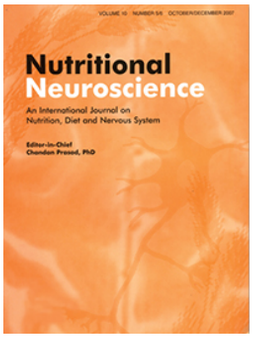


Taylor & Francis
Taylor & Francis Group

Nutritional Neuroscience

An International Journal on Nutrition, Diet and Nervous System

ISSN: 1028-415X (Print) 1476-8305 (Online) Journal homepage: http://www.tandfonline.com/loi/ynns20

Assessment of dietary factors, dietary practices and exercise on mental distress in young adults versus matured adults: A cross-sectional study

Lina Begdache, Maher Chaar, Nasim Sabounchi & Hamed Kianmehr

To cite this article: Lina Begdache, Maher Chaar, Nasim Sabounchi & Hamed Kianmehr (2017): Assessment of dietary factors, dietary practices and exercise on mental distress in young adults versus matured adults: A cross-sectional study, Nutritional Neuroscience, DOI: 10.1080/1028415X.2017.1411875

To link to this article: https://doi.org/10.1080/1028415X.2017.1411875

Assessment of dietary factors, dietary practices and exercise on mental distress in young adults versus matured adults: A cross-sectional study

Lina Begdache [1], Maher Chaar [2], Nasim Sabounchi [3], Hamed Kianmehr [3]

[1]Department of Health and Wellness Studies, Binghamton University, Binghamton, NY, USA, [2]Department of Biological Sciences, Binghamton University, Binghamton, NY, USA, [3]Thomas J. Watson School of Engineering and Applied Science, Binghamton University, Binghamton, NY, USA

The importance of the diet in modulating mental health is uncovering as many dietary factors have been described to alter brain chemistry. Brain maturation may not complete until the age of 30 which may explain the differential emotional control, mindset, and resilience between young adults and matured adults. As a result, dietary factors may influence mental health differently in these two populations.

Objectives: To study dietary intake, dietary practices and exercise in young adults (YA) (18–29 years) versus matured adults (MA) (30 years and older) in relation to mental distress. Another aim was to assess whether mental well-being potentially stimulates healthy eating, healthy practices, and exercising.

Methods: An anonymous internet-based survey was sent through social media platforms to different professional and social group networks. Best-fit models were constructed using the backward regression analysis to assess the relationship between dietary variables, exercise, and mental distress in YA versus MA.

Results: YA mood seems to be dependent on food that increases availability of neurotransmitter precursors and concentrations in the brain (such as frequent meat consumption and exercise, respectively). However, MA mood may be more reliant on food that increases availability of antioxidants (fruits) and abstinence of food that inappropriately activates the sympathetic nervous system (coffee, high glycemic index, and skipping breakfast).

Discussion and conclusion: Level of brain maturation and age-related changes in brain morphology and functions may necessitate dietary adjustments for improving mental well-being.

Keywords: Diet, Dietary practice, Mental distress, Mood, Mental well-being, Young adults, Mature adults, Exercise

Introduction

Nutritional neuroscience is an emerging interdisciplinary field of research that investigates the impact of nutrition on brain function and behavior. The importance of the diet in modulation of mental health is gaining ground in life sciences as the structural, functional, and biochemical roles of macro- and micronutrients in mental well-being have been surfacing.[1–5] Several dietary conditions and patterns may promote mental distress by altering levels of brain neurotransmitters or their receptor activity.[1,4] Mental distress is generally considered to ensue from an imbalance of key neurotransmitters that typically work in consortium to regulate synaptic transmission.[6] In addition, mental disorders are often linked to an altered activity of neurotransmitter receptors and transporters.[7] The three major monoamines that impact mental health are serotonin (5HT), norepinephrine (NE), and dopamine (DA).[8–10] Precursors for these monoamines are dietary amino acids that influence brain levels of these neurotransmitters.[9] Recent evidence suggests that brain maturation may not be completed until the age of 30.[11] Therefore, young adults (YA) exhibit differential emotional control and mindset compared to matured adults (MA). Typically, with incomplete prefrontal cortex (PC) maturation, YA have less control over their emotions when compared with MA.[12] Accordingly, MA recover more rapidly from stressful events.[13] In addition, MA tend to have a higher spirit and a more positive outlook then YA.[13] As a result, dietary factors may influence the brain differentially in these two age groups and consequently impact mental well-being. The purpose of this paper

Correspondence to: Lina Begdache, Department of Health and Wellness Studies, Binghamton University, POB 6000, Binghamton, NY 13902, USA. Email: lina@binghamton.edu

DOI 10.1080/1028415X.2017.1411875

was to study our hypothesis around dietary intake, dietary practices and exercise in YA (18–29 years) and MA (30 years and older) in relation to mental distress. Another aim was to assess whether mental well-being potentially stimulates healthy eating and healthy practices. To our knowledge, this is the first study that investigates the differential response of mental distress and mental well-being in relation to dietary intake and dietary behavior in these age groups. We hypothesized that mental well-being could lead to elevated brain dopamine levels which may promote motivation for healthiness. Less stressed or mentally healthier individuals would have an increased motivation to improve their diet, engage in healthy practices and exercise on a regular basis. Furthermore, the literature suggests that engaging in healthy behaviors leads to increased motivation for enhancement of well-being and improvement of mental health.[14,15]

Positive and negative causal relationships between mental health, healthy diet (HD), healthy dietary practice (HDP), and exercise are demonstrated in the causal loop diagram (Fig. 1). A positive causal link defines change in the same direction (e.g. more 'motivation to improve healthiness' leads to more 'exercise') and a negative link refers to change in the opposite direction. A feedback loop is a result of a closed sequence of causal links. There are three reinforcing loops demonstrated in Fig. 1 that describe virtuous improvement of mental well-being and healthy behaviors. These loops could become vicious, if one suffers from mental distress, which would then negatively impact eating healthy, and engaging in healthy practices including exercising routinely (Fig. 1).

