 (0·0, 4·0) |
| Male gender*‡* | 51 (24) | 91 (23) |
| Lives with partner*‡* | 122 (57) | 196 (50) |
| Medication (Depression)*‡* | 135 (63) | 269 (69) |
| Medication (Sleep)*‡* | 25 (12) | 77 (20) |
| Medication (Other)*‡* | 10 (5) | 15 (4) |
| **Outcomes over follow-up** | | |
| No. follow-up assessments | 603 | 1355 |
| Relapse*‡* | 38 (6·3) | – |
| IDS-SR total score*†* | 17·0 (12·0, 21·0)*§* | 28·0 (18·0, 37·0)*§* |
| *\** Note that these are overlapping samples. Participants in Sample 1 who also had at least one assessment of IDS-SR were also included in Sample 2. | | |
| *†* Median (IQR). | | |
| *‡* N (%). | | |
| *§* Due to the definition of relapse, which excluded participants with chronic depression, participants in Sample 1 tended to report lower depression severity and lower use of antidepressant medication compared to Sample 2. | | |

**Figure 1. Average marginal effects for 1 SD difference in each sleep measure.**

*Notes.* This presents the posterior distributions of the marginal effects for each sleep feature and outcome. The points represent the median of the distribution and the 50% and 89% credible intervals. The effects are presented unadjusted (in red) and adjusted (in blue).Δ refers to the change in the sleep feature between the four weeks before the previous three-monthly assessment (T1) and the four weeks before the current assessment (T2).

Chart

Description automatically generated

### Sleep duration

Greater intra-individual variability in total sleep time was associated with an increased probability of relapse and increased depression severity. A one standard deviation increase in ‘change in total sleep time variance’ was associated with a 3·0% increase in the probability of relapse (89% Credible Interval (CrI): 1·2, 5·0) a 0·7 (89% CrI: 0·3, 1·0) unit increase in depression severity. However, we found no evidence of an effect of total sleep time on either outcome.

### Sleep quality

Higher sleep fragmentation was associated with higher depression severity (AME = 0·3; 89% CrI: -0·1, 0·7), but otherwise, we found no consistent evidence for effects of sleep quality on either outcome.

### Sleep regularity

Participants with later or more variable sleep midpoints tended to report higher depression severity. For example, a one SD increase in sleep midpoint was associated with a 0·8 (89% CrI: 0·4, 1·3) unit increase in depression severity. The pattern of effects was similar for relapse, but in most cases the credible intervals crossed zero, suggesting no effect.

Figure 2 presents adjusted predictions of relapse and depression severity for selected sleep features. For total sleep variance, the probability of poorer outcomes increases rapidly for participants with more variable sleep. For example, the predicted probability of relapse among participants with average sleep variability is 5 percent, compared 10-15 percent among participants with sleep time variance 1 or 2 SD above average. By contrast, we see a u-shaped relationship for median hours of sleep, where high or low amounts of sleep are associated with poorer outcomes.

## Population attributable fractions

Adjusted population attributable fractions (Supplementary Table 2.3) ranged from 0·37 (95% CI: 0·17, 0·56) for change in total sleep time variance, to 0·04 (95% CI: -0·24, 0·15) for total sleep time. This suggests that an intervention to increase sleep consistency among individuals with the most variable sleep (in the upper quartile) could reduce the population risk for depression relapse by up to 18-37%.

**Figure 2. Adjusted predictions for selected sleep features**

Graphical user interface, application, PowerPoint

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### Sensitivity analyses

We found no evidence to suggest that the effect of sleep differed for participants with versus without atypical depression. In all cases, the improvement in model fit when including an interaction term (sleep feature × ​atypical subtype) was negligible (Supplementary Table 2.4).

Our findings were consistent when removing sleep items from IDS-SR, although some effect sizes were attenuated. For example, the AME for the change in total sleep time variance was 0·66 (89% CrI: 0·29, 1·01) when using the original scale and 0·52 (89% CrI: 0·18, 0·85) when removing the sleep items. However, the direction of evidence was otherwise unchanged (see Supplementary Table 2.5).

# Discussion

This study identified consistent associations between wearable-derived sleep features and our two outcomes of interest: depressive relapse and depression severity. Greater sleep variability was associated with a higher probability of relapse and increased depression severity in the subsequent month. We found no evidence of associations between measures of sleep quality and depression outcomes. Regarding sleep regularity, we found later and more variable sleep midpoints to be associated with increased depression severity.

We have previously reported short-term associations between sleep features and depressive symptoms in RADAR-MDD.12 Here, we report similar results, with positive associations between depression outcomes and sleep time and sleep variability and negative associations between depression and sleep efficiency. However, the present analysis expands on earlier findings by including estimates of effect size, more robust depression outcomes, considering non-linear effects, and accounting for important confounders.

The Lancet Psychiatry *Commission on Psychological Treatments Research in Tomorrow’s Science* highlights the potential for technology to deliver novel interventions.27 Our findings here demonstrate the potential of consumer technologies to measure sleep parameters that may be predictive of deterioration and relapse in MDD, and provide targets for personalised intervention. These findings broaden the existing evidence base5 to include measurements of *variability* in sleep parameters. Accurate assessments of sleep variability are challenging to capture using conventional use of short-term PSG or ESM, which often exhibits subjective reporting bias.28 Our findings highlight the importance of within-person variability for predicting future depression outcomes, over and above absolute sleep duration. Furthermore, due to the longitudinal nature of the dataset, we were able to show that more variable sleep patterns preceded relapse, and may therefore be targetable in interventions to improve depression outcomes.

We found no evidence to support a link between sleep quality and depression outcomes.5 Wearable-derived estimates of sleep quality differ significantly from PSG estimates which are prone to underestimating sleep onset latency, and lack accuracy in determining wake/sleep epochs which has implications for estimates of sleep fragmentation and efficiency.29

Our work has several limitations. Firstly, despite our target of identifying 100 relapses during follow-up, we only recorded 38 events. This is fewer than expected given past literature,30 and potentially due to our inclusive eligibility criteria: RADAR-MDD aimed to identify predictors of remission, and therefore did not exclude participants based on their baseline depression severity. This resulted in many participants not being able to experience a relapse due to their pre-existing high levels of depression severity at enrolment. It is also possible that due to the remote nature of data collection we missed relapses. The consistency of our findings for the two depression outcomes, with the same direction of effects for all sleep features, suggests that the absence of evidence for some relapse models may represent a lack of statistical power rather than lack of association. A further limitation is that we required participants to have sleep information for at least 8 weekdays in the four weeks preceding each outcome assessment. This minimum was chosen to balance the need for reliable summaries of sleep parameters against the number of excluded observations. We could have increased the minimum number of days, but this would have resulted in fewer observations and reduced overall power.

