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ORIGINAL RESEARCH

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Dietary inflammation, sleep and mental health in the United Kingdom and Japan: A comparative cross-sectional study

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Abstract

Diet has been repeatedly shown to affect mental and sleep health outcomes. However, it is well known that there are cross-cultural differences in dietary practices as well as the prevalence of mental and sleep health outcomes. Given that the dietary inflammatory potential of diets has been linked to mental and sleep health outcomes, in the current study we sought to assess the inflammatory status of habitual diets and examine its relationship with mental and sleep health outcomes in both the United Kingdom and Japan. Our aim was to determine if the associations between the dietary inflammation index (DII) score and these health outcomes could elucidate any potential cross-cultural differences in health. Online survey data was collected from 602 participants (aged 18–40 years) in the United Kingdom ($n = 288$) and Japan ($n = 314$). Participants self-reported their dietary intakes, as well as current mental health and sleep patterns. The DII score was calculated (score range −2.79 to 3.49) We found that although participants in the United Kingdom reported better overall mental wellbeing, participants in Japan reported less severe depression, anxiety and stress and better subjective sleep quality, less sleep disturbances and daytime dysfunction, despite sleeping shorter, and a better adherence to an anti-inflammatory diet. Moreover, across the United Kingdom and Japan, adherence to more anti-inflammatory diets predicted higher levels of subjective sleep quality, fewer sleep disturbances, less use of sleep medicine and less daytime dysfunction. In conclusion, there are several differences between mental and sleep health outcomes in the United Kingdom and Japan, which could be attributable to the inflammatory potential of respective regional diets. Future studies are warranted to examine the mental and sleep health benefits of adhering to anti-inflammatory traditional Japanese diets in clinical and subclinical cohorts.

KEYWORDS
anxiety, depression, inflammation, nutrition, sleep, stress

Piril Hepsomali and Hiroyo Kagami-Katsuyama are joint first authors.

INTRODUCTION

Diet, a modifiable lifestyle factor, has been repeatedly shown to affect chronic disease risk, including obesity, cardiovascular diseases, diabetes and even all-cause mortality (Chiavaroli et al., 2019; Qian et al., 2019; Shan et al., 2023). Additionally, it has been shown to play a significant role in mental and sleep health outcomes (Grajek et al., 2022; Hepsomali & Groeger, 2021; Zuraikat et al. 2021). Current research has shown that intakes of various nutrients that are abundant in healthy diets including eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), magnesium and folic acid (Muscaritoli, 2021), dietary fibre (Fatahi et al., 2021; Hepsomali & Groeger, 2021), antioxidants (Pereira et al., 2021) and polyphenols (Godos et al., 2017; Godos et al., 2020) have been linked to reduced anxiety and depression symptomatology and better sleep quality. Conversely, nutrients that are commonly found in higher amounts in suboptimal diets such as sugar, *trans* fats and saturated fats have been associated with an increased risk of stress and anxiety, as well as a higher risk of depressive symptoms (Sanchez-Villegas et al., 2018; Sánchez-Villegas et al., 2011) (but also see Currenti et al. (2023)) and poor sleep quality (Matsunaga et al., 2021; Wilson et al., 2022).

Since people do not consume single nutrients in isolation, nutritional research has been shifting towards food group and dietary pattern analysis (Hu, 2002). For instance, research has shown that adherence to healthy/prudent/Mediterranean diets has been associated with better mental health and sleep quality outcomes (Firth et al., 2019; Godos et al., 2019; Hepsomali & Groeger, 2021). Additionally, of specific importance, the traditional Japanese diet (*Washoku*), which is characterised by a high intake of vegetables, fruits, grains, soy products and seafood, and is high in polyunsaturated fatty acids (PUFA) and dietary fibre, but low in meat and dairy products (Gabriel et al. 2018), has been shown to be inversely associated with depression scores (Konishi, 2021; Nanri et al., 2010). On the other hand, a "Western-style diet", characterised as being rich in saturated fats, refined carbohydrates and sodium (Garcia-Gutierrez & Sayavedra, 2022), has been associated with worse mental health and sleep quality outcomes (Hepsomali & Groeger, 2021; Jacka et al., 2010; Sánchez-Villegas et al., 2012). Given that various researchers have reported that inflammatory biomarkers were (i) negatively associated with healthy/prudent/Mediterranean and healthy Japanese diets (Coe et al., 2020; Ferrie et al., 2013; Hepsomali & Groeger, 2022), (ii) positively associated with unhealthy/western diets with increased biomarkers of inflammation (Kuczmarski et al., 2013; Silveira et al., 2018), and (iii) negatively associated with mental and sleep health outcomes (Hepsomali & Coxon, 2022; Hepsomali & Groeger, 2022), findings linking different diets to mental and sleep health outcomes are not surprising.