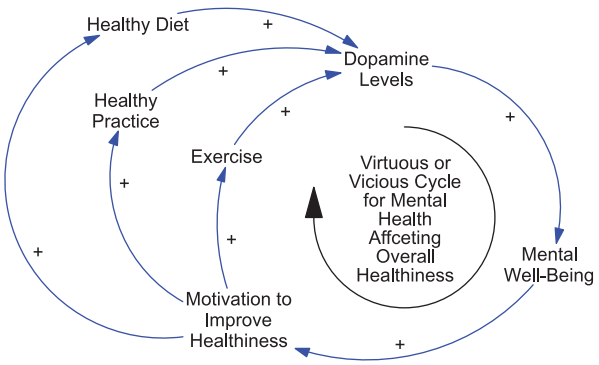


Figure 1 Reinforcing loop around healthy diet, healthy practice and mental well-being. A healthy diet, exercise, and healthy practices promote wellbeing by elevating brain dopamine levels. Mental well-being then acts as a positive reinforcement to further healthy diet, healthy practices and exercise to improve health. This loop can become a virtuous cycle optimizing mental health. When healthy diet, exercise, and healthy practices are absent, low brains levels of dopamine lead to a decreased mental well-being which in turn reduces healthy diet, exercise and healthy practices resulting in a vicious cycle.

Method

Survey

This is a cross-sectional study which was part of a larger project that examined dietary intake and mental distress at a global level. The study protocol was reviewed and approved by the Institutional Review Board at Binghamton University prior to the start of the study. An anonymous internet-based survey was sent through social media platforms from various parts of the world. Ascertainment bias was minimized by targeting different professional and social networks with no apparent skewed gender or socio-economical statuses. The only apparent bias was age.

All participants had to consent to the study before they accessed the survey. All data collection occurred electronically. Demographic questions included age, gender, level of education, region, and exercise frequency. Dietary and nutrient consumption patterns were evaluated using a validated Food-Mood Questionnaire (FMQ). The FMQ includes questions on food groups that constituents have been associated with neurochemistry and neurobiology. Mental distress was assessed using Kessler Psychological Distress Scale (K-6) questionnaire.[16] The total score of K-6 was used to account for the spectrum of mental distress. For the scope of this study, no modeling of individual K-6 items was considered.

Statistical relationship between variables was measured through generation of regression-based models. The best-fit model around different dependent and independent factors was selected based on the Akaike Information Criterion (AIC)[17] obtained for all models. The degree of association between variables was measured by the coefficient of determination.[18] Data were analyzed using R software[19] (Version 1.0.136).

Definition of backward regression with respect to AIC

Stepwise regression is a common statistical method in fitting regression models with the best subset of independent variables. The pre-specified AIC was applied in the R software to run backward stepwise regression procedure. The AIC measures the quality of each model relative to all other models developed in this approach. AIC is based on information theory and estimates the trade-off between information loss and model generated to represent the process used for generating the data. AIC values are obtained based on the below formula to compare different models fitted by the maximum likelihood approach to the same data.

$$-2*\ln(L) + k*npar$$

$\hat{L}$ = maximized value of the likelihood function of the model, $\hat{L} = p(x|\hat{\theta}, M)$, $\hat{\theta}$ is the parameter values that maximize likelihood function, $npar$ = number of

parameters to be estimated, $k = 2$ for the usual AIC, $x =$ the observed data.

Development of models

We aimed to identify relatively parsimonious models to reduce nuisance and improve their generality. In pursuit of creating the best-fit model, multiple regression procedures were employed using successive removal of non-significant variables (backward elimination). To address the limitation of this technique of making possibly unverifiable assumptions, the distributions of all concomitants with a potential to affect outcomes were as similar as possible in all groups. For all models, we combined the sum of values from the K-6 categories (nervous, hopeless, restless, fidgety, depressed, everything is an effort and worthless) to represent mental health. The study comprised of two phases designed to statistically model the relationship between mental distress, diet, dietary practices, and exercise (Fig. 1).

Model 1: Effect of diet, dietary practices and exercise on mental distress in YA versus MA using stepwise regression

Phase I – In this phase, a statistical framework was constructed aimed at determining the effect of the partitioned independent variables (diet, dietary practices, and exercise) on mental distress in these age groups. Independent variables were categorized into 'high' versus 'low' as representatives of healthy versus unhealthy subgrouping, respectively. The segregated groups were then assessed in relation to mental health in YA and MA. HD included whole grain, fruits and vegetables, and fish. HDP comprised of eating breakfast, taking multivitamin (MV) and fish oil (FO) supplements. It is worth noting that HDP was based on an actual healthy practice (eating breakfast) and perceived HDP such as taking supplements, which is generally exercised for the purpose of improving health. Another point worth clarifying is that HD refers to healthy diet intake and HDP alludes to optimizing nutritional intake. The criteria set for HD and HDP were based on findings from current literature in relation to mental distress.[20–25]

Model 2: Associations between mental well-being and HD, HDP, and exercise in YA versus MA using stepwise regression

Phase II – In this phase, we tested further independent associations between mental well-being and HD, HDP, exercise and established further positive associations between these factors. The combination of associations from Phase I assists in defining potential causal links that form a reinforcing loop describing a virtuous or a vicious cycle around mental health and HD, HDP, and exercise (Fig. 2).

Results

A total of 563 participants from diverse cultural backgrounds completed the questionnaire (Table 1). The age of respondents was recorded within four age groups: 18–29, 39–39, 40–49 and over 50. The breakdown of participants was as follows: 463 were between the age of 18–29 and 100 were 30 years or older.

Model 1: Effect of diet, dietary practices, and exercise on mental distress in YA versus MA

We evaluated the relationship between mental distress and predictor variables (diet, dietary practices, and exercise) in YA versus MA age groups (18–29 years and 30 years and older, respectively) by creating the best-fit model. To better understand the significance of these variables, food groups were categorized based on weekly recommendations set by the Dietary Guidelines for Americans (2015–2020) when possible and other references such as ChooseMyPlate.gov and Office of Health Promotion and Disease Prevention.[26–28] For nutrient categories or dietary practices with no specific recommendations, categories were assigned based on evidence from the literature on their frequency of use or practice in relation to health promotion (such as coffee, MV, and FO). Meeting the weekly recommendations were allotted to the 'High' category and not meeting the weekly recommendations were grouped into the 'Low' category.

