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Mapping insomnia symptoms and circadian preferences to mental health problems in men and women across the lifespan

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ABSTRACT

This study identified subgroups in the general population based on combinations in three night-time insomnia symptoms and four dimensions of circadian preferences ("sleep profiles") and investigated the associations between sleep profiles and nine common mental health problems. The data came from the Lifelines cohort add-on study "Comorbid Conditions of ADHD" and included 37,716 individuals (aged 4-91 years) from the Dutch general population who completed a digital survey. Latent profile analysis was used to identify sleep profiles in twelve age-sex subgroups. Linear regression was used to investigate whether sleep profiles differ in mental health problems. Participants were classified into three sleep profiles: "Healthy Larks", who had early circadian preferences and no insomnia symptoms; "Sleepy Owls" with late circadian preferences and nonrestorative sleep; and "Sleepless Doves" with intermediate circadian preferences and severe insomnia symptoms. Compared to "Healthy Larks", all mental health problems were significantly more severe in "Sleepy Owls" and even worse in "Sleepless Doves". These associations were similar in men and women but weakened with age. However, "Sleepy Owls" and "Sleepless Doves" did not differ in heavy alcohol drinking, drug use, and smoking. Our findings strengthened the evidence for the universal role of healthy sleep in mental wellbeing.

1. Introduction

Insomnia symptoms affect up to 20% of the world population and often accompany and even predict the onset of common mental disorders, such as depression, anxiety, attention deficit hyperactivity disorder, and autism spectrum disorder (Hertenstein et al., 2019, Kocevska et al., 2021, Lam and Lam, 2021, Scott et al., 2021, Sivertsen et al., 2021). In fact, the criteria of insomnia disorder include daytime symptoms, such as inattention and mood disturbances, which overlap with the symptoms of common mental health problems (Riemann et al., 2022). There is also evidence, although scarce and less consistent, that suggests a link between poor sleep and other problems related to mental health, such as aggression (Kamphuis et al., 2014, Sisman et al., 2021) and substance use (Hertenstein et al., 2019, Leger et al., 2022). Insomnia symptoms and the mental health problems associated with them are also more prevalent in individuals with late circadian preferences (Coogan and McGowan, 2017, Leger et al., 2022, Lin et al., 2021, Randler and Vollmer, 2013, Robillard et al., 2015). Some studies suggested that circadian preferences may be associated with mental health problems only in the presence of sleep problems (Bradford et al., 2021, Cox and Olatunji, 2019, Lin et al., 2021, Tokur-Kesgin and Kocoglu-Tanyer, 2021, Zhou et al., 2021). The associations with mental health problems, however, can vary for different insomnia symptoms and dimensions of circadian preferences, and potentially for their specific combinations. For example, worse morning affect was more strongly associated with depression and anxiety than later sleep-wake time preferences, while the opposite applied to aggressive behavior and impulsivity (Carciofo, 2020, Hasler et al., 2022, Muzni et al., 2021, Randler and Vollmer, 2013). In another study, smoking was associated with difficulties initiating sleep and early morning awakenings, but not difficulties maintaining sleep (Chen et al., 2017). Despite prolific research on the associations between sleep behavior and mental health, several remaining gaps in the available evidence hinder our understanding of these interrelations. Given the high prevalence of insomnia symptoms, late circadian preferences, and mental health problems, especially in the younger population (Kocevska et al., 2021, Randler and Engelke, 2019, Solmi et al., 2022), filling these gaps and getting a better overview of these associations is crucial for unravelling the mechanisms behind them and developing

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preventing and treatment strategies.

First, the majority of earlier studies focused on a single mental health problem at a time, and cross-disorder associations cannot be directly compared due to the heterogeneity of the study samples and other methodological differences. Moreover, the broad and heterogeneous measures of insomnia-related symptoms (such as "sleep disturbances" and "sleep quality") and different operationalizations of circadian preferences ("midpoint of sleep", "bedtime", "morning affect") do not allow to establish if the associations with mental health are present for all, or only specific, insomnia symptoms and dimensions of circadian preference. Except for the possible mediating role of sleep quality in the relations between circadian preference and depression/anxiety, little is known about the combined effects of insomnia symptoms and circadian preferences on mental health. Second, the prevalence of both insomnia symptoms and circadian preferences highly varies between men and women and across the lifespan, which can affect the relationship between them and mental health problems (Kocevska et al., 2021, Randler and Engelke, 2019). For instance, late circadian preferences and poor sleep quality were found to be more strongly associated with mood problems in women compared to men (Kim et al., 2020, Muzni et al., 2021). To our best knowledge, no prior study included a sufficiently large sample of the general population which would allow to compare the associations between sleep and mental health between men and women across the lifespan, from childhood till old age. Third, there is limited and often contradictory evidence of how insomnia symptoms and circadian preferences are related to aggression and substance use. For example, the findings disagree on whether there is an association between insomnia symptoms and alcohol drinking (Graupensperger et al., 2021, Hertenstein et al., 2019, Leger et al., 2022, Plescia et al., 2021). Aggression was associated with insomnia symptoms and late circadian preferences in several studies, but these studies used highly specific subpopulations (younger people, forensic patients) and inconsistent operationalizations of aggression (such as physical aggression, conduct disorders, anger expression) (Bersani et al., 2022, Hwang et al., 2016, Kamphuis et al., 2014, Lange and Randler, 2011, Randler and Vollmer, 2013, Sisman et al., 2021). Thus, it remains unclear whether the associations between insomnia symptoms, circadian preferences, and mental health generalize to all common mental health problems in all ages groups and sexes, and if it concerns only specific combinations of insomnia symptoms and circadian preferences.

To address these gaps, our study aimed to 1) identify latent subgroups in the general population based on the combinations in three cardinal insomnia symptoms and four dimensions of circadian preference ("sleep profiles"), 2) investigate the associations between these sleep profiles and common mental health problems (including depression, anxiety, inattention, hyperactivity/impulsivity, autism, reactive aggression, drug use, alcohol drinking, and smoking) and how these associations would differ with age and sex. We hypothesized that the sample will be divided into distinct subgroups with differing sleep characteristics, and that the subgroup with the most severe insomnia symptoms would show more severe mental health problems.

2. Methods

The pre-registration describing all methods and rationale behind our choices (https://osf.io/fm4b3) and R scripts (https://osf.io/qkuze/files/) can be found on the Open Science Framework. A few deviations from the pre-registered plan are described in the Supplement Section 2.

2.1. Sample

The data was collected during a cross-sectional add-on study Comorbid Conditions of Attention Deficit Hyperactivity Disorder (CoCA) integrated in the Lifelines study. Lifelines is a multi-disciplinary prospective population-based cohort study examining in a unique three-generation design the health and health-related behaviors of 167,729 persons (aged 0-93) living in the North of The Netherlands (Scholtens et al., 2015, Sijtsma et al., 2021). It employs a broad range of investigative procedures in assessing the biomedical, socio-demographic, behavioral, physical and psychological factors which contribute to the health and disease of the general population, with a special focus on multi-morbidity and complex genetics. Between 2006-2013, the first participants (N=81,652 aged 25-50 years) were invited by their general practitioners. The next participants were invited by their participating family members (N=64,489 aged 6 months - 93 years), and the remaining participants self-registered through the Lifelines' website (N=21,588 aged 18-93 years) (Scholtens et al., 2015). Participants with very severe illness, limited life expectancy (<5 years), or insufficient understanding of Dutch were excluded. Lifelines fairly represents the Northern Dutch general population, with small differences in demographics and general health (Klijs et al., 2015). Compared to the total population in northern Netherlands, Lifelines over-represents middle-aged adults and somewhat under-represents immigrants and those with lower educational attainment (Klijs et al., 2015). The CoCA sample comprises a subset of 37,727 Lifelines participants aged 4-91 years. For the current study, we included the CoCA participants who completed the sleep- and most of the mental health-related survey (N=37,027, around 98% of the full CoCA sample). All Lifelines participants with internet access were invited to the CoCA study between 2017-2019. Most demographic differences between the CoCA and Lifelines participants were small to negligible, but CoCA participants were somewhat older than those of Lifelines ($mean_{CoCA}$=48.86±15.90, $mean_{Lifelines}$=44.66±3.10; Cohen's d=0.29). Lifelines and CoCA were approved by the University Medical Center Groningen's ethics committee. All participants or their legal representatives gave their informed consent.

2.2. Variables and measuring instruments

Sex of the participants was classified as male or female. Age was measured in years and stratified into children (aged 4-12 years), adolescents (13-17), young adults (18-34), middle-aged adults I (35-49), middle-aged adults II (50-64) and older adults (≥65). The stratification of the sample by age and sex was done to account for the expected qualitative differences in sleep characteristics across age and between men and women in the latent profile analyses. The division of middle-aged adults into two subgroups was chosen due to previous research showing that women who reached menopause, unlike men of the same age, tend to have more severe, or different, sleep problems (Kocevska et al., 2021, Morssinkhof et al., 2020). All age-sex subgroups comprised a large number of individuals (N=806-9,115), except a relatively small subsample of adolescents (n_{boys}=267; n_{girls}=277).