To better understand how diet contributes to inflammation in the body, researchers developed the Dietary Inflammatory Index (DII®), a literature-based dietary score that was developed to measure the potential impact of a diet on the inflammatory status of an individual; high and low DII scores reflect pro-inflammatory and anti-inflammatory potential of the diet, respectively (Shivappa, Steck, Hurley, Hussey, & Hébert, 2014). The DII has been validated mainly in Western countries (Shivappa et al., 2017; Shivappa et al., 2018; Shivappa, Steck, Hurley, Hussey, Ma, et al., 2014) and in Japan (Kotemori et al., 2020; Yang et al., 2020). Despite the differences in diet and inflammatory status in these populations, research has demonstrated associations between DII and mental health outcomes. For instance, a meta-analysis of 16 observational studies found that higher DII scores were associated with an increased risk of symptoms of depression, anxiety, distress and schizophrenia (Chen et al., 2021). Further, according to a recent umbrella review of meta-analyses of observational studies, suggestive evidence was presented for depression risk (Marx et al., 2021). More recent evidence from a large population-based study also reported that a higher DII (or energy-adjusted DII) score was associated with a higher risk of depression (Luo et al., 2023). In terms of sleep, there have been comparatively fewer studies but some have shown a pro-inflammatory diet to be linked to poor sleep outcomes including increased self-reported sleep disturbances, poor sleep quality and daytime sleepiness and dysfunction (Coxon et al. 2024; Farrell et al., 2023; Kase et al. 2021; Masaad et al., 2021).

Studies from several countries have reported that common mental health disorders (such as depressive and anxiety disorders) affect around 300 million people (WHO, 2017) and the prevalence of sleep problems ranges from 1.6% to 56.0% (Koyanagi & Stickley, 2015; Léger et al. 2008; Stranges et al. 2012). In the United Kingdom, the prevalence of any common mental disorder was reported to be 15.7% (McManus et al. 2016), whereas the figure was 5.2% in Japan. It has been repeatedly shown that the prevalence of common mental disorders in Japan is much lower compared to rates in Western, especially English-speaking, countries (Ishikawa et al., 2018; Steel et al., 2014). Given that traditional dietary patterns are substantially different between Western, especially English-speaking countries and Japan, in the current study, we aimed to (i) compare the inflammatory status of these diets by utilising the DII score, as well as mental health sleep health outcomes, and (ii) assess whether the associations between the DII score and mental and sleep health outcomes could explain any potential cross-cultural differences.

METHODS

Study design

We used the Checklist for Reporting Results of Internet E-Surveys (CHERRIES) checklist for survey administration and reporting (Eysenbach, 2004) (see Supplementary Material Table 1). The current cross-sectional, open, web-based study was conducted (between January 2023 and May 2023) in the general population (recruited via online and local advertising) in the United Kingdom by using Qualtrics (Qualtrics, Provo, UT) and in Japan by using Google Forms after being approved by Ethics Committee of University of Roehampton, London, United Kingdom (Reference: PSYC/22420) and Ethics Committee of Hokkaido Information University, Ebetsu, Japan (Reference:2022–13). All participants provided informed consent to participate in the study. The survey was voluntary, anonymous and unincentivised. No identifiable information was collected. Items were not presented in a random or adaptive manner. The participants were able to change their answers by using a back button.

Participants

Exclusion criteria included: any history of, or taking medication for, psychiatric disorders or diseases (ADHD, depression, anxiety or mood disorders), sleep disorders or neurological disorders or diseases such as stroke, head injury, epilepsy, seizures, brain tumours, brain surgery, Parkinson's Disease.

Measures

The study team selected the questionnaires to be utilised in the current study. All participants completed a questionnaire to assess demographic and lifestyle parameters including (but not limited to) gender, age, height/weight, socio-economic status, physical activity, alcohol consumption, tobacco/medicinal drug use, diet type (i.e., omnivorous, vegetarian, vegan, pescatarian, flexitarian, other) and diet adherence duration (i.e., the amount of time, in months, that the participants have been following a specific diet). Information collected was translated from English to Japanese by one of the authors (H. K.-K.). Please see Table 1 for details.

To assess overall mental wellbeing the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) (Tennant et al., 2007) and the Japanese version of the Warwick-Edinburgh Mental Wellbeing Scale (菅沼 et al. 2016) were used. For both original and Japanese translations of this measure, total scores range from 14 to 70, with higher scores indicating better mental wellbeing.

