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Psychological stress and (poly)phenol intake in free-living healthy adults: an ecological momentary assessment study

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Stress can impact physical and psychological health, partially driven by a deterioration in dietary choices during periods of stress. Crucially, the nutritional composition of food choices made in the context of stress may protect from or exacerbate its impact on health. Dietary (poly)phenols can be cardioprotective during stress but whether individuals tend to consume (poly)phenol-rich foods during stressful periods is unknown. This study aimed to investigate within- and between-person associations between daily stress and (poly)phenol intake in a free-living environment. Daily levels of perceived stress and psychological wellbeing (anxiety, depression, positivity, energy, fatigue), (poly)phenol intake (including flavonoids and phenolic acids sub-groups), (poly)phenol-rich food intake (fruit and vegetables, tea and coffee, red wine), and diet composition (fat, saturated fat, sugar, fibre) were measured using ecological momentary assessment (EMA) in 67 young healthy participants over 7 days. Multilevel linear mixed models examined within- and between-person associations between daily perceived stress, psychological wellbeing and (poly)phenol intake, (poly)phenol-rich food intake and dietary composition. Higher stress at the within-person level and symptoms of depression at the between-person level were associated with more consumption of tea and coffee. This was paralleled by a tendency to increase polyphenol (p = 0.070) and phenolic acid (p = 0.064) intake during stress. Furthermore, the association between stress and tea and coffee consumption was stronger in participants with higher habitual stress. A lower perception of feeling positive at the within-person level was associated with higher saturated fat and sugar consumption, and higher fatigue at the between-person level was associated with increased fat intake. Our findings suggest that when perceived stress is higher, individuals show preference for consumption of (poly)phenol-rich beverages such as tea and coffee. Future research should investigate whether tea and/or coffee are a viable strategy to deliver (poly)phenols during stressful periods with the ultimate goal of protecting cardiovascular health.

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1. Introduction

Stress is increasingly prevalent, being the leading cause of work-related sickness with 22.1 million working days lost in 2024 due to stress, depression or anxiety, costing up to £22.9 billion annually.[1] Stress can negatively impact both physical and mental health. For example, stress has been associated with increased incidence of myocardial infarction and ischaemia,[2–4] disruptions to brain function and cognition,[5] increased incidence of depression[6] and other psychological disorders.[7] More specifically, stress can impact the vasculature, as shown by transient declines in endothelial function from 15 to 90 minutes following stress in young healthy adults.[8,9] These impairments in vascular function have been implicated as a mechanism linking chronic stress to poor cardiovascular health.[10]

Stress has also been associated with obesity:[11,12] 46% of adults report overeating or eat unhealthily during periods of stress,[13] with overweight individuals typically being more vulnerable to stress-induced overeating.[14] The relationship between stress and diet is complex, with several studies suggesting that food choices change during stress. For example, in an experimental human study, young adults opted for high-fat and high-sugar foods over fresh fruit following exposure to stress.[15] Additionally, greater calorie consumption

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was observed immediately following psychological stress in individuals whose cortisol levels rose the most during the stress (high cortisol reactors) compared to individuals with low cortisol responses (low cortisol reactors).[16] Whilst well-controlled experimental designs can elucidate underlying mechanisms linking stress and eating behaviour, many of these settings are not conducive to eating freely as food choices will be limited by the food provided and influenced by the social context.[17,18] In agreement with the experimental studies investigating food choices during stress, cross-sectional and prospective studies have also reported higher perceived stress to be linked with increased consumption of unhealthy snacks and reduced consumption of fruits and vegetables.[19–21]

Protective bioactive compounds, particularly (poly)phenols, are found abundantly in fruits and vegetables, as well as beverages such as tea, coffee, and wine. Observational studies have highlighted that diets rich in (poly)phenols improve cardiovascular health.[22,23] Further randomised controlled trials (RCTs) have also demonstrated positive effects of (poly)phenol intake, particularly its main sub-groups flavonoids and phenolic acids, on human vascular function following acute and chronic consumption.[24–29] A reduced consumption of fruits and vegetables during periods of stress might be detrimental for cardiovascular health, whilst foods rich in (poly)phenols may have the potential to protect vascular health during stressful periods. In line with this, we have shown that intake of a polyphenol-rich cocoa beverage prevents the acute decline in vascular function that occurs following an isolated episode of stress.[30] Importantly, such benefits persist even when polyphenols are consumed with a high-fat meal,[31] which we showed to worsen vascular recovery following stress.[32,33] In addition to benefits within the vasculature, cross-sectional studies indicate that higher (poly)phenol intake is associated with reduced depression and anxiety and reduced perceived stress.[34,35] Similarly, longitudinal studies suggest a lower risk for depressive symptomatology in individuals consuming more (poly)phenols in their diets.[36,37] Despite encouraging evidence of the potential protective effects of (poly)phenols in the context of stress, it is unclear whether people modify (increase or decrease) their (poly)phenol intake with increasing levels of stress in everyday settings/life. Therefore, identifying associations between perceived stress (and psychological wellbeing) and (poly)phenol intake in a free-living environment is key to help understand whether (poly)phenol-rich food choices may be a viable strategy to protect cardiovascular health from stress. Furthermore, identifying whether there are any daily associations between stress and some of the main food sources of (poly)phenol intake (particularly fruits and vegetables; tea and coffee, and red wine), would help identify which specific food groups may be more easily targeted to protect human vascular function from stress.

Ecological momentary assessment (EMA) is a methodology used to examine participant behaviour and experiences in real-time, in their free-living environment.[38] Furthermore, EMA enables the consideration of both between-person (deviation from average group level) and within-person (deviation from individuals own average) associations across the same period.[39] Previous research has typically focussed on differences between people (inter-individual variation),[39] and thus cross-sectional and longitudinal studies investigating the association between stress and (poly)phenol intake are unable to determine within-person (intra-individual) variation.[34,36] Given that stress exposure and dietary choices are likely to fluctuate differently within individuals, within-person analyses can reveal the extent of this fluctuation across time.[39] To our knowledge, this is the first study to use within-person and between-person analyses to investigate associations between perceived stress (and psychological wellbeing) and (poly)phenol intake.

In the present study, we aimed to investigate the associations between perceived stress and intake of (poly)phenols and its main sub-groups, flavonoids and phenolic acids, as well as main food sources of (poly)phenols. We further evaluated how perceived stress associated with key components of the daily diet (total fat, saturated fat, sugar, fibre) during the same period. We also explored the associations between other measures of psychological wellbeing, to provide a more comprehensive examination of overall mood states, and how they may be related to nutritional intake. We hypothesised that during stressful days, or days with poorer psychological wellbeing, participants would decrease their consumption of (poly)phenols, fibre, fruits and vegetables, and increase their intake of fat and sugar.