Among socio-economic characteristics, household income was measured as net monthly salary in euro. Educational attainment varied between the categories of not finishing primary education (1) to finishing a university degree (8). Occupational prestige was based on the International Standard Classification of Occupations 2008, where higher values (ranging from 0 to 100) indicated a more prestigious job (Westerman, 2008). Neighbourhood socioeconomic status was based on the

inhabitants' average educational level, income and job prospective; the scores are centered around zero (the average) and vary between around -8 to +3, where the higher values corresponded to higher status(Socio-economic status (SES), 2022). For participants aged <25 years, these variables were calculated as an average of their parents. Employment status (Broekstra et al., 2021) was classified as unemployed (all reasons except retirement), employed (paid work), or retired.

Our main variables included three night-time insomnia symptoms, four dimensions of circadian preferences, and nine common mental health problems[1], each described in detail in Table 1. All main variables were scaled as a continuum from no to most severe symptoms. Total scores were calculated as means of all relevant items. All numeric variables, except substance use, were rescaled to range between 0-4 points to allow direct comparison of the estimated parameters across the diagnostic categories and across age groups. We measured hyperactivity/impulsivity and inattention separately because these dimensions of attention deficit hyperactivity disorder may be related to different sleep problems (Díaz-Román et al., 2016). Some drug types can also vary in their effect on sleep (Boutrel and Koob, 2004, Kwon et al., 2019), so in addition to general drug use, we also analyzed the use of three drug subgroups, including cannabis, stimulants, and hallucinogens. In addition, participants were divided into those with and without 'probable clinical insomnia' (a score of ≥6 points for those younger than 65 years, or ≥7 for 64+ years) based on the cumulative severity of their insomnia symptoms (Broman et al., 2008; Hellström et al., 2010); this variable was used to illustrate that participants in some sleep profiles have insomnia symptoms that are severe enough to qualify for insomnia disorder according to a screening test. Similarly, participants were divided into those with and without "high" severity of mental health problems: 10% of the sample with the highest scores on the corresponding continuously measured mental health problem were put in the "high" severity group. This division was used to show how participants with very high severity of mental health problems were divided among the sleep profiles, which aids in the interpretation of the findings beyond more statistically-oriented effect sizes.

2.3. Statistical analysis

All analyses were performed in R Studio version 2023.03.0, R 4.2.3 for MacOS using the "Mclust" (Scrucca et al., 2016), "nnet" (Venables and Ripley, 2002), and "pscl" (Zeileis et al., 2008) packages. As preliminary analyses, we tested the correlations between all continuous variables, separately in men and women.

In the first part of the main analyses, we used latent profile analysis (LPA) to identify subgroups of individuals who have a similar scoring pattern for the three insomnia symptoms and four circadian preferences ("sleep profiles"). LPA is a mixture modelling technique which searches for unobserved, qualitatively different subgroups (latent profiles) within a sample (Spurk et al., 2020). We ran separate models for 2-4 classes in each age-sex subgroup using the "EEI" (i.e., diagonal distribution, equal volume, equal shape, orientation aligned with coordinate axes) parameterization of the within-group covariance matrix and the corresponding geometric characteristics, which corresponds to the default parameterization of LPA in MPlus (see (Scrucca et al., 2016) for a detailed explanation). We then selected the model with the optimal number of profiles, which was based on 1) the best model fit based on the lowest fit indices, including log-likelihood, Bayesian information criterion, and integrated complete data likelihood; 2) a sufficient sample size of the smallest sleep profile; and 3) meaningfulness of the sleep profiles. We strived for a minimal sample size of 64 persons per sleep profile based on the a priori power analysis in G*Power (version 3.1.9.6), which would be sufficient for detecting medium-sized differences between sleep profiles with a power of 0.80 in the following regression analyses. The meaningfulness of sleep profiles was determined based on their distinction in all age-sex subgroups. This was quantified by the certainty with which persons could be allocated to a certain profile; an allocation to a sleep profile was certain if a posterior probability was ≥0.80 and classification uncertainty ≤0.50 (Spurk et al., 2020, Zhang et al., 2020).

In the second part, we used sleep profiles (predictor) to predict the severity of various mental health problems (outcomes) in univariate regression models. Scores on depression, anxiety, reactive aggression, autism, inattention, and hyperactivity/impulsivity were standardized before the analyses. As sleep profiles were rather similar across age-sex subgroups in earlier analyses, we ran the regression models on the unstratified sample. Classification uncertainties were added to the models as weights (Sinha et al., 2021). Additional predictors included age, sex, and the three-way interactions between age, sex, and sleep profiles. Symptom severity of depression, anxiety, reactive aggression, autism, inattention, and hyperactivity/impulsivity was predicted using linear regression models. The severity of drug use, alcohol drinking, and smoking was predicted using zero-inflated negative binomial logistic regression. The differences were considered statistically significant if the *p*-value was lower than 0.05. False discovery rate method was used to correct the *p*-values for multiple comparisons. The clinical significance of the differences was judged by the effect size estimates. In linear regression models, the effect size was indicated by a standardized *beta* coefficient: one unit increase in the predictor variable, or a comparison to the reference in the case of a categorical predictor, results in an increase by *beta* standard deviations in the outcome variable. The effect size heuristics are as follows: $beta<0.3$ can be interpreted as a small effect, $beta=0.3$-0.5 as a medium effect and $beta\geq0.5$ as a large effect (Nieminen, 2022). The effects described with Cohen's *d* can be considered small if $d\leq0.5$, medium if $d=0.5$-0.8, and large if $d\geq0.8$.

In the sensitivity analyses, the covariates also included socio-economic characteristics, which were shown to be associated with both sleep and mental health (Generaal et al., 2019, Kocevska et al., 2021, Weinberg et al., 2019). In addition, we explored the associations between sleep profiles and several additional outcomes, including the categories of smokers/non-smokers (using logistic regression), users/non-users for each drug subgroup, light/moderate/heavy alcohol drinkers (multinomial logistic regression), and the scores on anxiety and depression that excluded the items related to sleep problems (linear regression).

3. Results

3.1. General characteristics

For most analyses, our analytical sample size comprised 37,027 individuals. Sizes of the age-sex subgroups varied between N=267 and 9,115 with the smallest sample size for male adolescents and the largest for female in the second group of middle-aged adults. Approximately half of children, adolescents and older adults were female (46-51%), but females prevailed among young and middle-aged adults (59-67%). Since there was no substance use reported in children, they were excluded from the analyses of alcohol drinking, drug use, and smoking, in which case the analytical sample sizes were smaller (N=35,212-35,392). There was also more missingness in the data used for the sensitivity analyses:

[1] In our study, "mental health problems" are used as an umbrella term that includes a broad range of symptoms of mental disorders included in the Diagnostic and Statistical Manual of Mental Disorders (DSM). Notably, when measured on a severity spectrum, these symptoms may be absent or "subclinical", i.e., too mild to qualify for an actual psychiatric diagnosis, and therefore, not necessarily constitute a "problem". For example, attention deficit hyperactivity disorder and autism spectrum disorder in their milder forms can be considered as signs of neurodiversity rather than a neurodevelopmental disorder. Similarly, moderate use of psychoactive substances (including tobacco, alcohol, and certain recreational drugs) are widely accepted socially and cannot be considered a substance use disorder in the majority of the general population.

Table 1
Detailed description of the measuring instruments and variables used in the study.