To assess mental health dimensions, the Depression, Anxiety and Stress Scale (DASS) (Lovibond & Lovibond, 1995) and the Japanese version of the Depression, Anxiety and, Stress Scale (Adachi & Ueno, 2011; Adachi et al. 2013) were used. While the original version of this measure contains 42 questions, the Japanese version includes 15 questions, hence, we created no/mild, moderate and severe/extremely severe depression, anxiety and stress groups, based on separate tercile splits for each country.

To assess sleep outcomes, the Pittsburgh Sleep Quality Index (Buysse et al. 1989) and the Japanese version of the Pittsburgh Sleep Quality Index (Doi et al., 2000) were used. Subjective sleep quality, sleep duration, sleep disturbances, use of sleeping medication and daytime dysfunction were assessed. Due to unforeseen circumstances, sleep latency and habitual sleep efficiency components couldn't be calculated, hence, total sleep quality score was not included in the final analyses. Lower scores indicate better sleep outcomes for each subscale.

To estimate habitual food intake, the *EPIC Norfolk* Food Frequency Questionnaire (FFQ) (Bingham et al., 1997) and the *Japan Public Health Centre-based Prospective Study for the Next Generation* (*JPHC-NEXT*) FFQ were used (Yokoyama et al., 2016). Dietary Inflammation Index (DII) was estimated as per Shivappa, Steck, Hurley, Hussey, and Hébert (2014) based on intakes of 23 nutrients that are available in the EPIC Norfolk FFQ and the JPHC-NEXT FFQ (alcohol, vitamin B_{12}, vitamin B_6, beta-carotene, carbohydrate, cholesterol, energy, total fat, folic acid, iron, monounsaturated fatty acids, polyunsaturated fatty acids, niacin, protein, riboflavin, saturated fat, selenium, thiamine, vitamin A, vitamin C, vitamin D, vitamin E and zinc), where positive scores reflect pro-inflammatory and negative scores reflect anti-inflammatory dietary patterns. Due to data unavailability in the United Kingdom, Japan or both samples, we could not utilise all 45 food parameters that are used to estimate the DII score. Therefore, the current DII score estimation does not include data from caffeine, eugenol, fibre, garlic, ginger, magnesium, omega 3 fatty acids, omega 6 fatty acids, onion, saffron, *trans* fats, turmeric, tea, flavan-3-ol, flavones, flavanols, flavanones, anthocyanidins, isoflavones, pepper, thyme/oregano and rosemary intakes. Descriptive statistics for intakes of 23 nutrients that were used to estimate the DII can be found in the Supplementary Material Table 2.

The questionnaires utilised in the current study have been previously validated (Adachi & Ueno, 2011; Adachi et al. 2013; Bingham et al., 1997; Buysse et al. 1989; Doi et al., 2000; Lovibond & Lovibond, 1995; Shivappa, Steck, Hurley, Hussey, & Hébert, 2014; Shivappa, Steck, Hurley, Hussey,

TABLE 1 Baseline characteristics of the participants in the United Kingdom and Japan.