2. Methods

2.1 Study design

The present study used a 7-day EMA design and was approved by the University of Birmingham Ethics Committee (ERN17_1755C). Informed consent was obtained online from all participants before enrolment in the study. The data was collected during the COVID-19 pandemic.

2.2 Participants

A total of 67 young, healthy adults were recruited *via* email advertisements. Inclusion criteria were (i) aged 18–45 years, (ii) able to read English, and (iii) no current medically diagnosed mental health condition, (iv) no medically diagnosed health conditions. Given the lack of previous work to base our sample size on, and as there is no universal minimum sample size for multilevel modelling, we recruited 67 participants, using previous between-person analyses as a guideline.[40]

2.3 Procedures

Data collection occurred between February 2021 and August 2021 using an online questionnaire platform (SmartSurvey). If eligible and consenting, participants were distributed with a set of questionnaires to obtain demographic information, habitual stress, and other psychological assessments (data not reported). Following completion of these questionnaires, data collection commenced for 7 days, including 5 weekdays and 2 weekend days, starting on a Monday where possible (Fig. 1). Participants were briefed about how to complete daily food

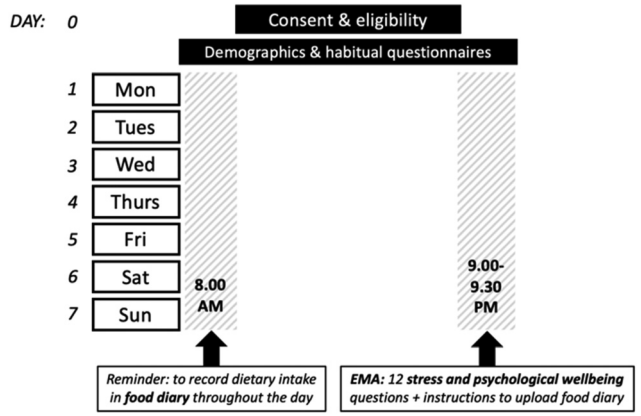


Fig. 1 Study protocol. Day 0: online questionnaire pack to obtain demographic information.

diaries (distributed approx. 8:00 am) and a daily questionnaire (distributed approx. 9:00–9:30 pm), which included stress and psychological wellbeing assessments and instructions to upload the food diary recorded that day. At the end of the data collection period, data was downloaded to a research computer, the surveys were closed, and the data was then organised and analysed.

2.4 Outcome measures

2.4.1 Demographic information. Demographic information was obtained during the initial questionnaire pack, and included measures of age, gender, ethnicity, nationality, height, and weight (and general health, engagement in extracurricular activities, long-term conditions/diseases, alcohol consumption and smoking status; data not reported). Terms 'male' and 'female' used in this paper refer to self-identified gender, and 100% of participants identified as male or female. COVID-19 lockdown status was also reported by the participant and assessed retrospectively using the UK Government's official lockdown dates and timestamps.

2.4.2 Daily dietary intake. Daily dietary intake was assessed using a food diary. Participants were asked to record their dietary intake throughout the day, using a food diary sent to them at 8:00 am, and a reminder to upload their diary sent with the evening EMA survey, *via* SmartSurvey. Instructions were distributed, including sections for the time the food was consumed, type of food consumed, amount (with indication of quantity), and other details such as brand/details on how the food was cooked. It was requested that participants used weighing scales and space for detailed recipes for home-cooked meals were provided. Participants were asked to eat and drink as they normally would and record everything they ate and drank across the day. Brand names and cooking methods were also recorded, as well as nutrient supplement usage. Following the first day of data collection, participants' food diaries were manually checked for accuracy and feedback was given as necessary; participants were asked to repeat a day if the detail was not sufficient.

2.4.2.1 (Poly)phenol analysis. (Poly)phenol intake was calculated from food items (g day^{-1}) based on a polyphenol database (PPDB), that includes common foods and beverages in the UK diet. The PPDB was developed at the Department of Nutritional Sciences of King's College London, which has been described in detail previously.[41] The PPDB integrated (poly)phenol content data of 1260 raw and processed food items or dishes, which were obtained from multiple sources such as the Phenol-Explorer database,[42] USDA databases,[43–45] and published analytical data. The (poly)phenol contents for composite dishes were calculated based on recipes from McCane and Widdowson's (6^{th} edition), see the SI of ref. 46 and retailer websites. Food items such as animal products with little or no (poly)phenol content were removed from the calculation. The total subclass, class, and total (poly)phenol intake were calculated by summarising the intake of all the compounds within the group. Total polyphenols, total flavonoids and total phenolic acids were included in data analysis. Daily fruit and vegetables, tea and coffee, and red wine consumption were manually estimated and included in data analysis as some of the main (poly)phenol-rich food sources.

2.4.2.2 Macronutrient and fibre analysis. Following the 7-day data collection, food diary data was processed into a dietary software analysis package, Dietplan 7.0 (Forestfield Software Ltd, Horsham, West Sussex, UK). Dietplan 7.0 was appropriate as it utilises UK-specific databases such as McCance and Widdowson, as well as relevant ethnic minority food databases. In instances in which a food item could not be found in the software databases, these were added to the database using food manufacturing websites and other food composition tables. All nutrients were exported, with fat, saturated fat, sugar, and fibre included in data analysis.

2.4.3 Daily stress and psychological wellbeing. One EMA survey was sent each day (*via* text message or email, depending on participant preference) and took less than 2 minutes to complete. The survey consisted of 12 questions examining how stressed, anxious, positive, depressed, fatigued, and energetic the participant felt (included in analysis) and cheerful, angry, happy, calm, and how well they felt they coped with stress, and how on top of things they felt across the day (data not reported). These single items were developed by the research group and adapted from the Perceived Stress Scale (PSS). The full PSS assesses perceived stress over a month, but it was considered too long to include in a daily diary. All items were pilot tested, and participants said they understood each item well. Items were scored on a scale of 1 to 5, with 1 being 'not at all' and 5 being 'extremely'. There was also a 'prefer not to answer' option. Each item was scored individually.

2.4.4 Habitual stress. The 10-item Perceived Stress Scale (PSS)[47] assessed how stressed participants felt over the last month. Each item (*e.g.*, "How often have you felt nervous and stressed?") was rated on a 5-point Likert scale from 0 (*never*) to 4 (*very often*). Positive items were reverse-scored, and a total score was calculated whereby higher scores indicate higher perceived stress. The scale demonstrated good internal reliability ($\alpha = 0.89$).