Future analyses should extend this work to develop and validate prediction models for relapse based on sleep and other biomarkers collected via wearable devices. Such models would enable personalised interventions targeting individuals with more variable sleep duration or timing. Our analyses suggested that interventions to reduce sleep variability could reduce the population risk of depression relapse by 18% to 38%. While these estimates indicate the upper limit of what personalised interventions could potentially achieve in the future, if effective, it’s important to note that they rely on strong causal assumptions (such as the absence of unmeasured confounding) and should be interpreted with caution.

In conclusion, disordered sleep is a prevalent and disruptive feature of depression, which is challenging to capture. Our study demonstrates a role for commercially-available activity trackers to predict relapse risk and depression severity in people with established, recurrent MDD. Specifically, variability in sleep duration and sleep midpoint on weekdays may be useful targets for personalised intervention.

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# Supplementary Material

## Supplementary Material 1: Questionnaires implemented in RADAR-MDD

### 1.0 Baseline Assessments

#### 1.1 Socio-demographics

1. What is your date of birth?
2. What was your age at your last birthday?
3. Are you:
   1. Male
   2. Female
   3. Other
4. What gender were you assigned at birth?
   1. Male
   2. Female
5. Are you:
   1. Single
   2. Cohabiting with your partner
   3. Married and living with your husband/wife
   4. Married and separated from your husband/wife
   5. Divorced
   6. Widowed
6. Are you living with someone in the household as a couple?
7. Do you have children?
   1. No
   2. Yes
      1. How many?
      2. How many live with you?
      3. How old is your youngest child?
8. What is your ethnic group?

Choose one option that best describes your ethnic group or background

**White**

* 1. English/Welsh/Scottish/Northern Irish/British
  2. Irish
  3. Gypsy or Irish Traveller
  4. Any other White background, please describe

**Mixed/Multiple Ethnic Groups**

* 1. White and Black Caribbean
  2. White and Black African
  3. White and Asian
  4. Any other Mixed/Multiple ethnic background, please describe

**Asian/Asian British**

* 1. Indian
  2. Pakistani
  3. Bangladeshi
  4. Chinese
  5. Any other Asian background, please describe

**Black/African/Caribbean/Black British**

* 1. African
  2. Caribbean
  3. Any other Black/African/Caribbean background, please describe

**Other ethnic group**

* 1. Arab
  2. Any other ethnic groups, please describe

1. What country were you born in?
2. How old were you when you finished your continuous full-time education or college?
3. Did you drop out of school before the age of 15 before you received your qualification?
4. Have you got any qualifications of any sort?
5. Which if the following qualifications do you have?
   1. Degree level qualification or above
   2. A-Level or equivalent (HNDs, NVQ level 3, Highers)
   3. GCSE level or equivalent (O-level, NVQ level 1-2)
   4. Below GCSE level
   5. Other qualifications
   6. No qualifications
6. Are you currently receiving any of the following benefits in your own right, that is, where you are the named recipient?
   1. Jobseekers allowance
   2. Employment support allowance
   3. Income support
   4. Family credit/working families tax credit
   5. State pension
   6. State pension credit
   7. Incapacity benefit
   8. Statutory sick pay
   9. Disability living allowance/working allowance
   10. Other
   11. No benefits
7. Do you or anyone else in your household receive Housing Benefit, either directly, or by having it paid to you or on your behalf?
   1. No
   2. Yes
8. Which of the following represents your household’s annual gross income (income from all sources before deductions for income tax and national insurance
   1. Less than £15,000
   2. £15,000-£24,000
   3. £24,000-£40,000
   4. £40,000-£55,000
   5. More than £55,000
9. How many people contribute to the household income?
10. In which of these ways do you occupy this accommodation?
    1. Own outright
    2. Buying it with the help of a mortgage or loan
    3. Share Pay part rent and part mortgage (shared ownership)
    4. Rent it from
       1. Local Authority
       2. Voluntary sector
       3. Private landlord
    5. Live here rent-free (including rent-free in relative’s/friend’s property; excluding squatting)
    6. Squatting
11. How satisfied are you with this accommodation?
    1. Very dissatisfied
    2. Slightly dissatisfied
    3. Neither satisfied nor dissatisfied
    4. Fairly satisfied
    5. Very satisfied
12. Have there been times during the past year when you were seriously behind in paying within the time allowed for any of these items:
    1. Rent
    2. Gas
    3. Electricity
    4. Water
    5. Goods on hire purchase
    6. Mortgage repayments
    7. Council Tax
    8. Credit card payments
    9. Telephone
    10. Other loans
    11. None of these

#### 1.2 Social Environment

1. In a typical week, how many of the following people do you come into contact with? By contact we mean talking either face-to-face or by phone
   1. Brother/sister
   2. In-laws
   3. Other relatives
   4. Close friends
   5. Neighbours
   6. Co-workers
   7. Boss/supervisor
   8. Other acquaintances
   9. Helping professionals
   10. Member of the same group or club
2. If you were in trouble or needed help, is there someone you could contact who would help you?
   1. No
   2. Yes

#### 1.3 Medical history

1. Have any of the following family members ever had depression:
   1. Parents
   2. Siblings
   3. Children
2. Have any other relatives ever had depression?
   1. No
   2. Yes
3. If yes, who:
4. Do you smoke?
   1. No, I have never smoked
   2. I do no smoke at the moment, but I have smoked in the past
   3. Yes
5. If yes, how many cigarettes, cigars or rollups do you smoke per day?
6. How long after waking do you up do you have your first cigarette/cigar or rollup?
   1. Within 5 minutes
   2. 6-30 minutes
   3. 31-60 minutes
   4. After 60 minutes
7. How often per week do you engage in physical activities in your leisure time that cause sweating?
   1. Never
   2. Once per week
   3. Twice per week
   4. Three times per week
   5. Four times per week or more
8. On a normal day, how many hours of sleep do you get?
9. Do you have a long-standing illness or disability which has troubled you for a period of time or is likely to affect you over a period of time?
   1. No
   2. Yes
10. If yes, please indicate which of the following applies:
    1. Asthma
    2. Chronic bronchitis
    3. Other chest trouble
    4. Diabetes
    5. Stomach or other digestive disorder
    6. Liver trouble
    7. Kidney trouble
    8. Rheumatoid arthritis
    9. Osteoarthritis
    10. Heart trouble
    11. Cancer
        1. Specify –
    12. High blood pressure
    13. Multiple Sclerosis
    14. Epilepsy/fits
    15. Stroke
    16. Other neurological trouble
    17. Migraine
    18. Back trouble
    19. Other
        1. Specify –
11. Which of these is the most serious or important to you?
12. How old when you when this illness started?

#### 1.4 The Lifetime Depression Assessment Self-Report

The next questions are about periods of sadness and depression in your life.