	Total ($n = 602$)	UK ($n = 288$)	Japan ($n = 314$)	p
Gender (N/%)				<0.001
Male	170 (28.2%)	57 (19.8%) [a]	113 (36.0%) [b]	
Female	425 (70.6%)	224 (77.8%) [a]	201 (64.0%) [b]	
Other	7 (1.2%)	7 (2.4%) [a]	0 (0%) [a]	
Age, years, MD (IQR)	21 (10)	22.50 (10)	20 (11)	0.839
Education (N/%)				<0.001
Elementary/Junior High/GCSE/O Levels	12 (2%)	12 (4%) [a]	0 (0%) [b]	
Senior High/A Levels	190 (32%)	109 (38%) [a]	81 (26%) [b]	
Vocational/Apprenticeship	205 (34%)	5 (2%) [a]	200 (64%) [b]	
University	131 (22%)	98 (34%) [a]	33 (11%) [b]	
Postgraduate	46 (8%)	46 (16%) [a]	0 (0%) [b]	
Other	18 (3%)	18 (6%) [a]	0 (0%) [b]	
Total number of years in education, MD (IQR)	14 (3)	15 (4)	14 (3)	0.065
Employment (N/%)				<0.001
Employed (full-time)	166 (28%)	75 (26%) [a]	91 (29%) [a]	
Employed (part-time)	91 (15%)	74 (26%) [a]	17 (5%) [b]	
Home duties	7 (1%)	2 (1%) [a]	5 (2%) [a]	
Students	324 (54%)	127 (44%) [a]	197 (63%) [b]	
Unemployed (looking for a job)	12 (2%)	10 (4%) [a]	2 (1%) [b]	
Unemployed (retired)	1 (0%)	0 (0%) [a]	1 (0%) [a]	
Unemployed (disability)	1 (0%)	0 (0%) [a]	1 (0%) [a]	
Language (N/%)				<0.001
English	193 (32%)	193 (67%) [a]	0 (0%) [b]	
Japanese	311 (52%)	0 (0%) [a]	311 (99%) [b]	
Other	98 (16%)	95 (33%) [a]	3 (1%) [b]	
Ethnicity (N/%)				<0.001
English	173 (29%)	170 (59%) [a]	3 (1%) [b]	
Japanese	311 (52%)	0 (0%) [a]	311 (99%) [b]	
Other	118 (20%)	118 (41%) [a]	0 (0%) [b]	
Cigarettes per day, MD (IQR)	0 (0)	0 (0)	0 (0)	0.010
Caffeine per day (cups), MD (IQR)	2 (2)	2 (2)	2 (2.7)	0.138
Alcohol consumption (N/%)				0.009
Does not drink	197 (33%)	87 (30%) [a]	110 (35%) [a]	
Drinks occasionally	256 (43%)	121 (42%) [a]	135 (43%) [a]	
Drinks only at weekends (moderate)	102 (17%)	55 (19%) [a]	47 (15%) [a]	
Drinks only at weekends (uncontrolled)	18 (3%)	15 (5%) [a]	3 (1%) [b]	
Drinks every day (moderate)	22 (4%)	9 (3%) [a]	13 (4%) [a]	
Drinks every day, some days is drunk	7 (1%)	1 (0%) [a]	6 (2%) [a]	
Alcohol per day (weekdays; units), MD (IQR)	0 (1)	0 (0)	0 (2.5)	<0.001
Alcohol per day (weekends; units), MD (IQR)	1 (3)	1 (4)	0.09 (2.5)	0.907
Diet type (N/%)				<0.001
Omnivorous	472 (78%)	176 (61%) [a]	296 (94%) [b]	
Vegetarian	46 (8%)	45 (16%) [a]	1 (0%) [b]	
Vegan	30 (5%)	27 (9%) [a]	3 (1%) [b]	
Pescatarian	18 (3%)	17 (6%) [a]	1 (0%) [b]	
Flexitarian	22 (4%)	16 (6%) [a]	6 (2%) [b]	
Other	14 (2%)	7 (2%) [a]	7 (2%) [a]	

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TABLE 1 (Continued)

	Total ($n=602$)	UK ($n=288$)	Japan ($n=314$)	p
Diet adherence (months)*, MD (IQR)	226 (230)	72 (228)	240 (191)	<0.001
Moderate physical activity (N/%)				<0.001
Less than 30 min	228 (38%)	66 (23%) [a]	162 (52%) [b]	
30–90 min	174 (29%)	96 (33%) [a]	78 (25%) [b]	
90–150 min	98 (16%)	61 (21%) [a]	37 (12%) [b]	
150–300 min	57 (10%)	39 (14%) [a]	18 (6%) [b]	
More than 300 min	45 (8%)	26 (9%) [a]	19 (6%) [a]	
Vigorous physical activity (N/%)				<0.001
Less than 30 mins	359 (60%)	124 (43%) [a]	235 (75%) [b]	
30–90 min	124 (21%)	84 (29%) [a]	40 (13%) [b]	
90–150 min	58 (10%)	40 (14%) [a]	18 (6%) [b]	
150–300 min	39 (7%)	30 (10%) [a]	9 (3%) [b]	
More than 300 min	22 (4%)	10 (4%) [a]	12 (4%) [a]	
Body Mass Index, MD (IQR)	21.45 (4.79)	23.14 (5.85)	20.53 (3.89)	<0.001

Note: Mann Whitney *U*/Chi-Squared tests were used and the results were adjusted by using Bonferroni method. Each superscript letter denotes a subset of location categories whose column proportions do not differ significantly from each other at the 0.05 level.

Abbreviations: IQR, interquartile range; MD, median; N, number; *the amount of time (in months) that the participants were following their choice of diets.

Ma, et al., 2014; Tennant et al., 2007; Yokoyama et al., 2016; 菅沼 et al., 2016). The survey, which encompassed five questionnaires took around 30 minutes to complete.

Statistical analyses

Prior to statistical analyses, data cleaning was undertaken. By using built-in functionalities in Qualtrics in the United Kingdom and Google Forms in Japan, bot and duplicate submissions, abnormally fast and slow responses, submissions with ambiguous texts and submissions with a completion rate $<30\%$ were disregarded. Statistical analyses were carried out using IBM® Statistical Package for Social Sciences (SPSS Version 28, SPSS Inc., Chicago, Illinois). Groups (UK vs. Japan) were compared by using Mann Whitney *U* (as the results from separate Kolmogorov–Smirnov tests revealed non-normal distributions) or Chi-Squared tests where appropriate. Results from these tests were adjusted by using Bonferroni method. Separate linear regressions (controlling for gender, employment, vigorous physical activity, cigarette, caffeine and alcohol drinking status) were used to assess whether continuous DII score (independent variable) could predict mental/sleep health outcomes (dependent variables; continuous WEMWBS score, categorical depression, anxiety and stress scores, continuous sleep duration, categorical sleep disturbances, use of sleep medication, daytime dysfunction scores). A statistical significance threshold of $p<0.05$ (two-tailed) was applied.