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2.5 Data analysis

59 participants (30 female) were included in the analysis, following removal of 8 participants (exclusion reasons: $n = 2 > 50$ years, $n = 1$ current mental health condition, $n = 1$ not completing data collection period, $n = 4$ not starting data collection period). All analyses were conducted using IBM SPSS Statistics for Windows (version 29.0). Intra-class coefficients (ICC) are reported for daily dependent variables. One-way ANOVAs assessed gender differences across demographics and all daily study variables.

Multilevel linear mixed models were tested to examine within-and between-person associations between daily stress, psychological wellbeing, and dietary intake. These analyses investigated if (1) deviations from an individual's own average stress levels and wellbeing are related to their food intake (within-person associations) and (2) deviations from the sample's average stress levels and wellbeing are related to food intake (between-person associations). In each model, stress, anxiety, positivity, depression, energy, and fatigue were added as separate predictors with each (poly)phenol (polyphenols, flavonoids, phenolic acids) (aim 1), nutrient (fat, saturated fat, sugar), fibre (aim 2), and (poly)phenol-rich food source (fruit and vegetables, tea and coffee, red wine) (aim 3) as a separate outcome. Aims 1 and 2 were specified *a priori*, whereas aim 3 involved exploratory analyses conducted in response to findings from our primary aim. In all models, within-person predictors were person-centred, with positive values showing above person average stress/wellbeing and negative values showing below person average stress/wellbeing levels. At level 2, the average of daily assessments over the 7 days was entered as between-person (grand sample centred), providing 'typical' (or average across the data collection period) levels, with positive values reflecting higher than group average stress/wellbeing levels and negative values reflecting low average stress/wellbeing levels. Age, gender (0 = male, 1 = female), BMI, and COVID-19 status (0 = no lockdown, 1 = in a lockdown) were also entered at level 2 as covariates in all models. As exploratory analysis, one interaction was included in each set of stress models, investigating the interaction between each (poly)phenol, nutrient, and polyphenol-rich food source predictor with habitual stress (PSS). For all models the intercepts were random, and the slopes were fixed. Multilevel models' $\beta \pm SE$ are reported. For all analyses, significance was set at $\alpha < 0.05$.

To calculate the amount of variance in each dependent variable explained by within-and between-person predictors, a series of models were analysed. The pseudo-R squared models presented in the results investigated the amount of variance in the dependent variable explained by within-person predictors (R_1^2) and between-person predictors (R_2^2), relative to the empty model (model with covariates only).[48]

3. Results

3.1 Overview of results

Participants ($n = 59$) completed 412 (99.8%) of 413 (over 7 days) of daily questions assessing stress and psychological wellbeing and 410 (99.3%) of 413 daily food diaries (with 3 participants completing only 6 out of 7 days of their food diaries). The skewness scores for the dependent variables of stress and psychological wellbeing (stress: 0.70, anxiety: 0.73, positivity: −0.24, depression: 1.77, energy: −0.13 and fatigue: 0.40), (poly)phenols (polyphenols: 1.42, flavonoids: 1.70, phenolic acids: 1.61), nutrients (fat: 0.72, saturated fat: 1.40, sugar: 1.41), fibre (0.98), and (poly)phenol-rich food sources (fruit and vegetables: 0.94, tea and coffee: 1.86) were in an acceptable range (skewness ± 2).[49] The skewness score for red wine exceeded the acceptable range (red wine: 6.34), so analysis of red wine should be treated with caution.

Participant characteristics, stress and psychological wellbeing, and dietary intake are displayed in Table 1. Participants were young, with a healthy average BMI (between 19.9–32.0 kg m^{-2}) and reported to be relatively healthy. Participants were mostly British (81.3%) and of white ethnicity (88.1%). Almost 50% of participants were in a lockdown when completing the study ($n = 27$ in a lockdown, $n = 32$ not in a lockdown). Subsequently, lockdown status was included as a covariate in our analyses.

3.2 Gender differences

Gender differences are reported in Table 2. Females were younger ($p = 0.003$), had a lower BMI ($p < 0.001$) and reported a higher health rating ($p = 0.026$). Females reported lower

Table 1 Descriptive statistics and intraclass correlation coefficients for study variables ($n = 59$)

Demographics	Mean ± SD	ICC	Min	Max
Age (years)	24.24 ± 3.57	—	18.00	36.00
BMI (kg m^{-2})	23.35 ± 2.62	—	19.86	32.02
Health rating (/5)	3.39 ± 1.03	—	1	5
Gender (n(%))	F: 30 (51%), M: 29 (49%)			
Stress and psychological wellbeing				
Stress (/5)	2.08 ± 1.04	0.278	1	5
Anxiety (/5)	2.07 ± 0.98	0.361	1	5
Positivity (/5)	3.50 ± 0.95	0.426	1	5
Depression (/5)	1.46 ± 0.71	0.293	1	5
Energy (/5)	3.11 ± 0.96	0.363	1	5
Fatigue (/5)	2.65 ± 1.01	0.223	1	5
Habitual stress				
PSS (/40)	17.61 ± 6.33	—	4	32
(Poly)phenols (/day)				
Polyphenols (mg)	837.17 ± 717.17	0.729	0.33	4120.99
Flavonoids (mg)	351.94 ± 424.16	0.729	0.00	2188.78
Phenolic acids (mg)	439.77 ± 492.47	0.633	0.00	2652.98
(Poly)phenol-rich food sources (/day)				
Fruit and vegetables (g)	364.32 ± 261.77	0.388	0.00	1223.50
Tea & coffee (ml)	309.17 ± 356.86	0.712	0.00	2376.00
Red wine (ml)	13.20 ± 73.56	0.139	0.00	750.00
Nutrients (/day)				
Fat (g)	82.56 ± 38.28	0.315	11.12	225.10
Saturated fat (g)	30.37 ± 17.97	0.221	1.71	123.48
Sugar (g)	84.12 ± 54.23	0.491	3.90	391.24
Fibre (/*day*, g)	22.04 ± 10.65	0.458	1.00	59.78

SD: standard deviation, ICC: intraclass correlation coefficient, Min: minimum, Max: maximum, BMI: body mass index, F: female, M: male.