Phase I – development of the best-fit models

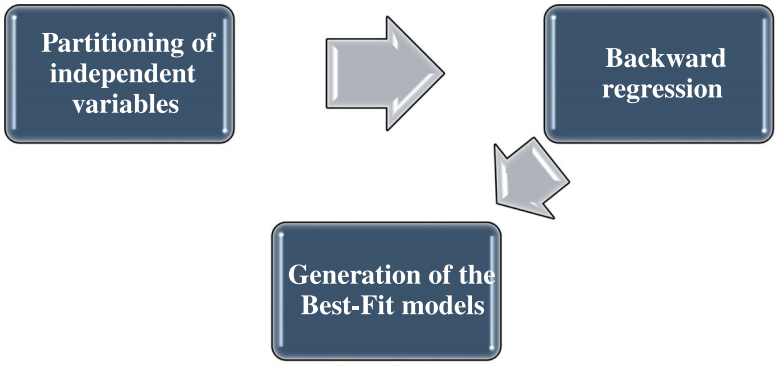
Mental distress was the dependent variable in this analysis. Independent variables comprised of education, exercise, breakfast, whole grain, dairy, coffee, fruits, nuts, rice/pasta, meat/chicken/turkey, leafy vegetables, beans, fish, fast-food, MV, and FO. The independent variables were selected based on the best-fit models generated using the lowest AIC values obtained.

Categorization of the independent variables into high and low

Age 18–29 years-YA group: To further evaluate the potential role of the significant independent variables in the YA group model, we categorized dietary groups, dietary practices, and exercise into 'High', if meeting the recommendations, or 'Low' if not meeting the recommendations as described previously. A stepwise linear regression model was followed based on the identified significant independent variables. Results of this analysis revealed that exercising three times or more per week was inversely associated with mental distress. Consuming fast-food more than

1: Effect of diet, dietary practices and exercise on mental distress in YA vs. MA using stepwise regression- Phase I

The research question: what food and /or practice is associated with mental distress?



Model 2: Associations between Mental well-being, HD, HDP and Exercise in YA vs. MA using stepwise regression. Phase II

The research question: Does mental well-being promote a healthy diet or engaging in a healthy dietary practice or exercise?

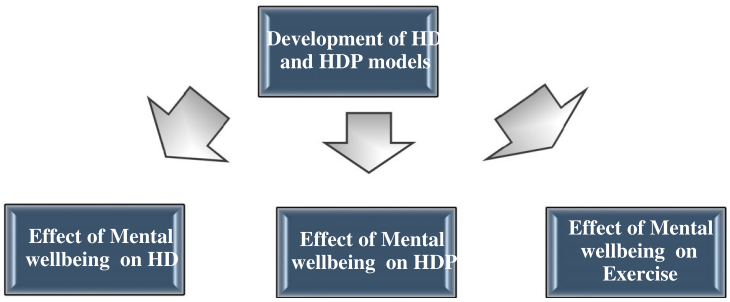


Figure 2 The study design.

three times a week and eating meat (red or white) less three times a week were positively associated with mental distress (Table 2).

Ages 30 years and older–MA group: A parallel study evaluated the potential role of the significant independent variables in the MA group on mental distress. The regression analysis revealed that high fruit consumption (at least three times a week) and low consumption of high glycemic index (GI) carbohydrates (rice or pasta) up to three times a week were inversely associated with mental distress. However, coffee consumption at both high and low concentrations and skipping breakfast positively associated with mental distress in MA (Table 2).

Table 1 Basic characteristics of participants

	Age 18–29	Age 30 and older
Male	222	50
Female	241	50
Total	463	100
Region		
North America/Central America	104	13
Asia	89	17
Europe	50	12
Near East/North Africa	211	56
Africa	9	2

Model 2: Associations between mental well-being and HD, HDP and exercise in YA versus MA using stepwise regression

Phase II – development of 'healthy diet' and 'healthy practice' models

The next aim was to assess the independent effects of mental well-being on HD, HDP, and exercise in YA

Table 2 Regression analysis of categorized independent variables

Age	Variables	Coefficients*
YA	Mental distress ~ exercise high + meat chicken turkey low + fast food high (best model)	
	Intercept	14.178
	Exercise high	−0.4554
	Meat/chicken/turkey low	0.5962
	Fast food high	0.8732
MA	Mental distress ~ breakfast not daily + coffee low + coffee high + fruits high + rice/pasta low (best model)	
	Intercept	10.5160
	Fruits high	−0.5414
	Rice/pasta low	−1.4801
	Coffee low	2.3685
	Coffee high	0.9012
	Breakfast not daily	0.5330

*Coefficient is a measure of success of predicting the dependent variable from the independent variables.

versus MA. The goal was to explore if mental wellness can potentially promote healthy eating or engaging in a known healthy practices (such as HDP and exercise). The rationale was that enhanced mood is typically associated with elevated brain dopamine levels and increased overall motivation. The criteria chosen for HD are as follows: (1) food groups are part of generally recognized healthy diets such as the Mediterranean diet with evidence-based mental health benefits[29] and (2) foods groups generally less consumed regularly in diets recognized as unhealthy such as the Western diet.[30] Therefore, HD consisted of beans, whole-grain, fruit, nuts, leafy vegetables, and fish. HDP criteria were based on commonly known healthy practices (i.e. eating breakfast) and perceived HDPs such as taking MV and FO supplements to improve health. When the dependent variable was HD, the independent variables were education, exercise, breakfast, dairy, coffee, rice/pasta, meat/chicken/turkey, fast-foods, MV, FO, and mental distress. When the dependent variable was HDP or exercise, the independent variables included HD and all the previously mentioned variables with the omission of the dependent variable under investigation.

HD as a dependent variable

Age 18–29 years-YA group: The outcomes for the YA when HD was the dependent variable were significant for fast-food, education, dairy, coffee, high GI carbohydrates (rice and pasta), HDP, and exercise. All variables showed a positive association with HD, except for fast-food, which supports the notion of a healthy diet. Interestingly, mental well-being was not among the significant independent variables in the best-fit model.