RESULTS

Descriptive statistics of the study sample

Six hundred and two participants (170 males, 425 females, seven not reported/specified) between the ages of 18–40 years (mean age = 25.03 years, SD = 7.32 years) took part in the study. Participant characteristics in the total sample and separately in the United Kingdom and Japan are reported in Table 1. There were no differences in age ($p=0.839$), total number of years in education ($p=0.065$), caffeine intake ($p=0.138$) and alcohol consumption during weekends ($p=0.907$), however, all other measures differed statistically (gender: $p<0.001$; education: $p<0.001$; employment: $p<0.001$; language: $p<0.001$; ethnicity: $p<0.001$; cigarettes per day; $p=0.010$; alcohol consumption: $p=0.009$; alcohol/day during weekdays: $p<0.001$; diet type: $p<0.001$; diet adherence: $p<0.001$; moderate physical exercise: $p<0.001$; vigorous physical exercise: $p<0.001$; body mass index: $p<0.001$). Compared to Japan, participants in the United Kingdom were more likely to (i) be females, (ii) have earlier and graduate and postgraduate educations, (iii) be working part-time or looking for a job, (iv) be English or other ethnicity and speak English and another language, (v) smoke more cigarettes/day, (vi) drink uncontrolled in the weekend, (vii) adhere to non-omnivorous diets, (viii) adhere to their current diets for a shorter period, (ix) engage in moderate and vigorous physical activity for more than 30 mins, and (x) have higher BMI. Whereas, compared to the United Kingdom, participants in Japan

TABLE 2 Comparisons of sleep and mental health outcomes and the Dietary Inflammatory Index (DII) in the United Kingdom and Japan.

	UK (n = 288)	Japan (n = 314)	p
Mental Wellbeing, MD (IQR)	47 (15)	44 (14)	0.041
Depression (N/%)			<0.001
No/mild	204 (71%) [a]	225 (72%) [a]	
Moderate	37 (13%) [a]	70 (22%) [b]	
Severe/extremely severe	47 (16%) [a]	19 (6%) [b]	
Anxiety (N/%)			<0.001
No/mild	218 (76%) [a]	263 (84%) [b]	
Moderate	24 (8%) [a]	46 (15%) [b]	
Severe/extremely severe	46 (16%) [a]	5 (2%) [b]	
Stress (N/%)			<0.001
No/mild	178 (62%) [a]	206 (66%) [a]	
Moderate	50 (17%) [a]	88 (28%) [b]	
Severe/extremely severe	60 (21%) [a]	20 (6%) [b]	
Subjective sleep quality (N/%)			<0.001
Very good	0 (0%)[a]	34 (11%) [b]	
Fairly good	31 (11%) [a]	168 (54%) [b]	
Fairly bad	181 (64%) [a]	101 (32%) [b]	
Very bad	61 (21%) [a]	11 (4%) [b]	
Sleep Duration (hours), M (*SD*)	7.19 (2.03)	6.79 (1.25)	<0.001
Sleep Disturbances (N/%)			<0.001
No disturbance	3 (1%) [a]	116 (37%) [b]	
Low/mid disturbance	70 (24%) [a]	195 (62%) [b]	
Mid/high disturbance	150 (52%) [a]	3 (1%) [b]	
High disturbance	65 (23%) [a]	0 (0%) [b]	
Use of Sleep Medication (N/%)			<0.001
Not during the last month	0 (0%) [a]	303 (97%) [b]	
Less than once a week	252 (88%) [a]	5 (2%) [b]	
Once or twice a week	23 (8%) [a]	3 (1%) [b]	
Three or more times a week	10 (4%) [a]	3 (1%) [b]	
Daytime Dysfunction (N/%)			<0.001
No dysfunction	3 (1%) [a]	131 (42%) [b]	
Low/mid dysfunction	70 (24%) [a]	138 (44%) [b]	
Mid/high dysfunction	150 (52%) [a]	39 (12%) [b]	
High dysfunction	65 (23%) [a]	6 (2%) [b]	
Dietary Inflammation Index, MD (IQR)	0.39 (2.41)	−0.31 (1.38)	<0.001

Note: Mann Whitney U/ Chi-Squared tests were used and the results were adjusted by using Bonferroni method. Each superscript letter denotes a subset of location categories whose column proportions do not differ significantly from each other at the 0.05 level.