1. Have you ever had a time in your life when you felt sad, empty or depressed for two weeks or longer**?**
   1. Yes
   2. No (**go to question 3**)
2. For the next question, think about a period of two weeks in your life when these feelings were worst. During this period of two weeks, how often did you feel this way?
   1. Almost every day, most of the day (**go to question 5**)
   2. Less often
3. Have you ever had a time in your life lasting two weeks or more when you lost interest in most things like hobbies, work, or activities that usually give you pleasure?
   1. Yes
   2. No (**go to question 29**)
4. For the next question, think about the period of two weeks in your life when your loss of interest was worst. During this period of two weeks, how often did you feel this way?
   1. Almost every day, most of the day (**go to question 7**)
   2. Less often (**go to question 29**)
5. During this period that you felt sad, empty or depressed, did you ever have a period lasting two weeks or more when you lost interest in most things like hobbies, work, or activities that usually give you pleasure?
   1. Yes
   2. No (**go to question 7**)
6. For the next question, think about the period of two weeks in your life when your loss of interest were worst. During this period of two weeks, how often did you feel this way?
   1. Almost every day, most of the day
   2. Less often

**People who have periods in which they feel sad, empty or depressed or lose interest, often have other problems at the same time. During this period of at least two weeks when you felt sad, empty or depressed or lost interest in things:**

1. …did you lack energy or feel tired more than usual?
   1. Yes
   2. No
2. … did you have less appetite than usual almost every day?
   1. Yes
   2. No
3. … did you lose weight without trying to, as much as a kilo a week for several weeks?
   1. Yes
   2. No (**go to question 11**)
4. About how much weight did you lose in those weeks? ­­\_\_\_kg

**During this period of at least two weeks when you felt sad, empty or depressed or lost interest in things:**

1. … did you have a much larger appetite than usual almost every day for two weeks or more?
   1. Yes
   2. Yes but only because of a pregnancy of growth spurt
   3. No
2. … did your eating increase so much that you gained weight, as much as a kilo a week for several weeks?
   1. Yes
   2. No (**go to question 14)**
3. About how much weight did you gain in those weeks? \_\_kg

**During this period of at least two weeks when you felt sad, empty or depressed or lost interest in things:**

1. …did you have trouble sleeping almost every night, either trouble falling asleep, waking in the middle of the night, or waking up too early?
   1. Yes
   2. No (**go to question 16**)
2. …did you wake up at least two hours before you wanted to, every day for at least two weeks?
   1. Yes
   2. No
3. …. were you sleeping too much almost every day?
   1. Yes
   2. No

**During this period of at least two weeks when you felt sad, empty or depressed or lost interest in things:**

1. … did you talk or move more slowly than is normal for you almost every day, in a way that other people have noticed?
   1. Yes, I talked or moved more slowly and other people did notice
   2. Yes, I talked or moved more slowly but other people did not notice
   3. No
2. … did you have to be moving all the time, that is, you couldn’t sit still and paced up and down or couldn’t keep your hands still when sitting, in a way that other people noticed?
   1. Yes, I had to be moving all the time and other people did notice
   2. Yes, I had to be moving all the time but other people did not notice
   3. No
3. During this period of two weeks, did you have a lot more trouble concentrating than usual?
   1. Yes
   2. No
4. During this period, were you able to make up your mind about things you ordinarily had no trouble deciding about?
   1. Yes
   2. No
5. People sometimes feel down on themselves, no good, or worthless. During this period of two weeks, did you feel guilty or worthless?
   1. Yes
   2. No
6. During this period of two weeks, did you think a lot about death – either your own, someone else’s, or death in general?
   1. Yes
   2. No

**For the next question, please think about the periods of at least two weeks in your life when you when you felt sad, empty or depressed or lost interest in things.**

1. Did any period lasting two weeks or longer seriously interfere with your ability to do your job, take care of your house or family, or take care of yourself?
   1. Yes
   2. No
2. About how long did the longest period like this last? *You may give an estimate.*

*\_\_\_*weeks

1. How many periods like this did you have in your life?
   1. 1
   2. 2 or more
2. Did you have a period like this in the last 12 months?
   1. Yes
   2. No
3. About how old were you the first time you had a period like this? (whether or not you received any help for it)

\_\_\_weeks

1. Did you ever tell a professional about these problems (for example a medical doctor, psychologist, social worker, nurse, or other helping professional)?
   1. Yes
   2. No
2. Have you ever had contact with a social service organisation for problems that you had that were not related to your physical health? (for example a mental health institute, psychologist, or social work)
   1. Yes
   2. Yes in the past, not anymore
   3. No
3. Please tick the disorders that you have ever been diagnosed with by a professional or medical doctor. *You can tick more than one answer.*
   1. Depression
   2. Bipolar disorder
   3. Schizophrenia or psychosis
   4. Eating disorder
   5. Anxiety disorder
   6. Panic disorder
   7. Obsessive compulsive disorder
   8. Post-traumatic stress disorder
   9. Phobia
   10. ADD/ADHD
   11. Alcohol addiction
   12. Drug addiction
   13. Other
       1. Specify –
   14. None (**go to question 32**)
4. Please tick the disorders that you have ever received treatment for by a professional or medical doctor. *You can tick more than one answer.*
   1. Depression
   2. Bipolar disorder
   3. Schizophrenia or psychosis
   4. Eating disorder
   5. Anxiety disorder
   6. Panic disorder
   7. Obsessive compulsive disorder
   8. Post-traumatic stress disorder
   9. Phobia
   10. ADD/ADHD
   11. Alcohol addiction
   12. Drug addiction
   13. Other
       1. Specify –
   14. None
5. Did you ever have the following treatments? *You can tick multiple answers.*
   1. Antidepressants
   2. Psychotherapy (for example cognitive behavioural therapy, interpersonal therapy or other consults with a psychologist or psychotherapist)
   3. Online help program or e-health intervention
   4. Running therapy or physical activity
   5. Light therapy
   6. Hospitalization in psychiatric hospital
   7. Electroconvulsive therapy (ECT)
   8. Other
      1. Specify –
   9. None of these treatments
6. What is your height in cm? *Please round your answer to the nearest whole number.*
7. What is your weight in kg? *Please round your answer to the nearest whole number.*

#### 1.5 Standardised Assessment of Personality

Please ask your patients the following questions. Only tick a response if the patient

thinks that the description applies *most of the time* and *in most situations*.

* + - 1. In general, do you have difficulty making and keeping friends?

1. No
2. Yes
3. Would you normally describe yourself as a loner?
4. No
5. Yes
6. In general, do you trust other people?
   1. No
   2. Yes
7. Do you lose your temper easily?
   1. No
   2. Yes
8. Are you normally an impulsive sort of person?
   1. No
   2. Yes
9. Are you normally a worrier?
   1. No
   2. Yes
10. In general, do you depend on others a lot?
    1. No
    2. Yes
11. In general, are you a perfectionist?
    1. No
    2. Yes

#### 1.6 Technology Usage

* + - 1. Do you currently own a smartphone?