Subgroup/Variable name	Instrument and Units			Score range
	Children	Adolescents	Adults	
Circadian preferences ("eveningness")				
(Preferred) Bedtime (Preferred) Wake time (Negative) Morning affect Peak performance time	The multi-item morningness-eveningness scale from the parent-reported Children's Chronotype Questionnaire (CCTQ) Werner et al. (2009) Note: A comprehensive review of these instruments and our reasoning behind the division into four factors (dimensions) is included in the *Supplement* Section 1.		Composite Scale of Morningness (CSM) Smith et al. (1989)	0 – 4 points
(Night-time) Insomnia symptoms				
Difficulties initiating sleep Difficulties maintaining sleep Nonrestorative sleep	The version of the Minimal Insomnia Scale (MISS) adapted for parent-report	Minimal Insomnia Scale (MISS) Broman et al. (2008), Hedin et al. (2022), Hellström et al. (2010), Westergren et al. (2015) Note: For adolescents who did not have self-reported version, the values were imputed based on the available parent-reported data.		0 – 4 points
Mental health problems				
Depression Anxiety	Child Behavior Checklist (CBCL) Achenback and Rescorla (2001)	Youth Self-Report (YSR) Achenback and Rescorla (2001)	Digital version of the MINI-international Neuropsychiatric Interview Sheehan et al. (1998)	0 – 4 points
Reactive aggression			Adult Self Report (ASR) Achenbach and Rescorla, 2003	0 – 4 points
Inattention Hyperactivity/ impulsivity	Parent-Report Questionnaire on Attention Problems and Hyperactivity (ADHD Rating Scale-IV) Kooij et al. (2005)	ADHD DSM-IV rating scale DuPaul et al. (1998)		0 – 4 points
Autism	Children's Social Behaviour Questionnaire (CSBQ) Hartman et al. (2006)		Adult Social Behaviour Questionnaire (ASBQ) Horwitz et al. (2016)	0 – 4 points
Alcohol drinking	Reported by their parents as the frequency of "drinking alcohol without the consent of older people" ranging from 1 ("never") to 3 ("often"), or 4 ("not applicable")	Reported as the frequency of drinking alcoholic drinks in the past month, with response options ranging between 1 for "not this month" and 7 for "6-7 days a week", and the number of glasses drunk on an average drinking day Monthly alcohol drinking was calculated as the average number of glasses per month, and additionally divided it into three categories of light (<12 drinks per month), moderate (<32 for women and <60 for men) and heavy drinkers (≥32 for women and ≥60 for men)		0 – *Infinity* drinks/ month, orlight/ moderate/heavy drinker
Drug use	Parents reported how frequently their child "uses drugs" ranging from 1 ("never") and 3 ("often"), or 4 ("not applicable")	Reported as "yes", "no", or "I do not want to answer", and how often they used each of the drug types (cannabis, amphetamines, cocaine, heroin, psilocybin or LSD, and ecstasy) in the last year, which ranged between 1 ("never") and 8 ("40 times or more") Approximate times of using any of these drug types per year was calculate based on these data Based on the International Drug Evaluation and Classification Program, drug use was divided into use of specific drug subgroups, including cannabis products (weed, marijuana, or hashish), stimulants (amphetamines and cocaine), and hallucinogens (psilocybin/LSD and ecstasy)		0 – *Infinity* times/year, or 0 = Non-user; 1 = User
Smoking	Smoking in children was reported by their parents as a frequency of "smoking, chewing, or snorting tobacco" ranging from 1 ("never") to 3 ("often"), or 4 ("not applicable")	Reported as the frequency of smoking tobacco ranging from 1 ("no") to 3 ("every day") For adolescents without self-reported data, we imputed values based on the available parent-report data The number of cigarettes smoked per day was reported during the wave 2b of the general Lifelines study		0 = Non-smoker; 1 = Smoker, or 0 – *Infinity* cigarettes/ day

11.3% for household income, 2.8% occupational prestige, 2.5% educational attainment, and 2.7% for neighborhood socio-economic status. Most participants had no to very low insomnia symptoms, with the highest scores in female adults (Supplement Table S1). Circadian preferences were relatively early in children, late in adolescents and young adults, and more intermediate in middle-aged and older adults across all dimensions. The correlations between all sleep characteristics and most mental health problems were low to moderate and statistically significant in both men and women (Fig. 1). As an exception, drug use and smoking were not correlated with difficulties maintaining sleep, and alcohol drinking was not correlated with morning affect, difficulties initiating sleep, and nonrestorative sleep.

3.2. Sleep profiles based on the combinations of insomnia symptoms and circadian preferences

3.2.1. The choice of the best fitting latent profile model based on the predefined criteria

The classification into sleep profiles was based on the best fitting latent profile model which was chosen using the predetermined set of criteria as explained in Methods. First, the lowest fit indices (including log-likelihood, Bayesian information criterion and Integrated Complete-data Likelihood) favorited the two- and three-profile models (Supplement Table S2). Second, the minimal sample size limitation to secure adequate statistical power in the regression analyses no longer applied because the consistency of sleep profiles across age-sex subgroups in the two- and three-profile models made the stratification by age and sex in

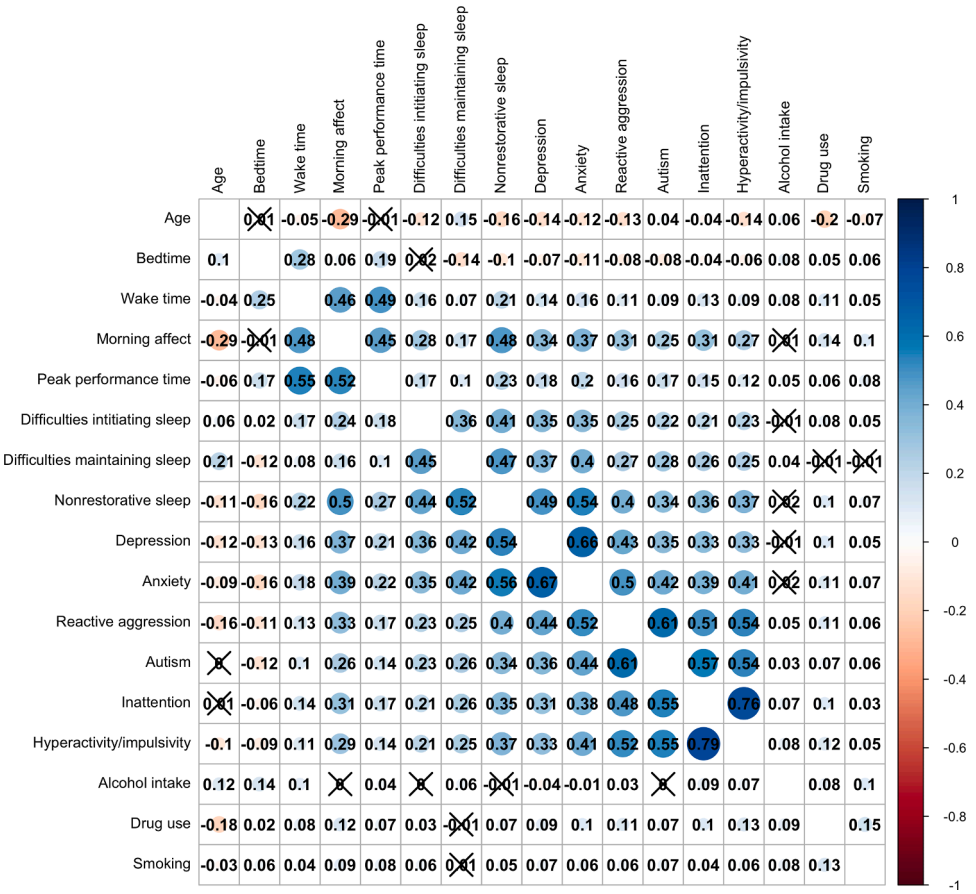

Fig. 1. Correlations between the main variables in men and women
Brighter color indicates a stronger negative (red) or positive (blue) correlation between the pair of variables in men (top right) or women (bottom left). Numbers indicate the strength of the association measured as a correlation coefficient (Spearman's rho). A cross indicates that the correlation was not statistically significant at the significance level of 0.05.

the subsequent use of regression models unnecessary (the smallest sleep profile size in the unstratified sample was N=5,309). Third, the interpretability of the sleep profiles was the easiest for the two- and three-profile models. Unlike the two-profile model (Fig. S1), the three-profile model separated those with relatively late circadian preferences and mildly nonrestorative sleep from those with more intermediate circadian preferences and severe insomnia symptoms (Fig. 2). The four-profile model (Fig. S2) tended to also distinguish those with severe insomnia symptoms and either relatively early or late circadian preferences, but these sleep profiles were inconsistent across age-sex subgroups. Classification uncertainty estimates further supported a more robust distinction of the sleep profiles in the three-profile model for all age-sex subgroups: mean uncertainty in the three-profile model ranged between 0.02 and 0.11, with only up to 1.61% of the subsample having uncertainty $\geq$0.50, and posterior probabilities exceeded 0.80 for most participants, i.e., 77-92% of the respective subsample (Supplement Table S3). Thus, the three-profile model was chosen as the best compromise between the less informative two-profile model and less consistent four-profile model.

3.2.2. *Description of the sleep profiles from the final model*

The general patterns in the scores in the three-profile model were remarkably consistent across age-sex subgroups, as can be seen in Fig. 2. The first sleep profile included participants with hardly any insomnia symptoms and the earliest circadian preferences on all dimensions, and thus, these participants were labelled "Healthy Larks". Participants in the second sleep profile had the latest circadian preferences and some insomnia symptoms, including nonrestorative sleep and, in younger people, difficulties initiating sleep; hence, they were labelled "Sleepy Owls". Participants in the third profile had similarly high scores on all three insomnia symptoms and their circadian preferences varied depending on the dimension (early bedtimes, intermediate wake time and peak performance time, and late in terms of negative morning affect); these participants were labelled "Sleepless Doves".

The proportions of participants classified into each sleep profile also remained similar across age-sex subgroups (*Supplement Table S4*): "Healthy Larks" were always the largest profile (on average, 62% of the whole sample) compared to the relatively rare "Sleepy Owls" (27%) and " Sleepless Doves" (12%). Women tended to have a higher proportion of "Sleepy Owls" and " Sleepless Doves" compared to men of the same age group: for example, 19.9% of female and only 5.2% of male adolescents were " Sleepless Doves". This sex difference was less pronounced among young and middle-aged adults, with a rather even distribution of persons between men and women (Supplement Table S4). Compared to the other sleep indicators used for classification, differences between sleep profiles in bedtime were inconsistent and very small.