Abbreviations: IQR, interquartile range; MD, median; M: mean; N, numbe; SD, standard deviation.

were more likely to be (i) males, (ii) have vocational/apprenticeship educations, (iii) be students, (iv) be Japanese and speak Japanese, (v) smoke less cigarettes/day, (vi) engage in uncontrolled drinking less in the weekend, (vii) adhere to omnivorous diets, (viii) adhere to their current diets for a longer period, (ix) engage in moderate and vigorous physical activity less than 30 mins, and (x) have lower BMI.

Comparisons of sleep and mental health outcomes and DII in the United Kingdom and Japan

While overall mental wellbeing was reported to be better in the United Kingdom (p = 0.041), participants in Japan reported having more moderate (but less severe) depression (p < 0.001) and stress (p < 0.001); and reported not having or having only mild or moderate anxiety and less severe anxiety ($p < 0.001$).

Japanese participants reported having very good or fairly good subjective sleep quality ($p < 0.001$), despite sleeping less ($p < 0.001$), on the contrary, participants in the United Kingdom reported having fairly bad or very bad subjective sleep quality, but longer sleep duration. In terms of sleep disturbances and daytime dysfunction, participants from Japan reported no or low/mild levels of sleep disturbance ($p < 0.001$), and accordingly, no or low/mild levels of daytime dysfunction ($p < 0.001$). In contrast, mid/high or high sleep disturbances and daytime dysfunction were reported by the participants from the United Kingdom. They also reported using sleep medication less than once a week, once or twice a week, or three or more times a week ($p < 0.001$).

Based on the FFQ-derived DII, participants in the United Kingdom were found to be adhering to more pro-inflammatory diets compared to Japanese participants who were found to be more likely to be adhering to anti-inflammatory diets ($p < 0.001$).

Predicting sleep and mental health outcomes from the DII

In combined analyses for the United Kingdom and Japan, continuous DII scores significantly predicted subjective sleep quality (beta = 0.09, $p = 0.005$), sleep disturbances (beta = 1.14, $p < 0.001$), use of sleep medicine (beta = 0.08, $p < 0.001$), and daytime dysfunction (beta = 0.14, $p < 0.001$). Individuals who adhered to more anti-inflammatory diets (higher DII score) reported higher levels of subjective sleep quality, fewer sleep disturbances, less use of sleep medicine and less daytime dysfunction. DII did not predict other mental and sleep health outcomes (all $p > 0.05$), Table 3.

Separate linear regressions (controlling for gender, employment, vigorous physical activity, cigarette, caffeine, and alcohol drinking status) were used to assess whether continuous DII score (independent variable) could predict mental/sleep health outcomes (dependent variables); continuous WEMWBS score, categorical depression, anxiety and stress scores. CI: confidence intervals; LL: lower level; UL: upper level.

DISCUSSION

The current cross-sectional study assessed (i) the inflammatory status of diets (using the DII) and mental and sleep health in the United Kingdom and Japanese populations and (ii) the associations between DII, sleep and mental health in these populations. Our findings revealed that while overall mental wellbeing was reported as higher in the United Kingdom, participants in Japan reported less severe mental health concerns and better sleep outcomes. The Japanese participants also demonstrated a stronger adherence to an anti-inflammatory diet, as indicated by lower DII scores. Importantly, our analysis revealed that adhering to an anti-inflammatory diet is associated with improved sleep outcomes across both cohorts. This suggests the possibility of dietary choices playing a significant role in influencing sleep quality, potentially explaining some of the cross-cultural differences in mental and sleep health outcomes observed in this study.

The current research reported conflicting results in relation to mental health and wellbeing, such that, although the individuals in the United Kingdom reported better overall wellbeing (as measured by the WEMWBS), they reported more severe depression, anxiety and stress, compared to their Japanese counterparts. Although our finding of better mental health outcomes in the Japanese sample is consistent with previously published cross-cultural reports (Ishikawa et al., 2018; Steel et al., 2014) (possibly due to key cultural factors such as stigma and other protective factors such as diet), the aforementioned inconsistency requires an explanation. Although the WEMWBS has demonstrated psychometric properties exhibiting acceptable validity and reliability (Marmara et al., 2022), it was developed, in part, to (i) enable monitoring population health (Tennant et al., 2007)

TABLE 3 Associations between the Dietary Inflammatory Index (DII) score with mental and sleep health outcomes ($n = 602$).