1. No
2. Yes
3. If yes, what kind?
4. Android
   1. Specify make/model
5. iPhone
6. Who is your current contract with?
7. What is your monthly call, text and data allowance?
8. When is your contract due to expire?
9. If no to question 2, would you be willing to use a smartphone for the purposes of this research study?
10. No
11. Yes
12. Have you ever used a wearable fitness tracker before?
13. How long did you use it for?
14. Are you still using it?
15. No
16. Yes
17. If no, why did you stop using it?
18. How long ago did you stop using it?
19. Do you have a job that would prevent you from using a wrist-worn wearable during working hours?
20. Do you have a job that prevents you from using a mobile phone for long periods of time?

### 2.0 Primary Outcome Assessments

#### 2.1 Inventory of Depressive Symptomatology – Self-Reported (IDS-SR)

Please indicate the one response to each item that best describes you for the past seven days.

1. Falling asleep
   1. I never take longer than 30 minutes to fall asleep
   2. I take at least 30 minutes to fall asleep, less than half the time.
   3. I take at least 30 minutes to fall asleep, more than half the time.
   4. I take more than 60 minutes to fall asleep, more than half the time.
2. Sleep during the night
   1. I do not wake up at night
   2. I have a restless, light sleep with a few brief awakenings each night.
   3. I wake up at least once a night, but I go back to sleep easily.
   4. I awaken more than once a night and stay awake for 20 minutes or more, more than half the time.
3. Waking up too early
   1. Most of the time, I awaken no more than 30 minutes before I need to get up.
   2. More than half the time, I awaken more than 30 minutes before I need to get up.
   3. I almost always awaken at least one hour or so before I need to, but I go back to sleep eventually.
   4. I awaken at least one hour before I need to, and can’t go back to sleep.
4. Sleeping too much
   1. I sleep no longer than 7-8 hours per night without napping during the day.
   2. I sleep no longer than 10 hours in a 24 hour period, including naps.
   3. I sleep no longer than 12 hours in a 24-hour period, including naps.
   4. I sleep longer than 12 hours in a 24-hour period, including naps.
5. Feeling sad
   1. I do not feel sad
   2. I feel sad less than half the time
   3. I feel sad more than half the time
   4. I feel sad nearly all of the time.
6. Feeling irritable
   1. I do not feel irritable
   2. I feel irritable less than half the time
   3. I feel irritable more than half the time
   4. I feel extremely irritable nearly all of the time.
7. Feeling anxious or tense
   1. I do not feel anxious or tense
   2. I feel anxious (tense) less than half the time
   3. I feel anxious (tense) more than half the time
   4. I feel extremely anxious (tense) nearly all of the time.
8. Response of your mood to good or desired events
   1. My mood brightens to a normal level which lasts for several hours when good events occur.
   2. My mood brightens but I do not feel like my normal self when good events occur.
   3. My mood brightens only somewhat to a rather limited range of desired events.
   4. My mood does not brighten at all, even when very good or desired events occur in my life.
9. Mood in relation to the time of day
   1. There is no regular relationship between my mood and the time of day.
   2. My mood often relates to the time of day because of environmental events (e.g., being alone, working).
   3. In general, my mood is more related to the time of day than to environmental events.
   4. My mood is clearly and predictably better or worse at a particular time each day.

9a. Is your mood typically worse in the morning, afternoon or night? (select one).

9b. Is your mood variation attributed to the environment? (yes or no) (select one).

1. The quality of your mood
   1. The mood (internal feelings) that I experience is very much a normal mood.
   2. My mood is sad, but this sadness is pretty much like the sad mood I would feel if someone close to me died or left.
   3. My mood is sad, but this sadness has a rather different quality to it than the sadness I would feel if someone close to me died or left.
   4. My mood is sad, but this sadness is different from the type of sadness associated with grief or loss.

Please complete 11 or 12 (not both)

1. Decreased appetite
   1. There is no change in my usual appetite.
   2. I eat somewhat less often or lesser amounts of food than usual.
   3. I eat much less than usual and only with personal effort.
   4. I rarely eat within a 24-hour period, and only with extreme personal effort or when others persuade me to eat.
2. Increased appetite
   1. There is no change in my usual appetite.
   2. I feel a need to eat more frequently than usual.
   3. I regularly eat more often and/or greater amounts of food than usual.
   4. I feel driven to overeat both at mealtime and between meals.

Please complete either 13 or 14 (not both)

1. Within the last two weeks:
   1. I have not had a change in my weight
   2. I feel as if I’ve had a slight weight loss
   3. I have lost 2 pounds (1 kg) or more
   4. I have lost 5 pounds (2.5 kg) or more
2. Within the last two weeks:
   1. I have not had a change in my weight
   2. I feel as if I’ve had a slight weight gain
   3. I have gained 2 pounds (1kg) or more
   4. I have gained 5 pounds (2.5 kg) or more
3. Concentration/decision making
   1. There is no change in my usual capacity to concentrate or make decisions.
   2. I occasionally feel indecisive or find that my attention wanders.
   3. Most of the time, I struggle to focus my attention or to make decisions.
   4. I cannot concentrate well enough to read or cannot make even minor decisions.
4. View of myself
   1. I see myself as equally worthwhile and deserving as other people.
   2. I am more self-blaming than usual.
   3. I largely believe that I cause problems for others.
   4. I think almost constantly about major and minor defects in myself.
5. View of my future
   1. I have an optimistic view of my future.
   2. I am occasionally pessimistic about my future, but for the most part I believe things will get better.
   3. I’m pretty certain that my immediate future (1-2 months) does not hold much promise of good things for me.
   4. I see no hope of anything good happening to me anytime in the future.
6. Thoughts of death or suicide
   1. I do not think of suicide or death.
   2. I feel that life is empty or wonder if it’s worth living.
   3. I think of suicide or death several times a week for several minutes.
   4. I think of suicide or death several times a day in some detail, or I have made specific plans for suicide or have actually tried to take my life.
7. General interest
   1. There is no change from usual in how interested I am in other people or activities.
   2. I notice that I am less interested in people or activities.
   3. I find I have interest in only one or two of my formerly pursued activities.
   4. I have virtually no interest in formerly pursued activities.
8. Energy level
   1. There is no change in my usual level of energy.
   2. I get tired more easily than usual.
   3. I have to make a big effort to start or finish my usual daily activities (e.g. shopping, homework, cooking or going to work).
   4. I really cannot carry our most of my usual daily activities because I just don’t have the energy.
9. Capacity for pleasure or enjoyment (excluding sex)
   1. I enjoy pleasurable activities just as much as usual.
   2. I do not feel my usual sense of enjoyment from pleasurable activities.
   3. I rarely get a feeling of pleasure from any activity.
   4. I am unable to get pleasure or enjoyment from anything.
10. Interest in sex (please rate interest not activity)
    1. I’m just as interested in sex as usual.
    2. My interest in sex is somewhat less than usual or I do not get the same pleasure from sex as I used to.
    3. I have little desire for or rarely derive pleasure from sex.
    4. I have absolutely no interest in or derive no pleasure from sex.
11. Feeling slowed down
    1. I think, speak, and move at my usual rate of speed.
    2. I find that my thinking is slowed down or my voice sounds dull or flat.
    3. It takes me several seconds to respond to most questions and I’m sure my thinking is slowed.
    4. I am often unable to respond to questions without extreme effort.
12. Feeling restless
    1. I do not feel restless
    2. I’m often fidgety, wring my hands, or need to shift how I’m sitting.
    3. I have impulses to move about and am quite restless.
    4. At times, I am unable to stay seated and need to pace around.
13. Aches and pains
    1. I don’t have any feeling of heaviness in my arms or legs and I don’t have any aches or pains.
    2. Sometimes I get headaches or pains in my stomach, back or joints but these pains are only sometimes.
    3. It takes me several seconds to respond to most questions and I’m sure my thinking is slowed.
    4. I am often unable to respond to questions without extreme effort.
14. Other bodily symptoms
    1. I don't have any of these symptoms: heart pounding fast, blurred vision, sweating, hot and cold flashes, chest pain, heart turning over in my chest, ringing in my ears, or shaking
    2. I have some of these symptoms but they are mild and are present only sometimes.
    3. I have several of these symptoms and they bother me quite a lot.
    4. I have several of these symptoms and when they occur I have to stop doing whatever I am doing.
15. Panic/phobic symptoms
    1. I have no spells of panic of specific fears (phobia) (such as animals of heights)
    2. I have mild panic episodes or fears that do not usually change my behaviour or stop me from functioning.
    3. I have significant panic episodes or fears that force me to change my behaviour but do not stop me from functioning.
    4. I have panic episodes at least once a week or severe fears that stop me from carrying on my daily activities.
16. Constipation/diarrhoea
    1. There is no change in my usual bowel habits.
    2. I have intermittent constipation or diarrhoea which is mild.
    3. I have intermittent constipation or diarrhoea most of the time but it does not interfere with my day-to-day functioning.
    4. I have constipation or diarrhoea for which I take medicating or which interferes with my day-to-day activities.
17. Interpersonal sensitivity
    1. I have not felt easily rejected, slighted, criticised or hurt by others at all.
    2. I have occasionally felt rejected, slighted, criticised or hurt by others.
    3. I have often felt rejected, slighted, criticised or hurt by others, but these feelings have only had slight effects on my relationships or work.
    4. I have often felt rejected, slighted, criticised or hurt by others and these feelings have impaired my relationships and work.
18. Leaded paralysis/physical energy
    1. I have not experiences the physical sensation of feeling weighted down and without physical energy.
    2. I have occasionally experienced periods of feeling physically weighted down and without physical energy, but without a negative effect on work, school, or activity level.
    3. I feel physically weighted down (without physical energy) more than half the time.
    4. I feel physically weighted down (without physical energy) most of the time, several hours per day, several days per week.