Ages 29 years and older – MA group: A corresponding analysis revealed that fast-food, dairy, exercise, and HDP were the variable outcomes that significantly associated with HD in MA. As in the YA analysis, fast-food negatively associated with HD. Interestingly, all these variables are also part of the HD models in YA.

Once more, mental well-being was not among the independent variables in this best-fit model (Table 3).

HDP as a dependent variable

Age 18–29 years-YA group: Using HDP as a dependent variable, the regression analysis revealed that HDP was negatively associated with high GI carbohydrates (rice/pasta), fast-food, and education, while positively associated with dairy, exercise, and HD.

Ages 29 years and above–MA group: A similar analysis for the MA group revealed that exercise negatively and HD positively associated with HDP. Although both exercise and HD were also selected in the YA model, interestingly exercise negatively associated with HDP in MA (Table 4).

Table 3 HD as a dependent variable

Age	Variables	Coefficients
YA	HD ~ education + dairy + coffee + rice/pasta + fast food + HDP + exercise (best model)	
	Intercept	3.6085
	Fast food	−0.2685
	Education	0.3891
	Dairy	0.2945
	Coffee	0.2783
	Rice/pasta	0.4199
	HDP	0.6802
	Exercise	0.6802
MA	HD ~ dairy + coffee + fast food + HDP + exercise (Best Model)	
	Intercept	3.3759
	Fast food	−0.5125
	Coffee	0.8789
	Dairy	0.9731
	Exercise	0.4531
	HDP	0.1903

Exercise as a dependent variable

Age 18–29 years-YA group: Exercise was positively associated with metal well-being, HD, and HDP and negatively associated with high GI carbohydrates (rice and pasta) in YA.

Ages 29 years and above–MA group: Exercise was positively associated with HD and coffee and surprisingly negatively associated with HDP in MA. (Table 5)

Discussion

Summary of the main findings

One of the major findings of this paper is that diet and dietary practices differentially affect mental health in YA versus MA. YA mood appears to be sensitive to availability of neurotransmitter precursors (low meat) and neurotransmitter concentrations (exercise) in the brain. Conversely, MA mood seems to be more sensitive to availability of antioxidants (fruits) and abstinence of food that inappropriately activates the

Table 4 HDP as a dependent variable

Age	Variables	Coefficients
YA	HDP ~ education + dairy + rice pasta + fast foods + HD + exercise (best model)	
	Intercept	8.8032
	Rice/pasta	−0.1789
	Fast food	−0.2066
	Education	−0.4176
	Dairy	0.2473
	Exercise	0.3435
	HD	0.1614
MA	HDP ~ HD + exercise (best model)	
	Intercept	8.3581
	Exercise	−0.6067
	HD	0.3043

Table 5 Exercise as a dependent variable

Age	Variables	Coefficients
YA	Exercise ~ mental well-being + rice/ pasta + HD + HDP (best model)	
	Intercept	1.60394
	Rice/pasta	−0.04298
	Mental well-being	0.07712
	HDP	0.07857
	HD	0.08842
MA	Exercise ~ coffee + HD + HDP (best model)	
	Intercept	1.26734
	HDP	−0.07901
	HD	0.23723
	Coffee	0.06814

sympathetic nervous system (coffee, high GI food and skipping breakfast) (Fig. 3). Interestingly, there is a strong association between HD, HDP, and exercise in YA, but not in MA. Therefore, engaging in one activity may promote the other two activities. Furthermore, our results show that mental well-being may not necessarily promote HD and HDP, but it is more likely to stimulate exercise in YA, but not in MA.

Interpretation of results based on evidence form the literature

Many dietary factors play a fundamental role in neurotransmitter biosynthesis and their receptor activity.[31–33] Serotonin (5HT), norepinephrine (NE), and dopamine (DA) are the three major monoamines described to impact mental health.[9–11] Consequently, plasma concentration of these amino acids directly influences brain levels of these neurotransmitters.[9] Precursors for these monoamines are amino acids that are naturally obtained from the diet. Our results show that diet and dietary practices have different effects on YA and MA. Evidence from the literature describes that chronological changes occur

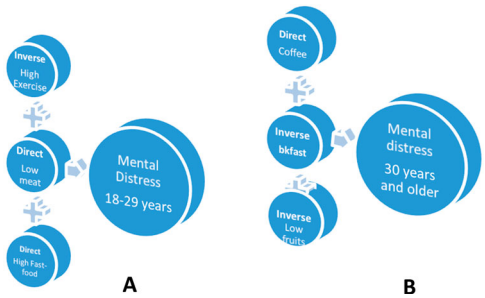


Figure 3 Relationship between dietary factors frequency and mental distress in YA versus MA. (A) Mental distress in YA was strongly associated with low meat consumption (less than three times a week, and high consumption of fats food (three or more times a week). There was an inverse association between high exercise (three or more times a week). (B) Mental distress in MA was strongly associated with caffeinated coffee consumption (any amount) and inversely associated with low fruit consumption (less than three times a week) and with skipping breakfast.

in the human brain which explain the disparity in mental well-being in response to diet and dietary practices between these two groups.[34] Furthermore, emotional control appears to differ between YA and MA.[12] MA have a better control over their emotions and can bounce back more efficiently from mental distress than YA.[35] In addition, MA are inclined to exhibit a more positive state of mind compared to YA.[13] One proposed theory discusses that age-related changes in brain structures include a reduction in the hyperactivation of corticolimbic circuits, which makes individuals less sensitive to negative emotions[36] Another potential reason is the differential maturation level of the PC in YA. Since PC maturation is a continuum through the late 20 s, level of neuromaturation dictates degree of emotional maturity[37,38] Neuroimaging studies revealed that older adults have greater level of frontal activity and an overall recruitment of brain regions when performing a cognitive task compared to their younger counterparts.[39–41]