	B	*SE*	*t*	Sig.	CI [LL, UL]	R^2(adjusted)
Mental wellbeing	−0.51	0.37	−1.39	0.16	[−1.233, 0.209]	0.05
Depression	−0.04	0.02	−1.79	0.07	[−0.091, 0.004]	0.02
Anxiety	−0.04	0.02	−1.83	0.07	[−0.077, 0.003]	0.02
Stress	−0.03	0.03	−1.13	0.26	[−0.082, 0.022]	0.02
Subjective sleep quality	0.09	0.03	2.84	0.005	[0.026, 0.143]	0.03
Sleep duration	0.04	0.06	0.64	0.53	[−0.084, 0.164]	0.06
Sleep disturbances	1.14	0.03	4.59	<0.001	[0.083, 0.206]	0.11
Use of sleep medication	0.08	0.02	3.31	<0.001	[0.031, 0.121]	0.11
Daytime dysfunction	0.14	0.03	4.15	<0.001	[0.073, 0.205]	0.07

and (ii) support the evaluation of mental wellbeing programmes (Stewart-Brown et al., 2009). Therefore, the WEMWBS may not be culturally appropriate for the Japanese sample, as it covers items which were likely to receive endorsement from the general UK population as related to mental wellbeing (Tennant et al., 2007). Furthermore, as conceptions and experiences of wellbeing vary across cultural contexts (Christopher et al., 2000; Tov & Diener, 2000), mental wellbeing for many members of the Japanese public could be a different construct (Karasawa et al., 2011; Uchida et al., 2015).

Our findings in relation to sleep outcomes revealed that despite sleeping shorter, Japanese participants reported better subjective sleep quality, lower levels of sleep disturbances and better daytime functioning. Contrastingly, participants in the United Kingdom reported poorer sleep quality, higher sleep disturbances, and more significant daytime dysfunction, even with longer sleep durations. Studies have consistently shown shorter sleep durations (Ackermann & Angus, 2017; Soldatos et al. 2005; Tozer, 2018), but a lower prevalence of sleep problems (Léger et al., 2008; Leger & Poursain, 2005) in Japan compared to the rest of the world. In line with this, recent research by Cheung et al. (2021) discovered that despite shorter sleep durations, Japanese participants reported better subjective health and fewer negative consequences of shorter sleep on daytime functioning when compared to Canadian participants. Cultural variability in sleep practices could explain why Japanese participants prefer to sleep less (Cheung et al. 2021; Steger, 2006), as common attitudes towards sleep in a culture are known to be related to people's sleep behaviours (Arslan et al., 2015; Jeon et al., 2021; Worthman & Melby, 2002). However, the consequences of shorter sleep duration did not necessarily translate into worse sleep outcomes, therefore, it could be speculated that the better sleep outcomes in Japan may be a function of under-reporting because of the possible cultural reticence among Japanese people to associate sleep problems and psychiatric disorders (Leger & Poursain, 2005). Alternatively, it is also possible that cultural protective factors, such as dietary habits (Gabriel et al., 2018; Konishi, 2021; Nanri et al., 2010) and self-medication via the use of easily-accessible over-the-counter sleep and other supplements (Aoyama et al., 2012; Masumoto et al., 2018; Shiina et al., 2021) may play a pivotal role in mitigating the potential negative consequences of shorter sleep in the Japanese population.

With regards to dietary inflammatory status, Japanese participants had lower DII scores, indicating an anti-inflammatory diet, while UK participants presented with higher DII scores, signalling a pro-inflammatory diet. This aligns with the Western-style diet observed for the UK population, characterised by high intakes of red/processed meat, saturated fat and free sugars, but lower intakes of fruit and vegetables and dietary fibre (University of Cambridge, 2022). This dietary pattern has been shown to be associated with higher inflammatory potential and pro-inflammatory biomarkers (Christ et al., 2019; Hepsomali & Groeger, 2022; Khayyatzadeh et al., 2018; Shi et al., 2022; Silveira et al., 2018). Conversely, in Japan, despite shifting dietary trends (i.e., Westernisation) (Fauzi et al., 2022; Nishi & Takimoto, 2023), possibly due to the recent cultural and governmental efforts to preserve the traditional Japanese diet as a national culinary heritage (Lusiana et al., 2022; Wong & Murata, 2017), research has reported that individuals in Japan consume comparatively higher intakes of vegetables, fish and legumes, but lower intakes of dairy, saturated fat and added sugars (Nomura et al., 2023), a pattern which is associated with reduced pro-inflammatory biomarkers (Ma et al., 2021; Sureda et al., 2018). A more anti-inflammatory diet and activities (such as bathing, possibly due to its tonic regulatory effect on inflammatory activity) in Japan may contribute to better health outcomes (Coe et al., 2020).