#### 2.2 World Health Organisation Composite International Diagnostic Interview -Short Form

1. Since your last assessment, has there been a period when you felt sad, empty or depressed for two weeks or longer**?**
   1. Yes
   2. No (**go to question 3**)
2. For the next question, think about a period of two weeks since your last assessment when these feelings were worst. During this period of two weeks, how often did you feel this way?
   1. Almost every day, most of the day (**go to question 5**)
   2. Less often
3. Since your last assessment, has there been a period lasting two weeks or more when you lost interest in most things like hobbies, work, or activities that usually give you pleasure?
   1. Yes
   2. No (**go to question 26**)
4. For the next question, think about the period of two weeks since your last assessment when your loss of interest was worst. During this period of two weeks, how often did you feel this way?
   1. Almost every day, most of the day (**go to question 7**)
   2. Less often (**go to question 26**)
5. During this period that you felt sad, empty or depressed, did you have a period lasting two weeks or more when you lost interest in most things like hobbies, work, or activities that usually give you pleasure?
   1. Yes
   2. No (**go to question 7**)
6. For the next question, think about the period of two weeks since your last assessment when your loss of interest were worst. During this period of two weeks, how often did you feel this way?
   1. Almost every day, most of the day
   2. Less often

**People who have periods in which they feel sad, empty or depressed or lose interest, often have other problems at the same time. During this period of at least two weeks since your last assessment when you felt sad, empty or depressed or lost interest in things:**

1. …did you lack energy or feel tired more than usual?
   1. Yes
   2. No
2. … did you have less appetite than usual almost every day?
   1. Yes
   2. No
3. … did you lose weight without trying to, as much as a kilo a week for several weeks?
   1. Yes
   2. No (**go to question 11**)
4. About how much weight did you lose in those weeks? ­­\_\_\_kg

**During this period of at least two weeks since your last assessment when you felt sad, empty or depressed or lost interest in things:**

1. … did you have a much larger appetite than usual almost every day for two weeks or more?
   1. Yes
   2. Yes but only because of a pregnancy of growth spurt
   3. No
2. … did your eating increase so much that you gained weight, as much as a kilo a week for several weeks?
   1. Yes
   2. No (**go to question 14)**
3. About how much weight did you gain in those weeks? \_\_kg

**During this period of at least two weeks since your last assessment when you felt sad, empty or depressed or lost interest in things:**

1. …did you have trouble sleeping almost every night, either trouble falling asleep, waking in the middle of the night, or waking up too early?
   1. Yes
   2. No (**go to question 16**)
2. …did you wake up at least two hours before you wanted to, every day for at least two weeks?
   1. Yes
   2. No
3. …. were you sleeping too much almost every day?
   1. Yes
   2. No

**During this period of at least two weeks since your last assessment when you felt sad, empty or depressed or lost interest in things:**

1. … did you talk or move more slowly than is normal for you almost every day, in a way that other people have noticed?
   1. Yes, I talked or moved more slowly and other people did notice
   2. Yes, I talked or moved more slowly but other people did not notice
   3. No
2. … did you have to be moving all the time, that is, you couldn’t sit still and paced up and down or couldn’t keep your hands still when sitting, in a way that other people noticed?
   1. Yes, I had to be moving all the time and other people did notice
   2. Yes, I had to be moving all the time but other people did not notice
   3. No
3. During this period of two weeks, did you have a lot more trouble concentrating than usual?
   1. Yes
   2. No
4. During this period, were you able to make up your mind about things you ordinarily had no trouble deciding about?
   1. Yes
   2. No
5. People sometimes feel down on themselves, no good, or worthless. During this period of two weeks, did you feel guilty or worthless?
   1. Yes
   2. No
6. During this period of two weeks, did you think a lot about death – either your own, someone else’s, or death in general?
   1. Yes
   2. No

**For the next question, please think about the periods of at least two weeks since your last assessment when you when you felt sad, empty or depressed or lost interest in things.**

1. Did any period lasting two weeks or longer seriously interfere with your ability to do your job, take care of your house or family, or take care of yourself?
   1. Yes
   2. No
2. About how long did the longest period like this last? *You may give an estimate.*