Table 2 Gender differences in study variables

Demographics	Male (mean ± SD)	Female (mean ± SD)	Difference*	η_p^2
Age (years)	24.76 ± 3.65	23.73 ± 3.43	**$p = 0.003$**	0.021
BMI (kg m^{-2})	24.07 ± 2.76	22.65 ± 2.28	**$p < 0.001$**	0.073
Health rating (/5)	3.28 ± 0.95	3.50 ± 1.09	**$p = 0.026$**	0.012
Stress and psychological wellbeing				
Stress (/5)	2.27 ± 1.06	1.90 ± 0.98	**$p < 0.001$**	0.033
Anxiety (/5)	2.00 ± 0.94	2.13 ± 1.02	$p = 0.153$	0.005
Positivity (/5)	3.47 ± 0.99	3.53 ± 0.91	$p = 0.552$	0.001
Depression (/5)	1.46 ± 0.73	1.45 ± 0.70	$p = 0.826$	0.000
Energy (/5)	3.00 ± 0.95	3.22 ± 0.96	**$p = 0.015$**	0.014
Fatigue (/5)	2.67 ± 1.03	2.63 ± 0.99	$p = 0.677$	0.000
(Poly)phenols (/day)				
Polyphenols (mg)	706.67 ± 677.43	953.86 ± 717.17	**$p < 0.001$**	0.030
Flavonoids (mg)	303.79 ± 428.11	410.82 ± 423.75	**$p = 0.011$**	0.016
Phenolic acids (mg)	362.12 ± 410.19	492.28 ± 535.40	**$p = 0.006$**	0.018
(Poly)phenol-rich food sources (/day)				
Fruit and vegetables (g)	348.35 ± 282.73	379.53 ± 239.81	$p = 0.228$	0.005
Tea & coffee (ml)	263.55 ± 381.14	353.27 ± 326.60	**$p = 0.010$**	0.047
Red wine (ml)	18.75 ± 88.81	7.92 ± 54.96	$p = 0.136$	0.024
Nutrients (/day)				
Fat (g)	83.46 ± 39.12	81.70 ± 37.54	$p = 0.643$	0.001
Saturated fat (g)	30.92 ± 17.26	29.84 ± 18.65	$p = 0.540$	0.001
Sugar (g)	80.23 ± 58.63	87.83 ± 49.55	$p = 0.156$	0.005
Fibre (/day, g)	22.74 ± 12.39	21.36 ± 8.61	$p = 0.195$	0.004

BMI: body mass index, SD: standard deviation, η_p^2: partial eta squared. *p value from ANOVAs.

levels of daily stress ($p < 0.001$) and higher levels of daily energy ($p = 0.015$) compared to males. Females reported to consume more polyphenols ($p < 0.001$), flavonoids ($p = 0.011$), phenolic acids ($p = 0.006$), and tea and coffee ($p = 0.010$) per day compared to males.

3.3 Stress and psychological wellbeing predicting dietary intake

Tables 3–5 display multilevel models with perceptions of stress and psychological wellbeing (anxiety, positivity, depression, energy, fatigue) predicting daily (poly)phenols (Table 3; polyphenols, flavonoids, phenolic acids), daily (poly)phenol-rich food sources (Table 4; fruit and vegetables, tea and coffee, red wine), and daily macronutrients (fat, saturated fat, sugar) and fibre (Table 5).

3.3.1 The impact of covariates on nutrient intake. All models included covariates age, gender, BMI, and COVID-19 status. BMI significantly predicted polyphenol intake (−76.28 (30.81) to −66.27 (31.96), p's < 0.043) in all models, whereby a higher BMI was associated with lower polyphenol intake. BMI significantly predicted fibre intake (−0.82 (0.36) to −0.74 (0.35), p's < 0.042) in all models, whereby a higher BMI was associated with lower fibre intake. BMI did not significantly predict any other dietary outcomes. Age significantly predicted higher polyphenol intake (60.04 (25.89) to 71.43 (26.18), p's < 0.028) in all models, and higher flavonoid intake in most models (32.87 (16.40) to 36.36 (16.50), p's < 0.050), with the exception of energy.

Age significantly predicted fruit and vegetable (16.17 (7.36) to 18.71 (7.52), p's < 0.036) and tea and coffee (39.64 (12.79) to 46.06 (12.72), p's < 0.004) consumption in all models. In other words, greater age associates with higher polyphenol, flavo-

Table 3 Multilevel modelling coefficients of stress and psychological wellbeing predicting (poly)phenol intake

	Polyphenols β (SE)	Flavonoids β (SE)	Phenolic acids β (SE)
Fixed effects			
Intercept	**628.99 (145.44)*** **	**299.83 (90.07)** **	**299.85 (93.97)** **
Level 1 predictors			
Stress	18.82 (21.63)	18.28 (14.18)	−3.34 (15.51)
Anxiety	−8.77 (24.28)	−1.29 (15.94)	−7.47 (17.39)
Positivity	−2.91 (26.83)	1.09 (17.61)	−1.11 (19.22)
Depression	−38.45 (33.03)	−4.38 (21.71)	−27.14 (23.65)
Energy	−0.76 (25.47)	−6.19 (16.71)	4.79 (18.24)
Fatigue	1.96 (21.42)	17.17 (14.03)	−18.42 (15.31)
Level 2 predictors			
Stress	233.27 (126.14)#	71.39 (79.93)	153.58 (81.37)#
Anxiety	111.82 (119.33)	−8.15 (74.48)	114.49 (76.16)
Positivity	−77.71 (116.30)	60.69 (71.88)	−132.37 (73.31)
Depression	280.97 (175.75)	85.24 (110.79)	194.65 (113.16)
Energy	−108.95 (128.19)	−27.88 (79.82)	−75.96 (82.73)
Fatigue	14.06 (138.71)	38.44 (85.76)	−26.00 (89.57)
Pseudo R^2			
R_1^2 (%)	0.02–6.09	0.02–1.41	0.14–6.52
R_2^2 (%)	0.00–0.41	0.00–0.52	−0.00–0.44
Model fit			
AIC	5744.43–5748.49	5416.97–5419.40	5477.31–5480.60
−2 LL	5726.43–5730.49	5398.97–5401.40	5459.31–5462.60

SE: standard error, AIC: Akaike's information criterion, LL: log likelihood. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, #$p = 0.05$–0.07. All models were run separately for each predictor (within and between-person), so intercept, pseudo R^2 and model fit indices are given as a range. R_1^2 – variance explained at level 1 (within-person) relative to the variance explained in the covariates only model, R_2^2 – variance explained at level 2 (between-person) relative to the variance explained in the covariates only model. The fixed effects intercept reflects the estimated mean in the outcome variable for a male with an average age and BMI and not in lockdown.