With regards to associations between the DII and sleep outcomes, we observed higher levels of subjective sleep quality, fewer sleep disturbances, less use of sleep medicine and less daytime dysfunction in individuals who adhere to more anti-inflammatory diets, irrespective of their location. This finding is consistent with previous research showing that a pro-inflammatory diet was linked to increased self-reported sleep disturbances, poor sleep quality and daytime sleepiness and dysfunction (Coxon et al., 2024; Farrell et al., 2023; Kase et al., 2021; Masaad et al., 2021). Pro-inflammatory and/or unhealthy dietary patterns are known to be associated with increased systemic inflammation markers, such as the C-reactive protein (Hepsomali & Groeger, 2022; Shivappa et al., 2018), and these markers are known to be associated with altered sleep outcomes (Ferrie et al., 2013; Hepsomali & Groeger, 2022; Lee et al., 2020; Liu et al., 2014), potentially due to their role in modulating neurotransmitters (Sanchez-Villegas & Martínez-González, 2013). These biomarkers were shown to mediate the relationship between diet and sleep health (Hepsomali & Groeger, 2022). Although the inflammatory potential of diet is a promising factor that can modulate sleep, directly affecting metabolic and immunologic responses, diet could also influence sleep outcomes indirectly via influencing the gut microbiota (and vice versa), which is known to play a role in driving systemic chronic inflammation (Hakansson & Molin, 2011). Supporting evidence comes from a review proposing a link between the gut microbiota and circadian rhythms, potentially contributing to poor sleep and/or sleep disorders (Teichman et al., 2020).

It is important to note that we observed no associations between DII and mental health outcomes. Although differences in DASS scoring may have contributed to this, our findings are not unusual, given that the existing cross-sectional and longitudinal studies have reported an inconsistent association between the inflammatory potential of diet and mental health outcomes (Shakya et al., 2021). Differences in the study design, especially tools for assessing mental health outcomes, inclusion/exclusion criteria and covariates included in the statistical models may explain this inconsistency (Quirk et al., 2013).

There are notable limitations in the current study. First of all, as the current study was cross-sectional, the findings do not necessarily indicate causality. Second, the original and Japanese translations of DASS included 42 and 15 questions, respectively, hence the maximum total scores differed. Due to this, we had to dichotomise the total scores, which may have resulted in a loss of information and study power. Third, due to the previous limitation, although sociodemographic and lifestyle data were collected in both samples, we could not adjust for known and potential confounders. Fourth, due to differing FFQ outcomes in the United Kingdom and Japan, we could not utilise all 45 food parameters that are used to estimate the DII score, though previous studies have shown that the reduction in the number of food parameters did not attenuate the association between DII and objective biomarkers of inflammation (Kotemori et al., 2020; Shivappa, Steck, Hurley, Hussey, Ma, et al., 2014) (though significant association between DII and objective biomarkers of inflammation found only in men in Kotemori et al. (2020)'s study, possibly due to generally lower levels of chronic systemic inflammation among Japanese women). Additionally, as the range of DII scores in the current study is consistent with the range of DII scores reported in previous studies and the DII score calculation treats all parameters equally, we do not expect the reduced number of food parameters used in the current study to affect our findings. Fifth, objective biomarkers of inflammation were not measured in the current study, however, previously strong associations between the DII and these biomarkers have been repeatedly observed (Kotemori et al., 2020; Shivappa et al., 2015; Shivappa et al., 2017; Shivappa, Steck, Hurley, Hussey, Ma, et al., 2014). Finally, we would like to highlight that although participants in the United Kingdom and Japan shared key characteristics, the risk of bias in the study participant's selection should not be underestimated.

CONCLUSION

In conclusion, in the current study, we have shown differences between mental and sleep health outcomes in the United Kingdom and Japan, and these differences could potentially be explained by the differing inflammatory potential of respective regional diets. Due to the high prevalence of mental and sleep health outcomes across the globe, and the social, economic and health burden of these disorders, targeting a modifiable risk factor, namely diet, could be an alternative strategy to improve mental and sleep health outcomes. Future studies are warranted to replicate our findings by utilising longitudinal and prospective studies across different cultures, ideally by accounting for known and potential confounders and measuring inflammatory biomarkers, and to assess the mental and sleep health benefits of adhering to anti-inflammatory traditional Japanese diets in clinical and subclinical cohorts.

AUTHOR CONTRIBUTIONS

Conceptualisation of this study, PH and JN; Methodology, PH and JN, statistical analyses, PH, Data analysis support and interpretation, PH, Execution of primary study and data collection, PH, HKK, CC, NH, KK, HH; writing, review and editing, PH, HKK, CC, NH, KK.

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CONFLICT OF INTEREST STATEMENT

PH and JN have received research funding, consultancy, travel support, and speaking honoraria from various industrial companies. Other authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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