Participants from these three sleep profiles significantly differed in their average socioeconomic, sleep, and mental health characteristics: Compared to "Healthy Larks" and "Sleepy Owls", "Sleepless Doves" had significantly lower educational attainment (Cohen's d=-0.13 and -0.24, respectively, both $p<0.001$), household income (both d=-0.16, $p<0.001$), and occupational prestige (d=-0.12 and -0.17, $p<0.001$). "Sleepless Doves" had considerably more severe insomnia symptoms than "Healthy Larks" and "Sleepy Owls" (d=1.52-2.65 depending on the given symptom, all $p<0.001$). In fact, 62% of "Sleepless Doves" had probable clinical insomnia, compared to only 0.3% and 2.6% in the

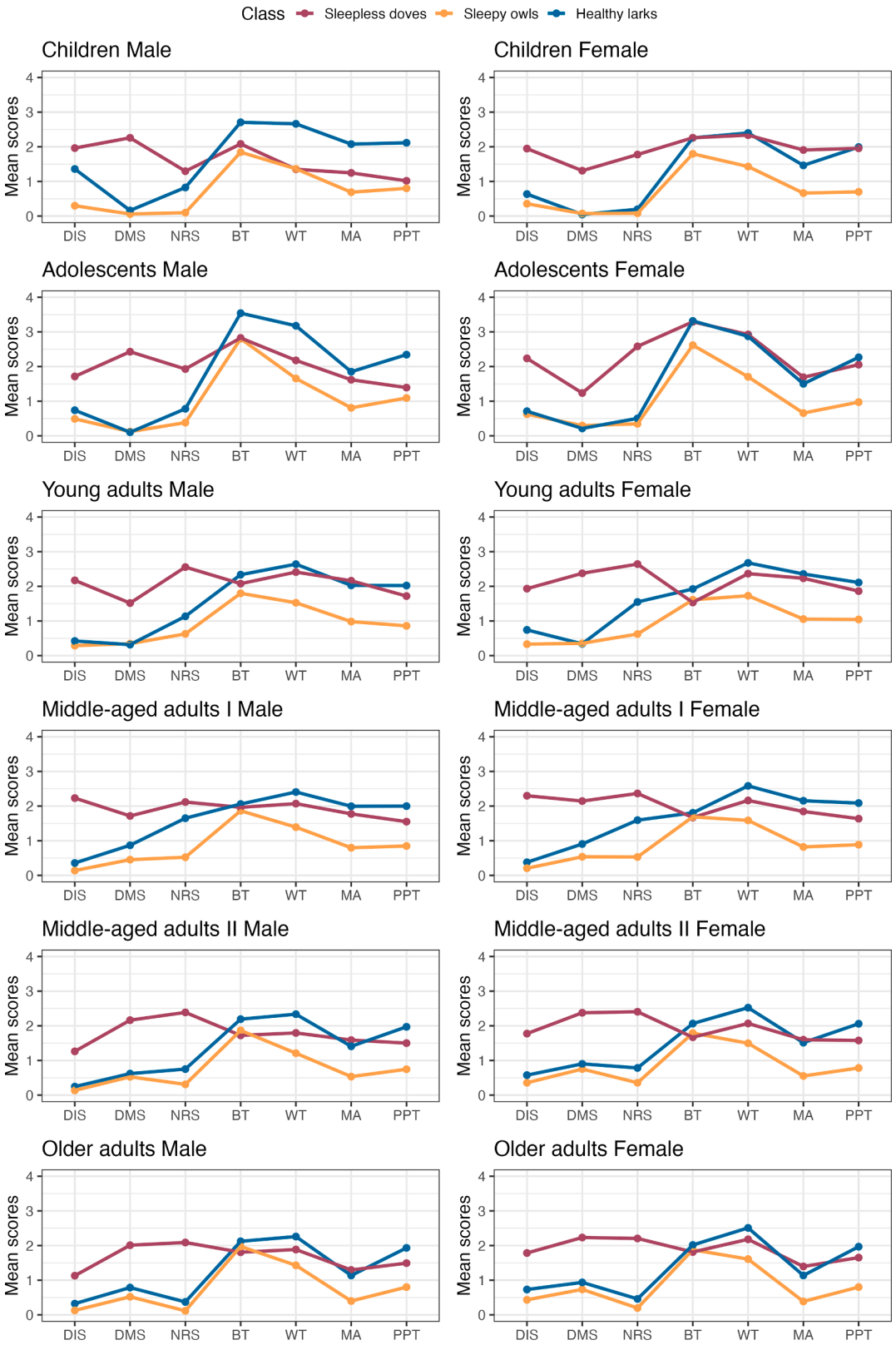

Fig. 2. Sleep profiles derived with latent profile analyses based on three insomnia symptoms and four circadian preferences per age-sex subgroup
The colored lines correspond to average scores (Y-axis) of each sleep profile on different insomnia symptoms and dimensions of circadian preference (X-axis). Abbreviations: DIS = difficulties initiating sleep; DMS = difficulties maintaining sleep; NRS = nonrestorative sleep; BT = Bedtime; WT = Wake time; MA = Morning affect; PPT = peak performance time.

other two profiles ($p<0.001$). Furthermore, all profiles significantly differed from one another in their circadian preferences: "Sleepy Owls" and "Sleepless Doves" had similarly worse morning affect than "Healthy Larks" ($d=1.57$ and 1.44, $p<0.001$). "Sleepy Owls" uniformly had the latest circadian preferences in all four dimensions. "Sleepless Doves" had the earliest bedtime, whereas "Healthy Larks" had the earliest wake time and peak performance time. A detailed comparison of sleep profiles by their demographic, sleep, and mental health characteristics can be found in Table 2.

In the following regression analyses, these three sleep profiles were used as a predictor of various mental health problems.

3.3. Associations between sleep profiles and mental health problems

Compared to "Healthy Larks" and "Sleepy Owls", "Sleepless Doves" included considerably more participants in the high symptom severity groups (i.e., the upper 10% of each score distribution), which applied to the highest scores on depression, anxiety, reactive aggression, inattention, hyperactivity/impulsivity, and autism (Table 2): only up to 7% of "Healthy Larks" and 12-16% of "Sleepy Owls" were in the high symptom

Table 2
Descriptive statistics for the sleep-related characteristics and mental health problems of the sample and the three sleep profiles.