*\_\_\_*weeks

1. Did you tell a professional about these problems (for example a medical doctor, psychologist, social worker, nurse, or other helping professional)?
   1. Yes
   2. No
2. Since your last assessment, have you ever had contact with a social service organisation for problems that you had that were not related to your physical health? (for example a mental health institute, psychologist, or social work)
   1. Yes
   2. No
3. Since your last assessment, have you been diagnosed with by a professional or medical doctor as having one of the following. *You can tick more than one answer.*
   1. Depression
   2. Bipolar disorder
   3. Schizophrenia or psychosis
   4. Eating disorder
   5. Anxiety disorder
   6. Panic disorder
   7. Obsessive compulsive disorder
   8. Post-traumatic stress disorder
   9. Phobia
   10. ADD/ADHD
   11. Alcohol addiction
   12. Drug addiction
   13. Other
       1. Specify –
   14. None (**go to question 32**)
4. Since your last assessment, have you received treatment for by a professional or medical doctor for any of the following. *You can tick more than one answer.*
   1. Depression
   2. Bipolar disorder
   3. Schizophrenia or psychosis
   4. Eating disorder
   5. Anxiety disorder
   6. Panic disorder
   7. Obsessive compulsive disorder
   8. Post-traumatic stress disorder
   9. Phobia
   10. ADD/ADHD
   11. Alcohol addiction
   12. Drug addiction
   13. Other
       1. Specify –
   14. None
5. Since your last assessment, have you received any of the following treatments: *You can tick multiple answers.*
   1. Antidepressants
   2. Psychotherapy (for example cognitive behavioural therapy, interpersonal therapy or other consults with a psychologist or psychotherapist)
   3. Online help program or e-health intervention
   4. Running therapy or physical activity
   5. Light therapy
   6. Hospitalization in psychiatric hospital
   7. Electroconvulsive therapy (ECT)
   8. Other
      1. Specify –
   9. None of these treatments
6. What is your weight in kg? *Please round your answer to the nearest whole number.*

### 3.0 Secondary outcome assessments/contextual variables

#### 3.1 – 8-Item Patient Health Questionnaire (PHQ8)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Not at all | Several days | More than half the days | Nearly every day |
| 1. Little interest or pleasure in doing things | 0 | 1 | 2 | 3 |
| 1. Feeling down, depressed or hopeless | 0 | 1 | 2 | 3 |
| 1. Trouble falling asleep, staying asleep, or sleeping too much. | 0 | 1 | 2 | 3 |
| 1. Feeling tired or having little energy. | 0 | 1 | 2 | 3 |
| 1. Poor appetite or over eating | 0 | 1 | 2 | 3 |
| 1. Feeling bad about yourself, or that you are a failure or have let yourself or your family down. | 0 | 1 | 2 | 3 |
| 1. Trouble concentrating on things, such as reading the newspaper or watching television. | 0 | 1 | 2 | 3 |
| 1. Moving or speaking so slowly that other people could have noticed. Or, the opposite – being so fidgety or restless that you have been moving around a lot more than usual. | 0 | 1 | 2 | 3 |

#### 3.2 Rosenberg Self-Esteem Scale (RSES)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Strongly agree | Agree | Disagree | Strongly disagree |
| 1. On the whole, I am satisfied with myself | 3 | 2 | 1 | 0 |
| 1. At times, I think I am no good at all. | 3 | 2 | 1 | 0 |
| 1. I feel that I have a number of good qualities | 3 | 2 | 1 | 0 |
| 1. I am able to do things as well as most other people. | 3 | 2 | 1 | 0 |
| 1. I feel I do not have much to be proud of. | 3 | 2 | 1 | 0 |
| 1. I certainly feel useless at times. | 3 | 2 | 1 | 0 |
| 1. I feel that I’m a person of worth, at least on an equal plane with others. | 3 | 2 | 1 | 0 |
| 1. I wish I could have more respect for myself. | 3 | 2 | 1 | 0 |
| 1. All in all, I am inclined to feel that I am a failure. | 3 | 2 | 1 | 0 |
| 1. I take a positive attitude toward myself. | 3 | 2 | 1 | 0 |

#### 3.3– 7-item Generalised Anxiety Disorder questionnaire (GAD7)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Not at all | Several days | More than half the days | Nearly every day |
| 1. Feeling nervous, anxious or on edge. | 0 | 1 | 2 | 3 |
| 1. Not being able to stop or control worrying. | 0 | 1 | 2 | 3 |
| 1. Worrying too much about different things. | 0 | 1 | 2 | 3 |
| 1. Trouble relaxing | 0 | 1 | 2 | 3 |
| 1. Being so restless that it’s hard to sit still. | 0 | 1 | 2 | 3 |
| 1. Becoming easily annoyed or irritable. | 0 | 1 | 2 | 3 |
| 1. Feeling afraid as if something awful might happen. | 0 | 1 | 2 | 3 |

#### 3.4 – The Work and Social Adjustment Scale

If you are retired or choose not to have a job for reasons unrelated to your depression, tick here:

1. Because of my depression, my ability to work is impaired.

0 1 2 3 4 5 6 7 8

Not at all Very severely, to the point where cannot work

1. Because of my depression, my home management (cleaning, tidying, shopping, cooking, looking after home or children, paying bills) is impaired.

0 1 2 3 4 5 6 7 8

Not at all Very severely

1. Because of my depression, my social leisure activities (with people, e.g. parties, bars, clubs, outings, visits, dating, home entertaining) are impaired.

0 1 2 3 4 5 6 7 8

Not at all Very severely

1. Because of my depression, my private leisure activities (done alone, such as reading, gardening, collecting, sewing, walking alone) are impaired.

0 1 2 3 4 5 6 7 8

Not at all Very severely

1. Because of my depression, my ability to form and maintain close relationships with others, including those I live with, is impaired.

0 1 2 3 4 5 6 7 8

Not at all Very severely

#### 3.5 – The Brief Illness Perceptions Questionnaire (BIPQ)

For the following questions, please mark the number that best corresponds to your views:

1. How much does your depression affect your life?

0 1 2 3 4 5 6 7 8 9 10  
No affect Severely affects  
at all my life

1. How long do you think your depression will continue?

0 1 2 3 4 5 6 7 8 9 10  
A very Forever  
short time

1. How much control do you feel you have over your depression?

0 1 2 3 4 5 6 7 8 9 10  
Absolutely Extreme amount  
no control of control

1. How much do you think your treatment can help your depression?

0 1 2 3 4 5 6 7 8 9 10  
Not at Extremely helpful  
all

1. How much do you experience symptoms from your depression?

0 1 2 3 4 5 6 7 8 9 10  
No symptoms Many severe  
at all symptoms

1. How concerned are you about your depression?

0 1 2 3 4 5 6 7 8 9 10  
Not at all Extremely  
concerned concerned

1. How well do you feel you understand your depression?

0 1 2 3 4 5 6 7 8 9 10  
Don’t understand Understand  
it at all very clearly

1. How much does your depression affect you emotionally? (e.g. does it make you angry, scared, upset or depressed?

0 1 2 3 4 5 6 7 8 9 10  
Not at all Extremely affected  
affected emotionally emotionally