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Table 4 Multilevel modelling coefficients of stress and psychological wellbeing predicting (poly)phenol-rich food sources

	Fruit and vegetables β (SE)	Tea and coffee β (SE)	Red wine β (SE)
Fixed effects			
Intercept	**320.39 (40.55)–330.39 (40.58)*****	**242.51 (69.89)–261.92 (69.41)****	**20.59 (9.15)–21.77 (9.02)***
Level 1 predictors			
Stress	8.02 (12.55)	**27.79 (11.86)***	0.75 (4.22)
Anxiety	−3.92 (14.08)	0.38 (13.42)	−3.07 (4.73)
Positivity	−4.03 (15.55)	5.59 (14.85)	6.97 (5.21)
Depression	−15.78 (19.17)	−19.37 (18.31)	−1.74 (6.45)
Energy	−9.17 (14.76)	−0.46 (14.01)	2.07 (4.96)
Fatigue	4.93 (12.42)	−1.60 (11.86)	1.93 (4.17)
Level 2 predictors			
Stress	41.06 (36.19)	112.07 (62.36)	−1.31 (8.12)
Anxiety	47.52 (33.27)	43.74 (59.09)	1.04 (7.57)
Positivity	−21.02 (32.77)	−42.75 (57.37)	1.02 (7.34)
Depression	33.37 (50.49)	**178.44 (85.43)***	7.12 (11.30)
Energy	−40.19 (35.97)	−55.44 (63.25)	−8.29 (8.06)
Fatigue	65.38 (38.17)	18.18 (68.41)	12.32 (8.62)
Pseudo R^2			
R_1^2 (%)	0.92–6.39	0.14–5.82	−0.34–7.16
R_2^2 (%)	0.02–0.21	0.00–1.64	0.01–0.53
Model fit			
AIC	5248.50–5251.05	5302.28–5310.76	4369.13–4371.29
−2 LL	5230.50–5233.05	5284.28–5292.77	4351.13–4353.29

SE: standard error, AIC: Akaike's information criterion, LL: log likelihood.*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. All models were run separately for each predictor (within and between-person), so intercept, pseudo R^2 and model fit indices are given as a range. R_1^2 variance explained at level 1 (within-person) relative to the variance explained in the covariates only model, R_2^2 – variance explained at level 2 (between-person) relative to the variance explained in the covariates only model. The fixed effects intercept reflects the estimated mean in the outcome variable for a male with an average age and BMI and not in lockdown.

noid, fruit and vegetable, and tea and coffee intake. Age did not significantly predict any other dietary outcomes. Gender significantly predicted tea and coffee intake in the stress (181.19 (82.57), $p = 0.032$) model only, whereby being female associated with higher consumption of tea and coffee compared to males. Gender did not significantly predict any other nutrient intake. COVID-19 status did not significantly predict any nutrient intake.

3.3.2 (Poly)phenols: stress and psychological wellbeing did not associate with (poly)phenol intake. Within-person or between-person anxiety, positivity, depression, energy, or fatigue did not predict (poly)phenol, and their sub-groups, polyphenol, flavonoid, or phenolic acid consumption (Table 3). At a between-person level, stress tended to positively associate with polyphenol intake (233.27 (126.14), $p = 0.070$). This is driven mainly by phenolic acid intake given that between-person stress (153.58 (81.37), $p = 0.064$) tended to associate with increased phenolic acid intake. At within-person level, stress did not associate with polyphenol or phenolic acid intake, and within- or between-person stress did not predict flavonoid intake.

3.3.3 (Poly)phenol-rich food sources: higher levels of stress and depressive symptoms associated with increased tea and coffee consumption. Within-person stress significantly predicted tea and coffee consumption, whereby a 1 unit increase in perceptions of stress compared to their own average predicted 27.79 ± 11.86 ml more tea and coffee ($p = 0.020$) consumed (Table 4). Within-person stress did not predict fruit and vegetable, or red wine intake. Furthermore, between-person stress did not significantly predict any (poly)phenol-rich food sources. Between-person depressive symptoms also significantly predicted tea and coffee intake whereby a 1 unit increase in depressive symptoms compared to the group average predicted 178.44 ± 85.43 ml more tea and coffee consumed ($p = 0.041$). However, between-person depressive symptoms did not predict fruit and vegetable or red wine intake. Similarly, within-person depressive symptoms did not predict fruit and vegetable, tea and coffee, or red wine intake. Within-person and between-person anxiety, positivity, energy, and fatigue did not predict fruit and vegetable, tea and coffee, or red wine intake.

3.3.4 Macronutrients: low positivity associated with saturated fat and sugar intake, and higher fatigue associated with fat intake. Within-person positivity significantly predicted saturated fat and sugar consumption, whereby a 1 unit decrease in positivity compared to their own average predicted 2.38 ± 1.19 g more saturated fat ($p = 0.046$) and 6.41 ± 2.96 g more sugar ($p = 0.031$) consumed (Table 5). However, at the within-person level, positivity did not predict total fat consumption and at the between-person level positivity did not predict fat, saturated fat, or sugar consumption. Between-person fatigue significantly predicted total fat consumption, whereby a 1 unit increase in fatigue compared to the group average predicted 11.32 ± 5.44 g more fat consumed ($p = 0.042$). Between-person fatigue did not predict saturated fat or sugar consumption, and within-person fatigue did not predict fat, saturated fat, or sugar consumption. Within-person or between-person stress, anxiety, depression, or energy did not predict fat, saturated fat, or sugar consumption.

3.3.5 Fibre: higher levels of anxiety associated with fibre intake. Between-person anxiety significantly predicted fibre consumption, whereby a 1 unit increase in anxiety compared to the group average predicted 2.76 ± 1.32 g more fibre consumed ($p = 0.041$). However, within-person anxiety did not predict fibre consumption. Within-person or between-person stress, positivity, depression, energy, or fatigue did not predict fibre consumption (Table 5).

3.3.6 Interactions: habitual stress mediates the relationship between daily stress and coffee/tea intake. An interaction was included for each stress model, investigating the interaction between daily stress and habitual stress (PSS), in associating with each dietary outcome. A higher habitual stress positively increases the association between daily stress and tea and coffee intake (59.87(18.590), $p = 0.001$). Specifically, for each one unit increase in habitual stress (PSS), the effect of daily stress increases consumption of tea and coffee by 59.87 ml. No other significant interactions were found.