Based on this line of reasoning, the brain exhibits structural and functional changes with age that may translate into different responses to dietary patterns and practices. Furthermore, these fundamental age-related changes suggest the differential responses to emotional control and predisposition to mental distress.[42,43]

Mental distress in relation to diet and practices in 18–29 Years – YA group

The best-fit models were selected based on the lowest AIC values generated through the regression analysis. For the YA group, significant associations were detected between meat, fast-food, exercise and mental distress. Categorization of variables revealed that consuming fast-food more than three times a week and a low meat consumption (three times a week or less) were positively linked to mental distress in YA. However, exercising more than three times a week had a negative association with mental distress in the same age group (Table 2). Fast-food is typically devoid of essential nutrients and is high in saturated, trans- and omega-6 fatty acids, which collectively promote systemic low-grade inflammation (LGI).[44] LGI is associated with symptoms of anxiety and depression in human and animal models.[45–47] Proposed mechanisms include gut dysbiosis and permeability as well as upregulation of proinflammatory cytokines.[48–50] Additionally, dietary omega-6 fatty acid (linoleic acid; 18:2n-6) is metabolized systemically into arachidonic acid (20:4n-6), a precursor for prostaglandins PGE_2.[51] Therefore, mental distress induced from frequent fast-food consumption potentially ensues from LGI and a deficiency of essential nutrients.

On the other hand, animal meat is rich in saturated fat, but it does not appear in the model as a factor in mental distress since low, but not high, consumption of meat (three times a week or less) positively associates with mental distress in YA. This finding came as a surprise to the research group since the literature suggests that vegans suffer less than carnivores from mental distress.

One potential mechanism that explains this paradox is the build-up of amino acids tyrosine (Tyr) and phenylalanine (Phe) with regular consumption. Meat is a rich source of catecholamine precursors, Tyr and Phe. Tyr is a non-essential aromatic amino acid produced in the human body from the essential amino acid phenylalanine. The rate of catecholamine synthesis is dependent on brain concentrations of these two precursors. Tyr levels are influenced by a repeated ingestion of proteins, and not much affected by a single meal consumption. Therefore, a threshold of brain Tyr stimulates dopamine synthesis. Tyrosine hydroxylase (TH) is the rate-limiting enzyme in catecholamine biosynthesis. Although Phe and Tyr are substrates for TH, the latter binds with higher affinity. When Tyr levels are low, Phe becomes the co-substrate of choice. Nevertheless, unlike Tyr, Phe does not exhibit substrate inhibition at high concentrations. Therefore, repeated meat consumption boosts dopamine synthesis over time with a potential to impact mood positively.[52] It is worth noting that Phe is highly concentrated in red meat and poultry, to a lesser extent in fish and vegetables, and completely absent in fruits.[53] However, during acute physiological disturbances and pathophysiological conditions (as seen with aging), the rate of aromatic amino acid transport across the blood–brain barrier is reduced independently of dietary consumption.[11] Therefore, ingestion of food high in Phe during these situations may not increase dopamine biosynthesis. These biochemical and physiological phenomena may explain the reason behind the sensitivity of the YA to a lower consumption of meat in relation to mental distress. While this association was not detected in MA, it could be attributed to brain plasticity. Age-related homeostatic disturbances induce functional adaptations that change brain sensitivity to dietary factors.[54]

Exercise is among the best non-pharmacological approaches evidenced to reduce the risk of mental distress. During exercise, brain transport of tryptophan is elevated and consequently serotonin levels surge. In parallel, dopamine and endorphins concentrations increase which bring an added effect to mental well-being. Additionally, exercise promotes the release of brain-derived trophic factor (BDNF), the most prevalent growth factor in the central nervous system (CNS). BDNF stimulates neuronal survival and protects against oxidative damage. Consequently, low levels of BDNF cause mood disorders.[55] Taken all together, exercise promotes synthesis and concentration of neurochemicals known to reduce metal distress and promote mental well-being.

Mental distress in relation to diet and practices in 30 years and older years – MA group

A parallel analysis for the MA group revealed significant associations between fruits, coffee, high GI carbohydrates (rice and pasta), breakfast, and mental distress. These results suggest that frequent fruit consumption is negatively associated with mental distress. Surprisingly, consumption of low carbohydrates (i.e. less than three times a week) is also negatively associated with mental distress. Drinking coffee (low or high) and skipping breakfast are positively associated with mental distress in MA (Table 2).

Fruits are high in antioxidants known to cross the blood–brain barrier. Antioxidants neutralize the reactive oxygen species generated during LGI. Therefore, regular consumption of fruits improves mood potentially by limiting oxidative stress in the brain. Expectedly, coffee and mental distress positively associate in MA. The effect of coffee is mostly related to caffeine, a natural stimulant of the CNS. Caffeine antagonizes adenosine receptors, namely A1 and A2, and boosts dopamine, norepinephrine, glutamate release while reduces gamma-aminobutyric acid (GABA) levels.[56] Glutamate is the major excitatory neurotransmitter in the brain while GABA is the chief inhibitory neurotransmitter. A balance of both brain chemicals is needed for proper activation of glutamate receptors namely the *N*-methyl-D-aspartate. Elevated levels of glutamate and low levels of GABA lead to glutamate excitotoxicity characterized by excessive intracellular calcium ion release. Consequently, neuronal injury induces inflammation which exacerbates mental distress.[57,58] Therefore, disturbing the balance between glutamate and GABA, as potentially linked to inhibition of adenosine receptors, may promote further inflammation in the brain and worsens mental distress. Additionally, age-related changes in brain structures and functions reduce the ability of the CNS to regulate the autonomic nervous system.[59] Changes in gene expression, brain volume, sleep quality in concert with a deranged immune function produce a synergistic effect.[34,60] Taken together, these biochemical alterations along with the age-dependent LGI may increase MA sensitivity to caffeine.