### 4.0 Contextual variables

#### 4.1 – The Client Service Receipt Inventory (CSRI)

* 1. In the last 3 months, what consultations have you had with these practitioners:

(*Note: only record one-to-one contacts here; see next questions for inpatient care and investigations)*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Care provider | Have you used this service? | | Number of contacts in last 6 months | | Average length of contact |
|  | No | Yes | Depression related | Other reasons |  |
| General practitioner (GP) |  |  |  |  |  |
| Neurologist |  |  |  |  |  |
| Psychiatrist |  |  |  |  |  |
| Other doctor (specify) |  |  |  |  |  |
| Practice nurse |  |  |  |  |  |
| Pharmacist |  |  |  |  |  |
| Psychologist/therapist |  |  |  |  |  |
| Physiotherapist |  |  |  |  |  |
| Social worker |  |  |  |  |  |
| Community mental health worker |  |  |  |  |  |
| Acupuncturist |  |  |  |  |  |
| Osteopath |  |  |  |  |  |
| Homeopath/herbalist |  |  |  |  |  |
| Occupational therapist |  |  |  |  |  |
| Other (specify) |  |  |  |  |  |

* 1. In the last 3 months, have you been admitted as a hospital inpatient?
     1. No
     2. Yes
  2. If yes:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Admission | Hospital name, department, ward type | Reason for admission | Dates of admission | | Total days |
| 1st |  |  | Start | End |  |
| 2nd |  |  |  |  |  |
| … |  |  |  |  |  |

* 1. In the last 3 months, how many times have you attended A&E?
  2. In the last 6 months, have you received help from **friends or relatives**on any of the following tasks, as a consequence of health problems?

|  |  |  |
| --- | --- | --- |
| Type of help | Yes/No | Average number of hours help per week |
| Childcare (circle “no” if you have no children) |  |  |
| Personal care (e.g. washing, dressing) |  |  |
| Help in/around the house (e.g. cooking, cleaning etc.) |  |  |
| Help outside the home (e.g. shopping, transport) |  |  |
| Other (specify) |  |  |

* 1. Please list below use of any medications taken over the last 3 months.

|  |  |  |  |
| --- | --- | --- | --- |
| Drug name | Dosage (if known) | Dose frequency (e.g. daily) | For how long have you taken this drug? |
| 1. |  |  |  |
| 2. |  |  |  |
| … |  |  |  |

* 1. What is your current employment status?
     1. Employed full-time and working
     2. Employed full-time but ‘off-sick’
     3. Employed part-time
     4. Employed part-time but ‘off-sick’
     5. Unemployed
     6. Self employed and working
     7. Self-employed but ‘off-sick’
     8. Retired (because of age)
     9. Retired (because of ill health)
     10. Student
     11. Student but interrupted due to illness
     12. Housewife/husband
     13. Other \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  2. How many days (if any) have you had off work in the last 3 months because of any physical health problems?
  3. How many days (if any) have you had off work in the last 3 months because of any mental health problems?

#### 4.2 – The List of Threatening Experiences questionnaire

Since your last assessment, have any of the following happened:

|  |  |  |
| --- | --- | --- |
|  | Yes | No |
| You yourself suffered a serious illness, injury or an assault. |  |  |
| A serious illness, injury or assault happened to a close relative. |  |  |
| Your parent, child or partner died. |  |  |
| A close family friend or another relative (aunt, cousin, grandparent) died. |  |  |
| You had a separation due to marital/civil partnership difficulties |  |  |
| You broke off a steady relationship. |  |  |
| You had a serious problem with a close friend, neighbour or relative. |  |  |
| You became unemployed or you were seeking work unsuccessfully for more than one month. |  |  |
| You were sacked from your job |  |  |
| You had a major financial crisis |  |  |
| You had problems with the police and a court appearance. |  |  |
| Something you valued was lost or stolen:  At least one such event in the past 6 months.  At least one such event in the past 3 months |  |  |

#### 4.3 Medication Adherence

1. Are you currently taking medication?

Yes/No

If yes...

1. Are you currently taking medication for depression?

Yes/No

If yes…

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Always | Often | Sometimes | Rarely | Never |
| * + - 1. I forget to take my depression medication | 1 | 2 | 3 | 4 | 5 |
| 1. I change the dosage of my depression medication. | 1 | 2 | 3 | 4 | 5 |
| 1. I stop taking my depression medication for a while. | 1 | 2 | 3 | 4 | 5 |
| 1. I decide to skip my depression medication dosages. | 1 | 2 | 3 | 4 | 5 |
| 1. I only use my depression medication when I experience symptoms. | 1 | 2 | 3 | 4 | 5 |

## Supplementary Material 2: Supplementary tables and figures

**Supplementary Table 2.1.** Sociodemographic characteristics of excluded vs. included individuals at enrolment.

| **Characteristic** | **Excluded**, N = 233*1* | **Sample 1**, N = 213*1* | **Sample 2**, N = 390*1* |
| --- | --- | --- | --- |
| Age | 50 (32, 58) | 52 (34, 61) | 48 (32, 59) |
| IDS-SR total score | 32 (22, 44) | 19 (14, 23) | 30 (20, 42) |
| Missing | 10 | 0 | 0 |
| Male gender | 61 (26%) | 51 (24%) | 91 (23%) |
| Lives with partner | 95 (41%) | 122 (57%) | 196 (50%) |
| Years of education | 15·0 (12.0, 18.0) | 17·0 (14.0, 19.0) | 16·0 (13.0, 19.0) |
| Missing | 3 | 0 | 0 |
| Currently taking medication for depression | 162 (70%) | 133 (62%) | 264 (68%) |
| *1* Median (IQR); n (%) | | | |

**Supplementary Table 2.2.** Average marginal effects

*Notes.* This table presents the median of the posterior distribution and 89% credible intervals for marginal effects of each sleep feature and outcome. Adjusted estimates were adjusted for (at enrolment) age, gender, years of education, partnership status and (at each 3-monthly outcome assessment) atypical depression subtype, current medication use, alcohol use, and hours of daylight in the month before each outcome assessment.