3.3.7 Variance. The amount of variance explained by within-person fluctuations (R_1^2) was generally higher than the amount of variance explained by between-person differences

Table 5 Multilevel modelling coefficients of stress and psychological wellbeing predicting nutrient and fibre intake

	Fat β (SE)	Sat. fat β (SE)	Sugar β (SE)	Fibre β (SE)
Fixed effects				
Intercept	**79.32 (5.89)–80.55 (5.71)*** **	**29.65 (2.63)–30.02 (2.59)*** **	**79.93 (10.19)–80.73 (10.37)*** **	**19.71 (1.62)–20.30 (1.61)*** **
Level 1 predictors				
Stress	−0.82 (1.90)	−0.17 (0.97)	−2.12 (2.40)	0.05 (0.49)
Anxiety	0.08 (2.13)	0.60 (1.08)	0.21 (2.70)	−0.56 (0.54)
Positivity	−4.01 (2.34)	**−2.38 (1.19)***	**−6.41 (2.96)***	0.78 (0.60)
Depression	−0.71 (2.90)	0.43 (1.47)	4.98 (3.67)	−0.82 (0.74)
Energy	0.74 (2.23)	1.24 (1.13)	5.02 (2.82)	−0.34 (0.57)
Fatigue	−1.86 (1.88)	−1.02 (0.287)	−2.65 (2.38)	−0.46 (0.48)
Level 2 predictors				
Stress	3.46 (5.25)	0.66 (0.78)	4.10 (9.22)	2.57 (1.44)
Anxiety	1.70 (4.88)	−0.65 (2.15)	−2.51 (8.55)	**2.76 (1.32)***
Positivity	2.66 (4.73)	1.36 (2.08)	10.90 (8.17)	−1.75 (1.31)
Depression	1.32 (7.30)	−0.11 (3.23)	−3.80 (12.78)	2.57 (2.02)
Energy	−2.24 (5.23)	0.27 (2.31)	8.75 (9.10)	−2.14 (1.44)
Fatigue	**11.32 (5.44)***	2.86 (2.46)	3.88 (9.86)	2.86 (1.54)
Pseudo R^2				
R_1^2 (%)	0.06–9.53	−0.20–3.25	0.10–3.35	3.57–8.98
R_2^2 (%)	0.00–0.89	0.01–1.21	0.00–1.41	0.03–0.53
Model fit				
AIC	3794.13–3799.20	3260.87–3265.18	4009.66–4015.97	2698.40–2701.15
−2 LL	3776.13–3781.20	3242.87–3247.18	3991.66–3997.97	2680.40–2683.15

SE: standard error, AIC: Akaike's information criterion, LL: log likelihood. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. All models were run separately for each predictor (within and between-person), so intercept, pseudo R^2 and model fit indices are given as a range. R_1^2 – variance explained at level 1 (within-person) relative to the variance explained in the covariates only model, R_2^2 – variance explained at level 2 (between-person) relative to the variance explained in the covariates only model. The fixed effects intercept reflects the estimated mean in the outcome variable for a male with an average age and BMI and not in lockdown.

(R_2^2) in each of the outcome measures (Tables 3–5). For example, between-person fluctuations in stress and psychological wellbeing (anxiety, positivity, depression, energy, and fatigue) accounted for 0.00–0.41% of the variation in polyphenol intake and 0–0.89% of the variation in fat consumption and, whereas within-person fluctuations in stress and psychological wellbeing accounted for up to 6.09% of the variation in polyphenol intake and up to 9.52% of the variation in fat consumption and. Similarly, between-person fluctuations in stress and psychological wellbeing accounted for up to 0.21% of the variation in fruit and vegetable consumption, and within-person fluctuations accounted for up to 6.39% of the variation in fruit and vegetable consumption.

4. Discussion

The present study investigated the associations between stress, psychological wellbeing, and (poly)phenol intake. At a within-person level, perceived stress was positively associated with (poly)phenol-rich tea and coffee consumption, and this association was stronger in participants with higher habitual stress. Similarly, depressive symptoms were associated with higher consumption of tea and coffee. Contrary to our hypothesis, there was a trend towards a positive association between stress and polyphenol and phenolic acid intake, suggesting a tendency to increase intake of polyphenols/phenolic acids when stress is higher, likely through increased consumption of tea and coffee. Furthermore, and contrary to our hypothesis, perceptions of stress were not associated with the consumption of total fat, saturated fat, and sugar. However, feeling less positive related to higher consumption of saturated fat and sugar, and feeling more fatigued associated with higher consumption of total fat. Overall, our novel findings suggest that during stressful periods, individuals show preference for consumption of (poly)phenol-rich beverages such as tea and coffee.

4.1 Higher stress associates with increased (poly)phenol-rich tea and coffee intake

The present study revealed that within-person perceptions of stress associated with increased tea and coffee intake, with a one unit increase in daily stress compared to one's own average associating with 28 ml more tea and/or coffee consumed. Furthermore, habitual stress influenced the relationship between daily stress and tea and coffee consumption, as this association was stronger (more positive) in participants with higher habitual stress (assessed by the perceived stress scale). Therefore, elevated habitual stress in individuals seem to amplify the association between daily stress and tea and coffee intake. The level of habitual stress in this sample was within the moderate range and was similar to levels observed in the general population burdened by financial, work, and housing stressors.[50] There were also gender differences in habitual consumption of tea and coffee, as well as polyphenols and phenolic acids, with females having a higher intake. However, gender had no significant effect in the relationship between stress and coffee and tea intake (when entered as a covariate in the analysis). Higher sample sizes are likely needed to investigate the effects of gender in this context.

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Thus, future work should establish how individual differences such as gender and habitual stress, may affect (poly)phenol-rich tea and coffee intake in the context of stress.[51]

Importantly, the positive association between stress and tea and coffee intake, as well as the trend observed for polyphenols/phenolic acids, are inconsistent with previous cross-sectional work which reports higher perceived stress to associate with reduced intake of polyphenols.[34–37] However, previous cross-sectional work captures one time point, and between-person associations. The focus of our work is within-person, and how dietary choices change over time with fluctuations in perceptions of stress. Furthermore, the amount of variance explained by within-person fluctuations was consistently higher than that explained by between-person differences. In addition, the range of psychological outcomes between participants was limited, which likely explains why our findings differ from previous work.