	Healthy larks (N=23244)	Sleepy owls (N=8474)	Sleepless Doves (N=5309)	HL-SO	HL-SD	SO-SD	Overall (N=37027)
Age (years)	49.00 (15.69)	48.65 (16.48)	49.91 (13.67)	d=-0.02$^{.09}$	d=0.06$^{<.001}$	d=0.08$^{<.001}$	49.05 (15.61)
Sex				OR=1.32$^{<.001}$	OR=1.56$^{<.001}$	OR=1.18$^{<.001}$	
Male	10547 (45.4%)	3272 (38.6%)	1841 (34.7%)				15660 (42.3%)
Female	12697 (54.6%)	5202 (61.4%)	3468 (65.3%)				21367 (57.7%)
Educational attainment	5.68 (1.48)	5.84 (1.49)	5.48 (1.50)	d=0.11$^{<.001}$	d=-0.13$^{<.001}$	d=-0.24$^{<.001}$	5.69 (1.49)
Employment status				V=0.05$^{<.001}$	V=0.08$^{<.001}$	V=0.08$^{<.001}$	
Unemployed	1632 (7.0%)	785 (9.3%)	719 (13.5%)				3136 (8.5%)
Employed	12439 (53.5%)	4048 (47.8%)	2614 (49.2%)				19101 (51.6%)
Retired	2483 (10.7%)	1073 (12.7%)	440 (8.3%)				3996 (10.8%)
Household income (euro)	1717.22 (515.61)	1718.98 (526.51)	1634.12 (541.73)	d=0.0$^{0.80}$	d=-0.16$^{<.001}$	d=-0.16$^{<.001}$	1705.86 (522.71)
Occupational prestige	45.66 (13.08)	46.30 (13.10)	44.08 (13.33)	d=0.05$^{<.001}$	d=-0.12$^{<.001}$	d=-0.17$^{<.001}$	45.58 (13.14)
Neighborhood SES	-0.54 (1.06)	-0.55 (1.12)	-0.59 (1.09)	d=-0.01$^{.41}$	d=-0.05$^{.003}$	d=-0.03$^{.06}$	-0.55 (1.08)
Difficulties initiating sleep	0.25 (0.51)	0.49 (0.70)	1.82 (1.05)	d=0.39$^{<.001}$	d=1.90$^{<.001}$	d=1.49$^{<.001}$	0.53 (0.85)
Difficulties maintaining sleep	0.54 (0.73)	0.73 (0.81)	2.16 (0.95)	d=0.25$^{<.001}$	d=1.92$^{<.001}$	d=1.62$^{<.001}$	0.82 (0.96)
Nonrestorative sleep	0.38 (0.60)	0.99 (0.93)	2.35 (0.86)	d=0.78$^{<.001}$	d=2.65$^{<.001}$	d=1.52$^{<.001}$	0.80 (1.00)
Probable clinical insomnia[a]	60 (0.3%)	222 (2.6%)	3294 (62.0%)	OR=10.35$^{<.001}$	OR=654.59$^{<.001}$	OR=62.40$^{<.001}$	3576 (9.7%)
Morning affect	0.65 (0.52)	1.68 (0.77)	1.69 (0.88)	d=1.57$^{<.001}$	d=1.44$^{<.001}$	d=0.01$^{.50}$	1.04 (0.82)
Bed time	1.82 (0.48)	2.08 (0.61)	1.75 (0.65)	d=0.48$^{<.001}$	d=-0.11$^{<.001}$	d=-0.52$^{<.001}$	1.87 (0.55)
Wake time	1.46 (0.61)	2.50 (0.59)	2.08 (0.81)	d=1.73$^{<.001}$	d=0.87$^{<.001}$	d=-0.59$^{<.001}$	1.79 (0.77)
Peak performance time	0.82 (0.65)	2.03 (0.70)	1.60 (0.88)	d=1.80$^{<.001}$	d=1.01$^{<.001}$	d=-0.54$^{<.001}$	1.21 (0.87)
Depression	0.16 (0.38)	0.40 (0.66)	1.07 (0.99)	d=0.45$^{<.001}$	d=1.22$^{<.001}$	d=0.79$^{<.001}$	0.35 (0.66)
High depression group[b]	841 (3.6%)	1114 (13.1%)	2076 (39.1%)	OR=4.03$^{<.001}$	OR=17.09$^{<.001}$	OR=4.24$^{<.001}$	4031 (10.9%)
Anxiety	0.39 (0.71)	0.84 (1.00)	1.71 (1.13)	d=0.52$^{<.001}$	d=1.40$^{<.001}$	d=0.81$^{<.001}$	0.68 (0.97)
High anxiety group[b]	976 (4.2%)	1122 (13.2%)	1896 (35.7%)	OR=3.48$^{<.001}$	OR=12.66$^{<.001}$	OR=3.64$^{<.001}$	3994 (10.8%)
Reactive aggression	0.20 (0.35)	0.36 (0.47)	0.63 (0.63)	d=0.39$^{<.001}$	d=0.84$^{<.001}$	d=0.48$^{<.001}$	0.30 (0.45)
High reactive aggression group[b]	1390 (6.0%)	1118 (13.2%)	1559 (29.4%)	OR=2.39$^{<.001}$	OR=6.53$^{<.001}$	OR=2.74$^{<.001}$	4067 (11.0%)
Autism	0.39 (0.44)	0.55 (0.50)	0.79 (0.59)	d=0.34$^{<.001}$	d=0.77$^{<.001}$	d=0.44$^{<.001}$	0.49 (0.50)
High autism group[b]	1650 (7.1%)	1073 (12.7%)	1323 (24.9%)	OR=1.90$^{<.001}$	OR=4.34$^{<.001}$	OR=2.29$^{<.001}$	4046 (10.9%)
Inattention	0.75 (0.55)	1.00 (0.60)	1.24 (0.63)	d=0.44$^{<.001}$	d=0.84$^{<.001}$	d=0.40$^{<.001}$	0.87 (0.60)
High inattention group[b]	1556 (6.7%)	1334 (15.7%)	1507 (28.4%)	OR=2.60$^{<.001}$	OR=5.52$^{<.001}$	OR=2.12$^{<.001}$	4397 (11.9%)
Hyperactivity/impulsivity	0.69 (0.54)	0.87 (0.58)	1.17 (0.65)	d=0.34$^{<.001}$	d=0.82$^{<.001}$	d=0.49$^{<.001}$	0.80 (0.59)
High hyperactivity/ impulsivity group[b]	1719 (7.4%)	1150 (13.6%)	1461 (27.5%)	OR=1.96$^{<.001}$	OR=4.75$^{<.001}$	OR=2.42$^{<.001}$	4330 (11.7%)
Smoking				OR=1.74$^{<.001}$	OR=1.79$^{<.001}$	OR=1.03$^{.57}$	
Non-smoker	20013 (86.1%)	6912 (81.6%)	4422 (83.3%)				31347 (84.7%)
Smoker	2026 (8.7%)	1217 (14.4%)	802 (15.1%)				4045 (10.9%)
Smoking (cigarettes per day)	0.47 (2.52)	0.91 (3.63)	1.01 (3.99)	d=0.14$^{<.001}$	d=0.16$^{<.001}$	d=0.03$^{.15}$	0.65 (3.06)
Alcohol drinking (drinks per month)	17.51 (22.58)	21.08 (27.67)	19.32 (28.06)	d=0.14$^{<.001}$	d=0.07$^{<.001}$	d=-0.06$^{<.001}$	18.60 (24.73)
Alcohol drinking				V=0.05$^{<.001}$	V=0.04$^{<.001}$	V=0.03$^{<.001}$	
Light drinker	6797 (29.2%)	2363 (27.9%)	1751 (33.0%)				10911 (29.5%)
Moderate drinker	13117 (56.4%)	4579 (54.0%)	2766 (52.1%)				20462 (55.3%)
Heavy drinker	2103 (9.0%)	1180 (13.9%)	700 (13.2%)				3983 (10.8%)
Drug use				OR=1.75$^{<.001}$	OR=1.52$^{<.001}$	OR=0.87$^{.004}$	
Non-user	19433 (83.6%)	6578 (77.6%)	4323 (81.4%)				30334 (81.9%)
User	2533 (10.9%)	1498 (17.7%)	858 (16.2%)				4889 (13.2%)
Drug use (times per year)	0.44 (4.26)	0.94 (6.29)	1.20 (7.16)	d=0.09$^{<.001}$	d=0.13$^{<.001}$	d=0.04$^{.03}$	0.67 (5.29)

Sleep and mental health characteristics that were measured continuously are presented on the scale from 0 to 4, with higher values indicating more severe symptoms. Exceptions were measures of extent of alcohol drinking, drug use, and smoking, whose units are specified in round brackets or as categories.
The values in the cells of the first three columns correspond to a mean and standard deviation (in parentheses) for continuous variables or an absolute number of participants and the proportion compared to the whole subgroup (in parentheses) for categorical variables.
The differences between all sleep profiles were tested using t-test for continuous variables and chi-square test for categorical variables. The result for each comparison is presented in a separate column (*HL* = healthy larks; *SO* = sleepy owls; *SD* = Sleepless Doves), where the values correspond to the effect size, either Cohen's d (d), Cramer's V (V) or odds ratio (OR), and the p-values are indicated in superscript, highlighted in bold if statistically significant at $p<0.05$.

[a] Probable clinical insomnia is determined if the sum of the three insomnia symptom scores is higher than 6 (for those younger than 65 years) or 7 points (for 64+ years)

[b] The high symptom severity group on the given mental health problem was defined by the 10% highest scoring participants in the sample

severity groups compared to 25-40% of “Sleepless Doves”. These differences were particularly pronounced in the case of depression and anxiety; for example, “Sleepless Doves” were 17 and 13 times more likely to have participants with the 10% highest scores on depression and anxiety, respectively, than “Healthy Larks”.

Linear regression models of the continuous outcomes further showed that symptoms of depression, anxiety, reactive aggression, inattention, hyperactivity/impulsivity, and autism were significantly (all $p<0.001$) more severe in “Sleepy Owls” and “Sleepless Doves” when compared to “Healthy Larks” (*beta* coefficients and *p*-values from these models can be found in Table 3*)*. These differences between sleep profiles were small to moderate when comparing “Sleepy Owls” and “Healthy Larks” Cohen’s d=0.34-0.52; see Table 2), and moderate to large when comparing “Sleepless Doves” to “Sleepy Owls” (Cohen’s d=0.40-0.81) and “Healthy Larks” (Cohen’s d=0.77-1.40). As was described for the highest scoring groups, the effect sizes indicated that the differences between sleep profiles were larger for depression and anxiety, compared to reactive aggression, inattention, hyperactivity/impulsivity, and autism (Fig. 3, first two rows, and Supplement Fig. S3).

Regarding substance use, zero-inflated negative binomial models showed that compared to “Healthy Larks”, “Sleepy Owls” and “Sleepless Doves” were almost twice more likely to use drugs (17.7% and 16.2%, respectively, versus 10.9% of the participants were drug users) and smoke (14.4% and 15.1% versus 8.7% of the participants were smokers). Although frequency of drug use per year and the number of cigarettes smoked per day were not significantly associated with sleep profiles in the models (Table 4, second and third columns), visualization of these associations across the lifespan revealed significant differences in the age period between around 18 and 65 years (Fig. 3, last row); thus, it is possible that associations with frequency of drug use and the number of cigarettes smoked per day are only relevant at particular ages and obscured when considering the entire lifespan. The magnitude of these differences was relatively small (Cohen’s d=0.09/0.13 for frequency of drug use and d=0.14/0.16 for the number of smoked cigarettes when comparing “Healthy Larks” to “Sleepy Owls”/”Sleepless Doves”).