Another interesting finding is that low consumption of high GI carbohydrates is negatively associated with mental distress in MA. This was another unexpected finding as carbohydrate consumption indirectly promotes serotonin production and stimulates a positive

mood. One probable mechanism is the age-related hormonal decline and reduced ability to regulate blood sugar efficiently. Fluctuation in blood sugar leads to dopamine bioconversion into norepinephrine which triggers the fight-or-flight response. Additionally, insulin resistance and Type 2 diabetes are age-related phenomena; and frequent consumption of high GI food disturbs blood glucose homeostasis. Advanced blood sugar deregulation induces inflammation due to protein glycation and subsequent formation of advanced glycated end-products (AGEs).[61] Consequently, AGEs promote systemic inflammation and decrease cerebral blood flow adding to mental distress.[61,62]

Our results also suggest that eating breakfast daily in this age category may reduce mental distress, which supports some evidence in the literature.[63] Breakfast provides the necessary energy to the brain and reduces the fasting response linked to cortisol and catecholamine release.[15] In fact, regular consumption of breakfast is associated with lower cortisol levels and improved mental health.[64] In addition, habitually skipping breakfast causes a disruption in cortisol rhythm that exacerbates metal distress.[65]

Associations between mental well-being, healthy eating, perceived HDPs, exercise and mood in YA and MA groups

Our next step was to investigate further the associations between mental well-being, eating healthy, engaging in HDPs and exercising. The 'Healthy Diet-HD' includes food groups that are part of the Mediterranean diet (a model for a healthy diet) and that are generally not consumed regularly in the Western diet (a prototype of an unhealthy diet). 'Healthy Diet' consists of beans, whole-grain, fruit, nuts, leafy vegetables, and fish. 'Healthy dietary practice-HDP' criteria were based on evidence from the literature on healthy practices such as eating daily breakfast, and taking MV and FO supplements. In this phase, our question was: does mental well-being promote HD, HDP or exercise? The rationale behind this line of thinking is that a healthy diet and healthy practices promote mental well-being and motivation to improve healthiness, but little is known about the reversed effect. We hypothesized that a mental well-being motivates individuals to adopt HD, HDP, or engage in routine exercise. Interestingly, our results show that HD, HDP, and exercise consistently associated regardless of mental well-being in both YA and MA groups. However, exercise negatively associates with HDP in MA while it positively links with HDP in YA. This finding was interesting as YA are more likely to respond to current hypes which may include taking supplements or eating specific meals prior to exercising. Both groups had a negative association with fast-food consumption when HD was the dependent variable, which confirmed the notion of a healthy diet. However, coffee, dairy, exercise, and HDP were positively associated with HD in both YA and MA (Table 3). Although dairy has received negative reporting,[66] the Dietary Guidelines for Americans (2015–2020) recommends regular consumption of fat-free or low-fat dairy due to its nutrient density[67] and association with a healthy weight. Coffee is linked to improved heart and brain functions, as well as to an increase in metabolic rate. Additionally, caffeine, as an adenosine receptor inhibitor, fights fatigue which is usually associated with poor eating. Therefore, caffeine may not promote mental well-being but may associates with different healthful outcomes. Another interesting finding is that exercise is positively linked to coffee consumption in MA but not in YA. Energy level decreases with age which necessitates the use of an ergogenic aid to support exercise while YA tend to have inherently higher levels of energy.

In sum, our overall analysis suggests that the initial hypothesis regarding causal relationships and feedback loops around mental health and HD, HDP, and exercise bears certain validity (Fig. 1). Most of the initial links were confirmed by the results. However, some differences exist between YA and MA groups. In the YA group, there is a reinforcing loop between HD, HDP, and exercise. Engaging in one activity may promote the other two. However, mental well-being appears to be a catalyst specifically for exercise in YA (Fig. 4A). On the other hand, mental well-being does not significantly influence exercise habits among MA (Fig. 4B). Additional causal links were also verified such as a positive connection from HDP to HD. This association describes another virtuous cycle between both MA and YA. Another interesting insight observed among MA is that HDP and exercise do not associate, while the opposite is true for coffee and exercise in MA. It appears that MA rely on caffeine to draw their energy from more so than on taking supplements.

Strengths and limitations of the study

The strength of the study is that it adds to our current understanding of mental distress in relation to diet, dietary practices, and exercise in two different populations with documented differential brain morphology and physiology. Since the study was exploratory in nature, the limitation is that it is cross-sectional and was carried out at one specific time point. Another limitation is the use of a single assessment methodology which limits validity and reliability of the model. Additionally, some dietary factors that were not accounted for in the FMQ could have also influenced cardiometabolic status, hence mental well-being. Finally, due to the smaller number of older