(Poly)phenols are abundant in tea and coffee, with the average cup of black tea containing 335 mg total (poly)phenols and a serving of coffee containing 520 mg total (poly) phenols.[41] Notably, findings from the current study suggested a non-significant association between increased stress and higher intake of polyphenols ($p = 0.070$) and phenolic acids ($p = 0.064$). It is possible that this association is related to increased tea and coffee, but further studies in larger samples and across a greater time frame are warranted to confirm these findings. Yet, these preliminary results suggest that higher (poly)phenol intake, delivered through either tea or coffee, may be possible in the context of stress in free-living conditions. Notably, the motivation to consume tea and coffee during periods of stress may be driven by caffeine-seeking behaviour. Thus, whether (poly)phenol-rich tea and coffee can provide vascular protection during stress will need to be established in future research, in the context of caffeine-containing beverages. As such, future studies should compare the effects of caffeinated and decaffeinated versions of high-(poly)phenol tea and/or coffee on endothelial function in the context of stress. Furthermore, the relationship between caffeine intake and symptoms of stress, depression, and anxiety should be considered, given evidence of a positive association between caffeine intake and anxiety risk in healthy individuals without psychiatric disorders.[52] Currently, several pieces of evidence suggest that both (poly)phenol and coffee/tea consumption can improve vascular physiology in humans. For example, dietary flavanols (695 mg), a type of polyphenol also present in tea, attenuates stress-induced declines in endothelial function (measured by brachial flow-mediated dilatation, FMD) both in a fasted state[30] and following consumption of a high-fat meal.[31] This dose of flavanols could be achieved through consumption of 2 cups of green tea.[53] Furthermore, acute ingestion of green tea significantly improves endothelial function (FMD),[54] and similarly, short-term (1–4 weeks) supplementation of black tea significantly improved FMD in healthy men[55] and in patients with coronary heart disease.[56] The effect of coffee ingestion on endothelial function is mixed, with 14 studies reporting coffee to have beneficial effects on endothelial function, 3 studies revealing detrimental effects, and 3 studies reporting no effect.[57] Importantly, a RCT demonstrated that high-(poly)phenol coffee intake improves FMD, in comparison to a caffeine-matched low-polyphenol coffee,[26] demonstrating the mediating effect of (poly)phenols. Interestingly, (poly)phenol-rich tea and coffee can have additional benefits in psychological wellbeing which is also critical in the context of psychological stress. For example, green tea can reduce symptoms of anxiety[58] and regular tea and coffee drinkers (up to 1 cup/glass per day, $n = 1572$ adults) are less likely to have depressive symptoms.[35] More evidence is required to understand how symptoms of stress may influence tea and coffee intake, particularly as no other measures of psychological wellbeing were significant in this study. Although the literature seems promising, the efficacy of tea or coffee consumption to protect vascular function and mood/psychological wellbeing in the context of stress needs to be established in future work. Furthermore, because the levels of polyphenols/flavanols in a single cup of tea and/or coffee are likely lower than the dose used in previous stress-related studies, for example 695 mg of flavanols as used in our work,[30,31] future research should establish the minimum dose required to benefit endothelial function in the context of stress, before tea or coffee can be recommended as protective sources of polyphenols during stress. For example, specialised products with higher polyphenols might be needed.

4.2 Stress does not associate with fat and sugar consumption

We hypothesised that experiencing stress would associate with increased consumption of fat and sugar, yet perceived stress at neither within-person nor between-person level, predicted consumption of fat, saturated fat, or sugar. Previous laboratory studies have shown stress to increase consumption of high-fat and high-sugar foods.[15] However, highly controlled environments with provision of specific foods likely influence dietary choices.[51] Conversely, in a free-living environment, the context in which eating occurs, as well as food availability and access, can influence the quantity and type of nutrients consumed,[17,18] and thus, contextual conditioning may explain the disparity across laboratory and free-living findings. Perceptions of stress are subjective and vary between individuals. Previous EMA studies have assessed daily hassles as a specific stimulus of stress,[19,59,60] yet the present study assessed overall perceptions of stress, in a free-living environment, without targeting a particular hassle or stressful event. One study reported stress-induced increases in high-fat and energy-dense foods in emotional eaters only,[61] and another EMA study assessed cravings, hunger, and eating behaviour but found no associations with daily stress.[62] Previous work has shown stress to positively associate with increased food intake in the form of snacks, particularly those rich in fat and sugar,[59] and this association with snacking is stronger when foods are easily available.[60] Therefore, investigating eating behaviour and social context, as well as considering dietary intake in the form of snaking, might be required to detect the associations between stress, psychological wellbeing and fat and sugar consumption in a free-living context.

4.3 Positivity and fatigue associate with fat and sugar consumption

In free-living environments, other aspects of psychological wellbeing might be stronger predictors of unhealthy food choices. For example, a reduction in positivity at the within-person level associated with increased consumption of saturated fat and sugar. The aversive state reduction hypothesis[63,64] is a common explanation for stress-induced eating, which may underpin these findings. This hypothesis denotes that when people are in a negative psychological condition, they consume highly palatable food (*i.e.*, fat and sugar), which triggers neurophysiological reactions, creating a hedonic experience which improves mood and reverses the negative feelings associated with stress.[65] This pattern of comfort eating in response to low wellbeing poses a serious threat to obesity.[66] However, as there was no association between negative psychological outcomes, such as symptoms of stress, depression, and anxiety, with fat and sugar consumption, the interpretation of this finding should be taken with caution.

Furthermore, at a between-person level, fatigue positively associated with fat consumption. Previous research has reported associations between fatigue and increased fat consumption in shift workers.[67] Similarly, laboratory studies have reported increased consumption of fat following an enforced sleep restriction,[68,69] perhaps due to the impairment in self-control and decision-making following sleep deprivation.[70] Furthermore, lack of sleep and subsequent fatigue can negatively affect cognitive energy,[71] and hence, energy-dense foods (*i.e.*, fat) are chosen to compensate. Notably, this relationship is bidirectional, as consumption of high-fat food increased perceptions of fatigue 3 hours later.[72] In agreement with this, in our laboratory-based studies, we observed a greater mood disturbance following a high-fat meal, driven by an increase in fatigue.[33] Given these findings are in line with established hypotheses, an awareness of comfort eating and interventions to limit consumption of fat and sugar during periods of reduced wellbeing should be explored.

4.4 Anxiety positively associates with fibre intake

The present study revealed an unexpected positive association between anxiety and fibre intake at a between-person level. Fibre intake did not associate with perceptions of stress or any other assessment of psychological wellbeing. Previous cross-sectional evidence indicates an inverse association between perceived stress and fruit, vegetable, and whole grain food intake,[73] which seem contrary to our current observations. A review and meta-analysis presented a small but significant inverse association between fibre intake and depressive and anxiety outcomes.[74] However, this relationship between fibre and anxiety seemed to be influenced by specific characteristics, with differing findings across populations with/without depression, alcohol-use disorder, and population subsets (*i.e.*, sex and menopause status).[74] Additionally, most studies assessed depressive symptoms only, and not anxiety. There is only a limited number of RCTs in this topic, generally reporting no effect of fibre supplementation on depressive and anxiety symptoms.[74] Alternatively, this between-person association may reflect broader health-oriented behaviours amongst more anxious individuals, with conscious or subconscious increases in fibre consumption to support mental wellbeing. However, this is speculative, and more work is required to firmly establish the association between fibre intake and symptoms of anxiety.