In contrast to drug use and smoking, there was no significant difference between sleep profiles in the likelihood of alcohol drinking, but among alcohol drinkers, "Sleepy Owls" and "Sleepless Doves" drank heavier than "Healthy Larks" (Table 4, first column). “Healthy Larks” were almost twice less likely to be in the group of heavy drinkers compared to “Sleepy Owls” and “Sleepless Doves” (Supplement Table S6, columns 3-4): 9% versus 13.9% and 13.2%, respectively (Table 2, and Supplement Table S6 and Fig. S3). Unlike in other mental health problems, there was no significant difference in alcohol drinking, drug use, and smoking between "Sleepy Owls" and "Sleepless Doves".

The differences between sleep profiles in depression, anxiety, reactive aggression, inattention, hyperactivity/impulsivity, autism, and smoking tended to be smaller in older compared to younger participants. Similarly, differences in mental health between sleep profiles were generally more pronounced in men compared to women (see Table 3 and Fig. 3).

In the sensitivity analyses, the associations between sleep profiles and mental health problems were slightly weaker when adjusted for socio-economic differences (Supplement Table S5) and when depression and anxiety scores were calculated without the sleep-related items (Table S6). Regarding the drug subgroups, cannabis and stimulants use was twice more likely in "Sleepy Owls" and "Sleepless Doves" compared to "Healthy Larks", but hallucinogens use was more likely only in "Sleepy Owls" compared to "Healthy Larks" (Supplement Table S6).

4. Discussion

4.1. Summary of the main results

Our study found that individuals in the general population can be classified into subgroups based on their insomnia symptoms and circadian preferences, which we referred to as “sleep profiles”. The sleep profile with “Healthy Larks” had individuals with relatively early circadian preferences and minimal insomnia symptoms, “Sleepy Owls” had late circadian preferences and somewhat nonrestorative sleep, and “Sleepless Doves” had more intermediate circadian preferences and high severity on all three insomnia symptoms. These sleep profiles were shown to differ substantially in the severity of mental health problems. Compared to “Healthy Larks”, the severity of depression and anxiety was significantly higher in “Sleepy Owls” and, in an even higher degree, in “Sleepless Doves”. Similar differences (albeit less pronounced) were found for the severity of reactive aggression, inattention, hyperactivity/impulsivity, and autism. Furthermore, both “Sleepy Owls” and “Sleepless Doves” were twice as likely to be heavy alcohol drinkers, use drugs, and smoke compared to “Healthy Larks”. Our findings confirmed that these associations are present in both men and women, from early childhood until older adulthood, although their strength tended to weaken with age.

Table 3
Results of the linear regression analyses: effects of sleep profiles on mental health problems, adjusted for age, gender, their interaction effects with sleep profiles, and weighted according to the classification uncertainty.

Linear regression models	Depression	Anxiety	Aggression	Inattention	Hyperactivity/ impulsivity	Autism spectrum problems
Intercept	-0.32	-0.40	-0.18	-0.15	-0.16	-0.06
Sleepy Owls vs. Healthy Larks	$0.38^{\mathbf{<0.001}}$	$0.46^{\mathbf{<0.001}}$	$0.40^{\mathbf{<0.001}}$	$0.47^{\mathbf{<0.001}}$	$0.33^{\mathbf{<0.001}}$	$0.44^{\mathbf{<0.001}}$
Sleepless Doves vs. Sleepy Owls	$1.07^{\mathbf{<0.001}}$	$0.98^{\mathbf{<0.001}}$	$0.73^{\mathbf{<0.001}}$	$0.44^{\mathbf{<0.001}}$	$0.58^{\mathbf{<0.001}}$	$0.54^{\mathbf{<0.001}}$
Sleepless Doves vs. Healthy Larks	$1.45^{\mathbf{<0.001}}$	$1.44^{\mathbf{<0.001}}$	$1.13^{\mathbf{<0.001}}$	$0.92^{\mathbf{<0.001}}$	$0.91^{\mathbf{<0.001}}$	$0.98^{\mathbf{<0.001}}$
Men vs. Women	$0.05^{\mathbf{<0.001}}$	$0.15^{\mathbf{<0.001}}$	$-0.08^{\mathbf{<0.001}}$	$-0.14^{\mathbf{<0.001}}$	$-0.07^{\mathbf{<0.001}}$	$-0.25^{\mathbf{<0.001}}$
Age	$-0.05^{\mathbf{<0.001}}$	$-0.04^{\mathbf{<0.001}}$	$-0.09^{\mathbf{<0.001}}$	$-0.02^{\mathbf{0.024}}$	$-0.08^{\mathbf{<0.001}}$	$0.06^{\mathbf{<0.001}}$
*Sex * Age*	$-0.01^{0.591}$	$-0.02^{0.049}$	$-0.02^{0.063}$	$0.04^{\mathbf{<0.001}}$	$-0.00^{0.750}$	$-0.04^{\mathbf{0.002}}$
*Sleepy Owls vs. Healthy Larks * Age*	$-0.10^{\mathbf{<0.001}}$	$-0.10^{\mathbf{<0.001}}$	$-0.08^{\mathbf{<0.001}}$	$-0.07^{\mathbf{<0.001}}$	$-0.06^{\mathbf{0.001}}$	$-0.04^{\mathbf{0.017}}$
Sleepless Doves vs. Sleepy Owls Age*	$0.01^{0.793}$	$0.02^{0.375}$	$-0.06^{0.051}$	$-0.04^{0.217}$	$-0.10^{\mathbf{<0.001}}$	$-0.01^{0.780}$
Sleepless Doves vs. Healthy Larks Age*	$-0.10^{\mathbf{<0.001}}$	$-0.07^{\mathbf{0.002}}$	$-0.14^{\mathbf{<0.001}}$	$-0.10^{\mathbf{<0.001}}$	$-0.16^{\mathbf{<0.001}}$	$-0.05^{0.044}$
*Sleepy Owls vs. Healthy Larks * Sex*	$0.02^{0.606}$	$0.04^{0.087}$	$-0.03^{0.186}$	$-0.03^{0.285}$	$0.01^{0.600}$	$-0.12^{\mathbf{<0.001}}$
Sleepless Doves vs. Sleepy Owls Sex*	$-0.03^{0.310}$	$-0.13^{<0.001}$	$-0.17^{\mathbf{<0.001}}$	$-0.05^{0.169}$	$-0.08^{\mathbf{0.023}}$	$-0.08^{\mathbf{0.022}}$
Sleepless Doves vs. Healthy Larks Sex*	$-0.02^{0.452}$	$-0.09^{\mathbf{0.001}}$	$-0.21^{\mathbf{<0.001}}$	$-0.08^{\mathbf{0.012}}$	$-0.07^{\mathbf{0.026}}$	$-0.20^{\mathbf{<0.001}}$
*Sleepy Owls vs. Healthy Larks * Sex * Age*	$0.00^{0.980}$	$0.06^{\mathbf{0.010}}$	$0.02^{0.509}$	$0.04^{0.113}$	$0.06^{\mathbf{0.013}}$	$0.04^{0.111}$
Sleepless Doves vs. Sleepy Owls Sex * Age*	$-0.06^{0.097}$	$-0.00^{0.957}$	$-0.06^{0.086}$	$-0.06^{0.104}$	$0.01^{0.879}$	$-0.06^{0.126}$
Sleepless Doves vs. Healthy Larks Sex * Age*	$-0.06^{0.066}$	$0.06^{0.067}$	$-0.05^{0.150}$	$-0.02^{0.507}$	$0.07^{0.047}$	$-0.02^{0.583}$

Outcomes are listed in columns, and predictors (the contrast between two profiles and their interactions with age and sex) are listed in rows. Before the analyses, all continuous outcomes in linear regression models were standardized, so that a zero represents the sample’s mean and negative/positive values represent standard deviations from the mean. Sex differences are indicated for women compared to men. The values in the table cells are regression coefficients (B) which indicate the magnitude of differences in the given outcome as standard deviations from the average of the sample (zero). Statistical significance is indicated in superscript as a p-value, highlighted in bold if it was still significant after the correction for multiple testing ($p<0.05$). An asterisk (*) indicates an interaction between the given variables.