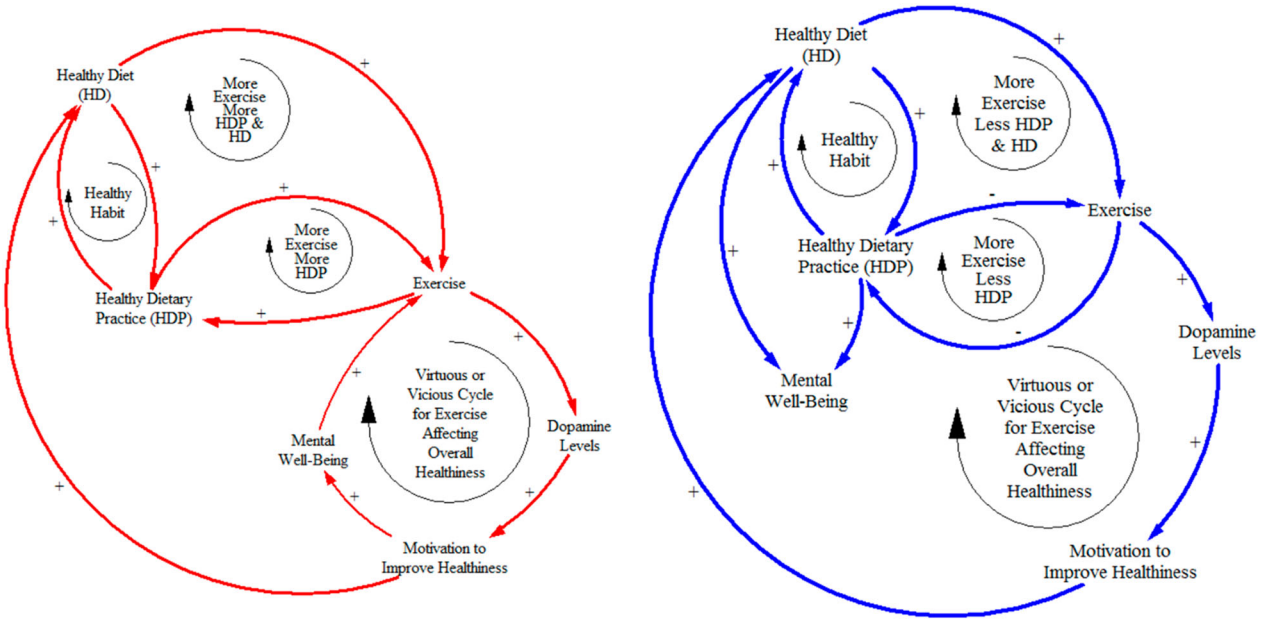


Figure 4 (A) Reinforcing loop around HD, HDP, and exercise in YA. In the YA group, there is a reinforcing loop between mental being, HD, HDP, and exercise. Mental well-being is likely to affect HD, HDP, and Exercise. Consequently, adopting HD, HDP, or an exercise regimen is likely to reinforce the other variables which promote motivation to increase healthiness and further improve mood. This becomes a virtuous cycle. (B) Reinforcing loop around HD, HDP, and exercise in MA. In the MA group, mental well-being does not significantly influence exercise habits and HDP do not necessarily promote exercise and vice-versa. However, HD can promote HDP, mental well-being, and exercise. HD along with HDP improve mental well-being in MA. Therefore, the key component of the virtuous cycle in MA is HD which promotes mental well-being, HDP, exercise, and motivation to improve healthiness.

adults in the study, individual changes in the people's brain could not be accounted for.

Implications for future research

Although the study revealed many interesting associations, further investigation of the effect of dietary components, individual dietary practices and type of exercise on mental well-being is needed at multiple time points. Additionally, it would be interesting to look at individual components of the K-6 items in relation to dietary patterns in young versus mature adults. Since the study did not assess dietary habits at very early stages of the lifespan, it is worth noting that these factors may influence subsequent cross-sectional or longitudinal studies outcome.

Conclusion

Individual food or dietary practices differed in their effect on mood between YA and MA. In addition, results of this study demonstrate that diet and dietary practices differentially affect mental well-being in YA versus MA. This differential response is most likely linked to level of brain maturation, age-related changes in brain morphology and the innate brain clock. Furthermore, our results suggest YA mood may be more likely dependent on food that increases availability of neurotransmitters precursors and concentrations in the brain (such as meat consumption and exercise, respectively). Whereas MA mood may be influenced by food that increases availability of antioxidants (fruits) and inappropriate activation of the sympathetic system (coffee, skipping breakfast, and high GI carbohydrates).

Acknowledgements

The authors would like to thank Dr Gale Spencer for her time in reviewing the manuscript.

Disclaimer statements

Contributors Lina Begdache designed the study and wrote the manuscript, Maher Chaar carried out the experimental work, Nasim Sabounchi and Hamed Kianmehr analyzed the data.

Funding This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

Conflicts of interest The authors declare that there is no conflict of interest.

Ethics approval None.

ORCID

Lina Begdache http://orcid.org/0000-0001-5213-6979
Maher Chaar http://orcid.org/0000-0002-3961-2982
Nasim Sabounchi http://orcid.org/0000-0002-8027-8779
Hamed Kianmehr http://orcid.org/0000-0002-7024-7864