4.5 Effect of individual differences

Individual differences have a substantial role in stress perceptions and subsequent eating behaviour.[51] Therefore, a strength of this work is including within-person as well as between-person analyses, particularly given that the amount of variance explained by within-person fluctuations was consistently higher than between-person differences, portraying how these nuanced associations could be overlooked in previous between-person analyses. Another strength is the inclusion of demographic outcomes and covariates. These findings presented lower levels of daily stress and higher levels of daily energy in females compared to males. Whilst this gender disparity contradicts some other research, females have previously been shown to utilise more coping mechanisms compared to males,[75] perhaps explaining their lower levels of stress in the present study. Females also reported to consume more polyphenols and tea and coffee compared to males, which is in line with previous research reporting females to consume more polyphenols than males across this age range (19–34 years).[76] BMI was inversely associated with fibre in all models, in line with previous research suggesting that diets rich in fibre reduce the risk of obesity.[77] Finally, age was positively associated with fruit and vegetable and tea and coffee consumption in all models, which is representative of a UK diet across ages.[78] Furthermore, based on the participants' food diaries, the included sample was representative of the general UK population. For example, the average intake of saturated fat in UK adults (age 19–64 years) is 25.1 g (ref. 79) compared to 30.37 g assessed by food diaries in the present sample (age 18–36 years). Similarly, most UK adults consume an average of 18–20 g fibre per day, not dissimilar to the present sample (22.04 g), yet both lower than recommended (30 g day^{-1}).[80] Therefore, these findings are representative of the general UK population.

4.6 Limitations

Whilst inclusion of demographic covariates is a strength, the recruited sample were young and healthy adults, which lacks diversity in characteristics such as BMI, age, self-reported health, and perhaps psychological wellbeing. Similarly, participants were predominantly from white ethnicity (88.1%) which is higher than the self-identified ethnic breakdown in the UK (81.7% white).[81] Therefore, future work should investigate the relationship between stress, psychological wellbeing and diet in other populations, such as overweight, older adults, or perhaps patient populations, as well as other ethnic groups (*e.g.*, South Asians, Black Africans). Furthermore, our sample size was moderate (n = 59, number of observations: n = 413),[40] which influences the power of these findings, as shown by the

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wider confidence intervals for some of our observations. It has been suggested that future experience sampling methods should aim for a level 2 (between-person) sample size of at least 83 participants, and at level 1 (within-person) 835 observations.[40] Whilst a moderate sample size, the adherence rate was excellent, with 99.8% of stress and psychological wellbeing assessments and 99.3% of food diaries completed across the 7-day data collection period. Furthermore, we did not include adjustment of the alpha level for multiple analyses. Whilst this is common in multilevel modelling, it may affect the precision of estimates and should be considered as a limitation. An additional limitation is that the dietary data was self-reported. Whilst detailed instructions were provided for participants to complete food diaries, and researchers were appropriately trained on food diary analysis, the self-reported nature of the dietary data should be considered. Furthermore, whilst we asked participants to complete their food diaries in real time throughout the day (and note the time of consumption), the psychological outcomes were retrospectively recorded at the end of each day. Finally, data collection occurred during the COVID-19 pandemic. Lockdown status was subsequently included as a covariate in our analyses as almost 50% of participants were in a lockdown when completing the study (n = 27 in a lockdown, n = 32 not in a lockdown), yet future work should aim to replicate these findings outside of a pandemic setting.

4.7 Future directions

Future research should aim to understand the relationship between stress and tea/coffee intake, as tea and coffee consumption may have the potential to deliver (poly)phenols during periods of stress in free-living individuals. Efficacy of tea and/or coffee polyphenols in protecting the vascular system during psychological stress should be established in future RCTs. Furthermore, to firmly establish the directionality between occurrence of stress and subsequent dietary choices, a better temporal resolution would be needed. For example, future work should capture perceived stress and subsequent dietary intake in real time throughout the day to establish both temporal and bidirectional associations. Additionally, monitoring physiological responses to stress (*e.g.*, heart rate), stress perceptions, and nutrient intake at specific time points in free-living individuals, would lead to greater precision and better validation of stress-related eating events. Finally, future work should consider moderating variables such as emotional eating, attitudes towards eating, restrained eating, age, weight, and gender,[51] as well as social norms and the environmental and social context by which stress influences dietary intake.[82]

5. Conclusions

The present study revealed that higher perceived stress associated with increased intake of tea and coffee, and this association was stronger in individuals with higher habitual stress. Yet, perceived stress did not associate with higher fat and sugar consumption, which may suggest that the trigger to consume tea and coffee requires lower levels of stress compared to fat and/or sugar. Whilst these findings are observational, they suggest a novel pattern of stress-induced dietary choices in a free-living environment compared to previous cross-sectional and laboratory work, which could be used in future research looking to increase the intake of cardioprotective (poly)phenols during periods of stress.

Author contributions

Conceptualization, R. B., C. R., J. VvZ., data curation, R. B., C. R., J. VvZ., formal analysis, R. B., C. R., J. VvZ., Y. L., A. RM., N. N., funding acquisition, R. B., C. R., J. VvZ., investigation, R. B., C. R., J. VvZ., methodology, R. B., C. R., J. VvZ., project administration, C. R., and J. VvZ., resources, R. B., C. R., J. VvZ., Y. L., A. RM., N. N., software, R. B., C. R., J. VvZ., Y. L., A. RM., N. N., supervision, C. R., J. VvZ., validation, R. B., C. R., J. VvZ., visualisation, R. B., C. R., J. VvZ., writing – original draft, R. B., writing – review & editing, C. R., J. VvZ., Y. L., A. RM., N. N. All authors have read and agreed to this version of the manuscript.

Conflicts of interest

There are no conflicts to declare.

Data availability

Data for this article, including participant characteristics, daily (poly)phenol intake, (poly)phenol-rich food intake, dietary composition, perceived stress and psychological wellbeing, and habitual stress, has been made available at our University of Birmingham repository: https://doi.org/10.25500/edata.bham.00001670.

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