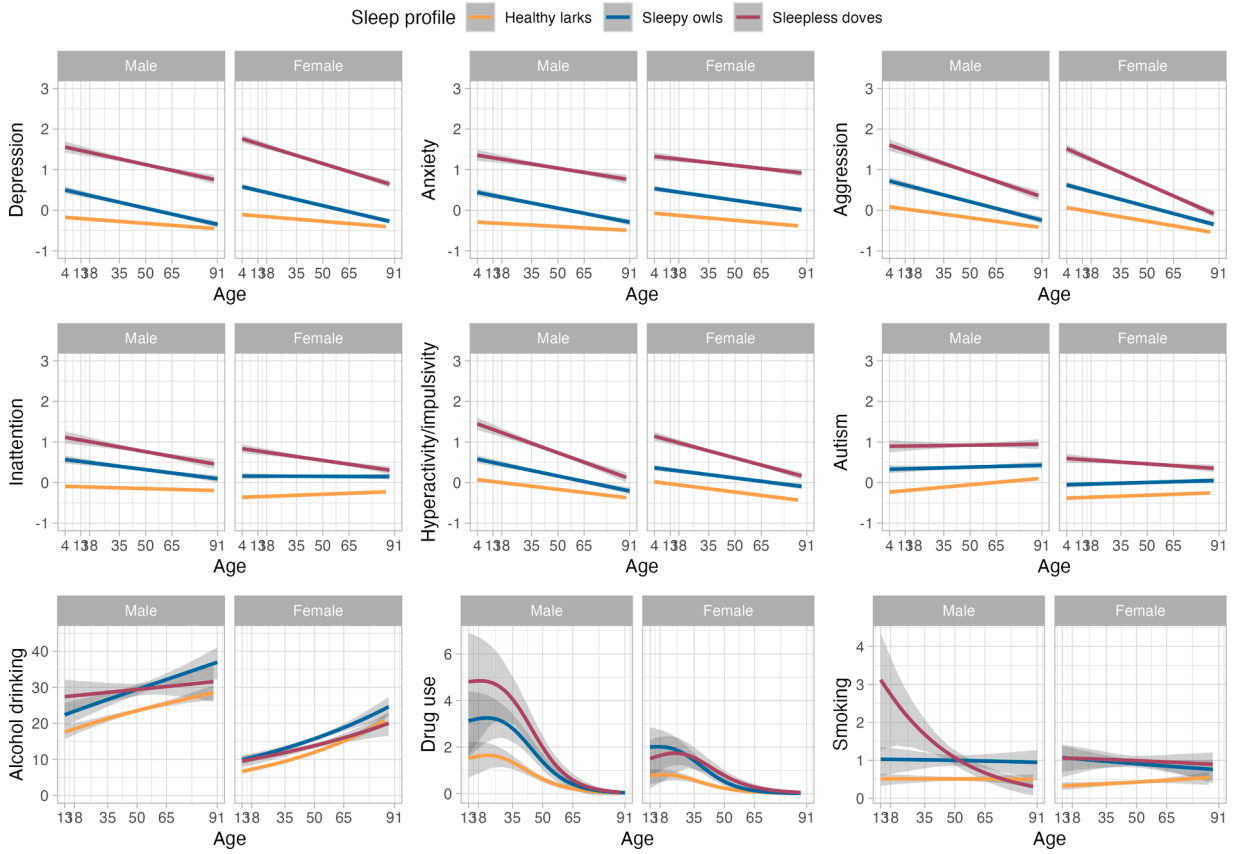

Fig. 3. Predicted severity of mental health problems for each sleep profile in men and women across the lifespan
The plots show predicted severity of different mental health problems (Y axis) for each sleep profile (colored lines) across the lifespan (X axis). The variables on the first two rows were standardized, with zero representing the mean and positive and negative values representing standard deviation from the mean. The last row (substance use measures) is on the original scale. Higher values indicate more severe problems. The wider the distance between the colored lines, the larger is the difference between the two given profiles. The shaded area (in grey) around the lines indicates the confidence intervals.

4.2. Relation to previous research

Our study not only demonstrated that insomnia symptoms can be a factor strongly associated with a wide range of common mental health problems, but also that this association applies to all ages and both men and women in the general population. Similarly, multiple earlier (variable-based) studies suggested that individuals with later circadian preferences are more likely to have more severe insomnia symptoms, and both are associated with more severe mental health problems (Coogan and McGowan, 2017, Lin et al., 2021, Randler and Vollmer, 2013, Robillard et al., 2015, Sivertsen et al., 2021).

Additionally, our study showed that the most severe mental health problems were usually observed in the participants with more severe insomnia symptoms, but not necessarily late circadian preferences. The worst mental health problems were reported by "Sleepless Doves", who had late or intermediate circadian preferences as indicated by their negative morning affect and later peak performance time, but their bedtime and wake time were usually earlier than that of "Sleepy Owls". In fact, most mental health problems were correlated with earlier, not later, bedtimes (Fig. 1). These findings indicate that daytime dysfunction due to insomnia symptoms, which prevailed in “Sleepless Doves”, may be more important for mental health than sleep-wake time preferences, which were latest in “Sleepy Owls”. This could mean that advancing circadian preferences alone, without addressing daytime dysfunction, may be less protective than previously suggested (Zhou et al., 2021). This was also suggested by two studies showing a mediating role of sleep problems and negative morning affect in the association between late circadian preferences and mental health problems (Lin et al., 2021, Merikanto and Partonen, 2021). Vice versa, it is possible that mental disorders may, in turn, exacerbate insomnia symptoms, but not necessarily change circadian preferences. However, due to the focus of the existing literature on sleep characteristics as a predictor, the predicting role of mental illness in sleep problems remains unclear: whereas there are some data showing that anxiety, depression and alcohol use can predict subsequent worsening of sleep problems (Shanahan et al., 2014, Singareddy et al., 2012), the evidence of a similar role for circadian preferences is lacking. Although previous studies focused mainly on depression and anxiety, our findings suggest that the same mechanisms may also apply to reactive aggression, inattention, hyperactivity/impulsivity, and autism.

In contrast to other mental health problems, the differences between “Healthy Larks” and “Sleepless Doves” in substance use (including alcohol drinking, drug use, and smoking) were not larger than the differences between "Sleepy Owls" and "Healthy Larks", which suggests that these associations were mainly driven by later circadian preferences and worse nonrestorative sleep, and not difficulties initiating and maintaining sleep. These findings are in line with previous research that associated drug use and heavy alcohol drinking with later circadian preferences and worse daytime dysfunction rather than sleep difficulties (Dokkedal-Silva et al., 2021, Graupensperger et al., 2021, Leger et al., 2022, Troxel et al., 2021). The associations between sleep profiles and all types of substance use were also stronger in men than women, in line with how later bedtime is more strongly associated to alcohol drinking and cannabis use in men (Troxel et al., 2021). In addition, the presence of the association between substance use and insomnia symptoms in earlier studies varied depending on how substance use problems were defined (Dokkedal-Silva et al., 2021, Leger et al., 2022, Troxel et al., 2021), such as frequency or likelihood, the kind of drugs used, etc. This

Table 4
Results of the zero-inflated negative binomial regression analyses: effects of sleep profiles on mental health problems, adjusted for age, gender, their interaction effects with sleep profiles, and weighted according to the classification uncertainty.

Zero-inflated negative binomial models	Alcohol drinking				Drug use				Smoking			
	B	exp(B)	$B_{zero's}$	exp ($B_{zero's}$)	B	exp(B)	$B_{zero's}$	exp ($B_{zero's}$)	B	exp(B)	$B_{zero's}$	exp ($B_{zero's}$)
Intercept	3.22	25.02	-2.66	0.07	1.51	4.51	1.75	5.76	2.25	9.45	2.86	17.46
Sleepy Owls vs. Healthy Larks	0.23	$1.25^{\mathbf{<0.001}}$	0.04	$1.04^{0.751}$	0.16	$1.17^{0.471}$	-0.78	$0.46^{\mathbf{<0.001}}$	0.05	$1.05^{0.521}$	-0.68	$0.51^{\mathbf{<0.001}}$
Sleepless Doves vs. Sleepy Owls	0.02	$1.02^{0.631}$	0.18	$1.20^{0.252}$	0.24	$1.27^{0.381}$	-0.20	$0.82^{0.305}$	0.04	$1.04^{0.656}$	-0.06	$0.94^{0.575}$
Sleepless Doves vs. Healthy Larks	0.24	$1.28^{\mathbf{<0.001}}$	0.23	$1.26^{0.078}$	0.40	$1.49^{0.100}$	-0.98	$0.38^{\mathbf{<0.001}}$	0.08	$1.09^{0.303}$	-0.74	$0.48^{\mathbf{<0.001}}$
Men vs. Women	-0.55	$0.58^{\mathbf{<0.001}}$	1.15	$3.16^{\mathbf{<0.001}}$	-0.43	$0.65^{0.038}$	0.64	$1.89^{\mathbf{<0.001}}$	-0.16	$0.86^{\mathbf{0.006}}$	0.03	$1.03^{0.666}$
Age	0.06	$1.06^{\mathbf{<0.001}}$	-0.55	$0.58^{\mathbf{<0.001}}$	0.42	$1.52^{\mathbf{0.002}}$	1.66	$5.23^{\mathbf{<0.001}}$	0.23	$1.26^{\mathbf{<0.001}}$	0.25	$1.28^{\mathbf{<0.001}}$
*Sex * Age*	0.16	$1.18^{\mathbf{<0.001}}$	0.43	$1.54^{\mathbf{<0.001}}$	0.09	$1.09^{0.664}$	0.11	$1.12^{0.525}$	0.01	$1.01^{0.912}$	-0.11	$0.90^{0.176}$
*Sleepy Owls vs. Healthy Larks * Age*	0.01	$1.01^{0.628}$	0.13	$1.13^{0.379}$	-0.21	$0.81^{0.308}$	0.05	$1.05^{0.813}$	-0.06	$0.94^{0.544}$	-0.04	$0.96^{0.636}$
Sleepless Doves vs. Sleepy Owls Age*	-0.05	$0.95^{0.277}$	0.33	$1.40^{0.063}$	-0.08	$0.92^{0.767}$	-0.02	$0.98^{0.936}$	-0.26	$0.77^{0.049}$	0.22	$1.24^{0.072}$
Sleepless Doves vs. Healthy Larks Age*	-0.03	$0.97^{0.374}$	0.47	$1.60^{\mathbf{0.004}}$	-0.29	$0.74^{0.263}$	0.03	$1.03^{0.924}$	-0.33	$0.72^{\mathbf{0.009}}$	0.17	$1.19^{0.128}$
*Sleepy Owls vs. Healthy Larks * Sex*	0.02	$1.02^{0.594}$	-0.22	$0.80^{0.120}$	0.02	$1.02^{0.950}$	0.05	$1.06^{0.794}$	0.13	$1.14^{0.158}$	0.04	$1.04^{0.691}$
Sleepless Doves vs. Sleepy Owls Sex*	-0.09	$0.92^{0.065}$	0.14	$1.15^{0.413}$	0.14	$1.16^{0.708}$	0.19	$1.21^{0.461}$	0.05	$1.05^{0.673}$	0.06	$1.07^{0.644}$
Sleepless Doves vs. Healthy Larks Sex*	-0.07	$0.93^{0.089}$	-0.09	$0.91^{0.542}$	0.17	$1.18^{0.644}$	0.25	$1.28^{0.281}$	0.18	$1.19^{0.089}$	0.11	$1.11^{0.390}$
*Sleepy Owls vs. Healthy Larks * Sex * Age*	-0.07	$0.93^{0.069}$	-0.20	$0.82^{0.214}$	-0.08	$0.92^{0.774}$	-0.03	$0.97^{0.927}$	-0.14	$0.87^{0.326}$	0.02	$1.02^{0.863}$
Sleepless Doves vs. Sleepy Owls Sex * Age*	0.03	$1.03^{0.602}$	-0.20	$0.82^{0.319}$	0.28	$1.44^{0.326}$	-0.08	$0.92^{0.840}$	0.43	$1.53^{<0.001}$	-0.07	$0.93^{0.631}$
Sleepless Doves vs. Healthy Larks Sex * Age*	-0.04	$0.97^{0.402}$	-0.41	$0.66^{\mathbf{0.023}}$	0.36	$1.32^{0.440}$	-0.11	$0.90^{0.766}$	0.29	$1.34^{0.076}$	-0.05	$0.95^{0.738}$