|  | **Depression relapse** | | **Depression severity (IDS-SR)** | |
| --- | --- | --- | --- | --- |
| Unadjusted | Adjusted | Unadjusted | Adjusted |
| **Sleep Duration** | | | | |
| Total sleep time, median | 0·3 [-1.2, 1.9] | -0·4 [-2.0, 1.3] | 0·1 [-0.3, 0.4] | 0·2 [-0.2, 0.6] |
| Total sleep time, variance | 2·0 [0.5, 3.7] | 2·0 [0.4, 3.8] | 1·2 [0.8, 1.5] | 0·9 [0.5, 1.2] |
| Δ Total sleep time, median | 0·5 [-1.4, 2.4] | 0·5 [-1.3, 2.3] | 0·3 [-0.1, 0.6] | 0·3 [-0.1, 0.6] |
| Δ Total sleep time, variance | 2·4 [0.6, 4.5] | 3·0 [1.2, 5.0] | 0·7 [0.3, 1.1] | 0·7 [0.3, 1.0] |
| **Sleep Quality** | | | | |
| Sleep efficiency, median | -0·3 [-1.6, 1.1] | -0·7 [-2.1, 0.8] | -0·2 [-0.7, 0.1] | -0·2 [-0.6, 0.2] |
| Sleep fragmentation index, median | 0·7 [-0.7, 2.0] | 1·2 [-0.3, 2.6] | 0·4 [0.0, 0.8] | 0·3 [-0.1, 0.7] |
| Sleep onset latency, median | -0·3 [-2.8, 1.8] | -0·3 [-2.8, 1.9] | 0·1 [-0.5, 0.6] | -0·0 [-0.5, 0.5] |
| Sleep onset latency, variance | -0·3 [-1.5, 1.0] | -0·3 [-1.5, 1.0] | 0·1 [-0.2, 0.5] | 0·2 [-0.2, 0.5] |
| **Sleep Regularity** | | | | |
| Sleep midpoint, median | 1·9 [0.2, 3.5] | 1·3 [-0.4, 3.0] | 1·0 [0.5, 1.5] | 0·8 [0.4, 1.3] |
| Sleep midpoint, variance | 0·7 [-0.6, 2.0] | 0·6 [-0.8, 2.0] | 0·9 [0.5, 1.3] | 0·7 [0.3, 1.0] |
| Social jet lag | -0·6 [-2.4, 1.1] | -0·6 [-2.4, 1.1] | -0·2 [-0.6, 0.2] | -0·2 [-0.6, 0.2] |
| Δ Sleep midpoint, median | 1·3 [-0.9, 3.7] | 1·1 [-1.0, 3.4] | 0·6 [0.3, 1.0] | 0·5 [0.2, 0.9] |
| Δ Sleep midpoint, variance | 0·7 [-1.2, 2.7] | 1·0 [-0.9, 2.9] | 0·2 [-0.2, 0.5] | 0·1 [-0.3, 0.5] |

**Supplementary Table 2.3. Adjusted population attributable fractions for selected sleep features based on binary logistic regression models for relapse.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Sleep feature** | **PAF** | **95% CI** | |
| Total sleep time | -0·04 | -0·24 | 0·15 |
| Total sleep time, variance | 0·18 | -0·01 | 0·38 |
| Change in total sleep time variance | 0·37 | 0·17 | 0·56 |

**Supplementary Table 2.4.** Difference in ELPD (expected log pointwise predictive density utility score) between models with and without an interaction term between the sleep feature and atypical depression subtype.

*Note.* A ELPD difference of 4 is considered significant.

|  |  | Depression severity  (IDS-SR) | Depression  relapse |
| --- | --- | --- | --- |
|  |  | Δ ELPD | Δ ELPD |
| **Sleep Duration** | Total sleep time, median | -0.01 | -0.19 |
| Total sleep time, variance | -0.01 | -0.30 |
| Δ Total sleep time, median | -0.06 | -0.02 |
| Δ Total sleep time, variance | -0.02 | -0.13 |
| **Sleep Quality** | Sleep efficiency, median | -0.00 | -0.33 |
| Sleep fragmentation index, median | -0.11 | -0.01 |
| Sleep onset latency, median | -0.09 | -0.19 |
| Sleep onset latency, variance | -0.03 | -0.08 |
| **Sleep Regularity** | Sleep midpoint, median | -0.02 | -0.13 |
| Sleep midpoint, variance | -0.05 | -0.72 |
| Δ Sleep midpoint, median | -0.00 | -0.28 |
| Δ Sleep midpoint, variance | -0.01 | -0.21 |
| Social jet lag | -0.04 | -0.05 |

**Supplementary Table 2.5.** Average marginal effects for IDS-SR with sleep items removed

|  | **IDS-SR** Original scale | | **IDS-SR** Sleep items removed | |
| --- | --- | --- | --- | --- |
| Unadjusted | Adjusted | Unadjusted | Adjusted |
| **Sleep Duration** | | | | |
| Total sleep time, median | 0·1 [-0.3, 0.4] | 0·2 [-0.2, 0.6] | 0·1 [-0.3, 0.4] | 0·2 [-0.2, 0.5] |
| Total sleep time, variance | 1·2 [0.8, 1.5] | 0·9 [0.5, 1.2] | 1·0 [0.6, 1.3] | 0·7 [0.3, 1.0] |
| Δ Total sleep time, median | 0·3 [-0.1, 0.6] | 0·3 [-0.1, 0.6] | 0·2 [-0.1, 0.6] | 0·2 [-0.1, 0.6] |
| Δ Total sleep time, variance | 0·7 [0.3, 1.1] | 0·7 [0.3, 1.0] | 0·6 [0.2, 0.9] | 0·5 [0.2, 0.9] |
| **Sleep Quality** | | | | |
| Sleep efficiency, median | -0·2 [-0.7, 0.1] | -0·2 [-0.6, 0.2] | -0·1 [-0.5, 0.2] | -0·1 [-0.4, 0.3] |
| Sleep fragmentation index, median | 0·4 [0.0, 0.8] | 0·3 [-0.1, 0.7] | 0·3 [-0.1, 0.7] | 0·2 [-0.2, 0.6] |
| Sleep onset latency, median | 0·1 [-0.5, 0.6] | -0·0 [-0.5, 0.5] | 0·0 [-0.4, 0.5] | -0·1 [-0.5, 0.4] |
| Sleep onset latency, variance | 0·1 [-0.2, 0.5] | 0·2 [-0.2, 0.5] | 0·1 [-0.2, 0.5] | 0·1 [-0.2, 0.5] |
| **Sleep Regularity** | | | | |
| Sleep midpoint, median | 1·0 [0.5, 1.5] | 0·8 [0.4, 1.3] | 0·9 [0.4, 1.3] | 0·7 [0.3, 1.1] |
| Sleep midpoint, variance | 0·9 [0.5, 1.3] | 0·7 [0.3, 1.0] | 0·7 [0.4, 1.1] | 0·5 [0.2, 0.9] |
| Social jet lag | -0·2 [-0.6, 0.2] | -0·2 [-0.6, 0.2] | -0·1 [-0.4, 0.3] | -0·1 [-0.4, 0.3] |
| Δ Sleep midpoint, median | 0·6 [0.3, 1.0] | 0·5 [0.2, 0.9] | 0·4 [0.1, 0.8] | 0·4 [0.1, 0.7] |
| Δ Sleep midpoint, variance | 0·2 [-0.2, 0.5] | 0·1 [-0.3, 0.5] | 0·2 [-0.2, 0.5] | 0·2 [-0.2, 0.5] |

**Supplementary**

**Supplementary Figure 2.1.** Distribution of sleep features

Shape, arrow

Description automatically generated

**Supplementary Figure 2.2.** Distribution of sleep measures after transformation and scaling

Shape, arrow

Description automatically generated