Outcomes are listed in columns, and predictors (the contrast between two profiles and their interactions with age and sex) are listed in rows. Alcohol drinking is measured as drinks per month, drug use as times of using last year, and smoking as number of cigarettes smoked per day. Sex differences are indicated for women compared to men. The values in the table cells are regression coefficients (B for the negative binomial count model and $B_{zero's}$ from the logit model for predicting excess zeros), which indicate the direction (negative/positive for lower/higher) of differences for each unit increase in the predictor. On the right, the coefficients are accompanied by their exponentiated values, exp(B) and exp($B_{zero's}$), which indicate the magnitude of difference on the original scale, calculated for easier interpretation. Statistical significance is indicated in superscript as a p-value, highlighted in bold if it was still significant after the correction for multiple testing ($p<0.05$). An asterisk (*) indicates an interaction between the given variables.

possible variation was supported by our own findings, in which alcohol drinking defined as heavy versus light/moderate drinking was associated with sleep profiles, whereas the general likelihood of being a drinker was not. Similarly, our sensitivity analyses suggested that the relationship between sleep and drug use may differ depending on the drug subgroup, since hallucinogen use was higher only in "Sleepless Doves" unlike the use of stimulants and cannabis which was higher in "Sleepy Owls". Furthermore, the fact that the differences between sleep profiles in alcohol drinking, drug use, and smoking were significant only at certain ages suggested that these associations can be nonlinear and likely missed if inferred strictly based on the estimates of the linear models. However, further investigation is needed to clarify the direction and exact mechanisms behind the association between sleep behavior and various types of substance use.

The frequent coexistence of insomnia symptoms and mental health problems can arise due to various reasons, ranging from the well-known role of healthy sleep in mental functioning and the detrimental effects of mental illness on sleep to third factors underlying both of these phenotypes. For example, current evidence supports that poor sleep can predict worse mental health in the future (Hertenstein et al., 2019, Lam and Lam, 2021, Scott et al., 2021, Sivertsen et al., 2021), and that at least some mental health problems have a rather high genetic overlap with insomnia symptoms (Jansen et al., 2019). The greater genetic overlap between depression/anxiety and insomnia symptoms (Jansen et al., 2019) can explain why these mental health problems, unlike others, had the strongest associations with "Sleepless Doves" and "Sleepy Owls", the sleep profiles in which participants had more insomnia symptoms. In fact, the associations between sleep profiles and other mental health problems could result from their frequent comorbidity with depression and anxiety (Lai et al., 2019, McGrath et al., 2020). For example, the association between sleep difficulties and substance use disappeared after controlling for depression and anxiety. (Troxel et al., 2021) Furthermore, the consistently larger role of circadian preferences and daytime dysfunction, and not sleep difficulties, in substance use suggests a potentially different mechanism behind these associations, which is largely unknown. Various explanations have been offered in the literature, such as the effects of substances on circadian preferences via photoreceptors, possible socio-behavioural differences in those with later circadian preferences in their affinity to substance use, and genetic overlap behind the propensities to later circadian preferences and substance use. Overall, our findings not only confirmed some prior conclusions in the literature but also refined our understanding of these relationships and offered relevant directions for future research.

4.3. Strengths and limitations

An important strength of this study concerns its large, representative sample of the general population. Due to the consistency of the measurement instruments across the lifespan and the inclusion of a wide range of mental health problems in one study, we were able to comprehensively characterize distinct sleep profiles. As both sleep and mental health problems in our study were measured on a spectrum, which is more in line with the modern understanding of psychiatric illness than a binary division into the “healthy” and “sick” (Fried, 2022), we could detect subtle variations in the symptom severity within the general population.

The findings of this study should be interpreted with several considerations in mind. First, the associations we established could have arisen due to a third factor (a shared mechanism) that was not the focus of our study. Second, the cross-sectional design of the study did not allow investigating the direction of the associations between sleep profiles and mental health problems. Third, our study assessed sleep behavior based on self-reports, which for children and partly for adolescents, could only be completed by their parents. The informant difference could introduce error in the estimation of personal experiences, such as sleep behavior (Mazza et al., 2020, Short et al., 2013). A more general problem with the use of self/informant report measures, is that they may be confounded by a misperception of what “good/healthy sleep behavior” should be in those with chronic sleep problems (Difrancesco et al., 2019, Harvey and Tang, 2012). However, the majority of our sample did not have severe sleep- and mental health problems and the instruments were the same (or very similar) for

different informants, so misestimation likely remained small. Nevertheless, our findings should ideally be complemented by the findings based on more objective sleep measures. Finally, latent profile analysis carries some subjectivity, meaning that with different measures (e.g., different sleep-related questionnaires), it may have resulted in a different solution with respect to the number of profiles or how people are distributed across these profiles.

4.4. Implications and future research agenda

Our study showed that sleep problems, late circadian preferences, and mental health problems frequently coexist even outside of the "clinical" subgroup ("Sleepless Doves"). "Sleepy Owls" also have highly nonrestorative sleep and constitute a rather large subgroup (23%) of the entire population, with an even higher prevalence in adolescents and young adults – the age period of the highest prevalence of most mental health problems. Thus, these individuals with sleep profiles of "Sleepless Doves" and "Sleepy Owls" can be used as target groups who would benefit the most from preventive and treatment programs orientated toward better sleep and thereby, potentially better mental health. However, more knowledge of the underlying mechanisms is essential to establish how to make such interventions effective. Longitudinal studies are needed to determine whether the identified sleep profiles change over time, as well as the direction and possible mediators of the associations between sleep and common mental health problems. In addition, genetic and neurobiological research is needed to clarify the (shared) pathophysiology behind these associations, such as specific symptoms and neural processes disrupted in both sleep and common mental disorders.

5. Conclusions

To conclude, our study demonstrated that the general population, regardless of age and sex, can be classified into three distinct subgroups ("Healthy Larks", "Sleepy Owls", and "Sleepless Doves") according to their specific circadian preferences and individual insomnia symptoms. "Sleepy Owls" and "Sleepless Doves" tend to have significantly more severe mental health problems than "Healthy Larks". More severe insomnia symptoms appeared to strengthen the association between sleep profiles and depression, anxiety, reactive aggression, inattention, hyperactivity/impulsivity, and autism, but not heavy alcohol drinking, drug use, and smoking. Although more research is needed to clarify the mechanisms behind these associations, our findings provide more evidence for the universal role of healthy sleep in mental wellbeing and the potential subgroups in the general population that could be used to identify risk groups in clinical and research practice.

CRediT authorship contribution statement

Dina Sarsembayeva: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. **Marieke J. Schreuder:** Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Writing – review & editing. **Catharina A. Hartman:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

Declaration of Competing Interest

None

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2023.115689.

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