References

1 Rebec GV, Christopher Pierce R. A vitamin as neuromodulator: ascorbate release into the extracellular fluid of the brain regulates dopaminergic and glutamatergic transmission. Prog Neurobiol 1994;43:537–65.
2 Alpert JE, Fava M. Nutrition and depression: the role of folate. Nutr Rev 1997;55:145–9.
3 Riedel WJ, Klaassen T, Schmitt JAJ. Tryptophan, mood, and cognitive function. Brain Behav Immun 2002;16:581–9.
4 Bourre JM. Effects of nutrients (in food) on the structure and function of the nervous system: update on dietary requirements for brain. Part 1: micronutrients. J Nutr Health Aging 2006;10:377–85.
5 O'Neil A, Quirk SE, Housden S, Brennan SL, Williams LJ, Pasco JA, *et al.* Relationship between diet and mental health in children and adolescents: a systematic review. Am J Public Health 2014;104:e42.
6 Jacka FN, Kremer PJ, Berk M, de Silva-Sanigorski AM, Moodie M, Leslie ER, *et al.* A prospective study of diet quality and mental health in adolescents. PLoS ONE 2011;6:e24805.
7 Biological Sciences Curriculum Study. Bethesda (MD): National Institutes of Health (US). Defining Mental Illness. 2007; Available from: https://www.ncbi.nlm.nih.gov/books/NBK20369/.
8 Fernstrom JD, Wurtman RJ. Brain serotonin content: physiological dependence on plasma tryptophan levels. Science 1971;173:149–52.
9 Fernstrom JD, Wurtman RJ. Brain serotonin content: physiological regulation by plasma neutral amino acids. Science 1972;178:414–6.
10 Fernstrom JD. Aromatic amino acids and monoamine synthesis in the central nervous system: influence of the diet. J Nutr Biochem 1990;1:508–17.
11 Somerville LH. Searching for signatures of brain maturity: what are we searching for? Neuron 2016;92:1164–7.
12 Charles ST, Piazza JR. Age differences in affective well-being: context matters. Soc Personal Psychol Compass 2009;3:711–24.
13 Nashiro K, Sakaki M, Mather M. Age differences in brain activity during emotion processing: reflections of age-related decline or increased emotion regulation? Gerontology 2012;58:156–63.
14 Atlantis E, Chow C, Kirby A, Fiatarone Singh M. An effective exercise-based intervention for improving mental health and quality of life measures: a randomized controlled trial. Prev Med 2004;39:424–34.
15 Smith AP. Stress, breakfast cereal consumption and cortisol. Nutr Neurosci 2002;5:141–4.
16 Furukawa TA, Kessler RC, Slade T, Andrews G. The performance of the K6 and K10 screening scales for psychological distress in the Australian national survey of mental health and well-being. Psychol Med 2003;33:357–62.
17 Akaike H. Information theory and an extension of the maximum likelihood principle. In: Petrov BN, Csaki F (eds.), Second international symposium on information theory. Budapest: Academiai Kiado; 1973. p. 267–81.
18 Allen MP. The coefficient of determination in multiple regression. Vienna: Springer US; 1997. p. 91–95.
19 R Core Team. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing.
20 Roberts SH, Bedson E, Tranter R. Half-baked? B vitamins and depression. Am J Clin Nutr 2010;92:269–270.
21 Boehm JK, Williams DR, Rimm EB, Ryff C, Kubzansky LD. Association between optimism and serum antioxidants in the midlife in the United States study. Psychosom Med 2013;75:2–10.
22 Alpert JE, Mischoulon D, Nierenberg AA, Fava M. Nutrition and depression: focus on folate. Nutrition 2000;16:544–6.
23 Kaplan BJ, Crawford SG, Field CJ, Simpson JSA. Vitamins, minerals, and mood. Psychol Bull 2007;133:747–60.
24 Martins JG. Eya but not DHA appears to be responsible for the efficacy of omega-3 long chain polyunsaturated fatty acid supplementation in depression: evidence from a meta-analysis of randomized controlled trials. J Am Coll Nutr 2009;28:525–42.
25 Song C, Li X, Leonard BE, Horrobin DF. Effects of dietary n-3 or n-6 fatty acids on interleukin-1β-induced anxiety, stress, and inflammatory responses in rats. J Lipid Res 2003;44:1984–91.
26 Health.gov. Active Adults. 2017. Available from: https://health.gov/YAguidelines/guidelines/chapter4.aspx.
27 Center for Nutrition Policy and Promotion. 2015–2020 Dietary Guidelines for Americans. 2017. Available from: https://www.cnpp.usda.gov/2015-2020-dietary-guidelines-americans.
28 U.S. Department of Agriculture. ChooseMyPlate.gov Website. Washington, DC. [cited 28 Apr 2017]. Available from: www.WebAddress.gov.
29 Muñoz M, Fito M, Marrugat J, Covas M, Schröder H. Adherence to the Mediterranean diet is associated with better mental and physical health. Br J Nutr 2009;101:1821–7.
30 Kanoski SE, Davidson TL. Western diet consumption and cognitive impairment: links to hippocampal dysfunction and obesity. Physiol Behav 2011;18(103):59–68.
31 Dakshinamurti K, Sharma SK, Bonke D. Influence of B vitamins on binding properties of serotonin receptors in the CNS of rats. J Mol Med 1990;68:142–5.
32 Delion S, Chalon S, Guilloteau D, Besnard J, Durand G. A-linolenic acid dietary deficiency alters age-related changes of dopaminergic and serotoninergic neurotransmission in the rat frontal cortex. J Neurochem 1996;66:1582–91.
33 Patrick RP, Ames BN. Vitamin D hormone regulates serotonin synthesis. Part 1: relevance for autism. FASEB J 2014;28:2398–413.
34 Peters R. Ageing and the brain. Postgrad Med J 2006;82:84–8.
35 Elhamdani A, Palfrey CH, Artalejo CR. Ageing changes the cellular basis of the 'fight-or-flight' response in human adrenal chromaffin cells. Neurobiol Aging 2002;23:287–93.
36 Scheibe S, Carstensen LL. Emotional aging: recent findings and future trends. J Gerontol B Psychol Sci Soc Sci 2010;65B:135–44.
37 Ochsner KN, Gross JJ. The cognitive control of emotion. Trends Cogn Sci 2005;9:242–9.
38 Benes FM. Brain development, VII: human brain growth spans decades. Am J Psychiatry 1998;155:1489.
39 Spreng RN, Wojtowicz M, Grady CL. Reliable differences in brain activity between young and old adults: a quantitative meta-analysis across multiple cognitive domains. Neurosci Biobehav Rev 2010;34:1178–94.
40 Vallesi A, McIntosh AR, Stuss DT. Over recruitment in the aging brain as a function of task demands: evidence for a compensatory view. J Cogn Neurosci 2011;23:801–15.
41 Cabeza R, Anderson ND, Locantore JK, McIntosh AR. Aging gracefully: compensatory brain activity in high-performing older adults. Neuroimage 2002;17:1394–1402.
42 Grady CL, Springer MV, Hongwanishkul D, McIntosh AR, Winocur G. Age-related changes in brain activity across the adult lifespan. J Cogn Neurosci 2006;18:227–41.
43 Spear LP. The adolescent brain and age-related behavioral manifestations. Neurosci Biobehav Rev 2000;24:417–63.
44 Giugliano D, Ceriello A, Esposito K. The effects of diet on inflammation. J Am Coll Cardiol 2006;48:677–85.
45 Krishnan V, Nestler EJ. The molecular neurobiology of depression. Nature 2008;455:894–902.
46 Wium-Andersen MK, Dynnes Ørsted D, Fallgaard Nielsen S, Nordestgaard BG. Elevated C-reactive protein levels, psychological distress, and depression in 73 131 individuals. JAMA Psychiatry 2013;70:176.
47 Kivimki M, Shipley MJ, Batty GD, Hamer M, Akbaraly TN, Kumari M, *et al.* Long-term inflammation increases risk of common mental disorder: a cohort study. Mol Psychiatry 2014;19:149–50.
48 Myles IA. Fast food fever: reviewing the impacts of the western diet on immunity. Nutr J 2014;13:413–61.
49 Reynolds CM, McGillicuddy FC, Harford KA, Finucane OM, Mills KHG, Roche HM. Dietary saturated fatty acids prime the NLRP3 inflammasome via TLR4 in dendritic cells-implications for diet-induced insulin resistance. Mol Nutr Food Res 2012;56:1212–22.
50 Ananthakrishnan AN, Khalili H, Konijeti GG, Higuchi LM, de Silva P, Fuchs CS, *et al.* Long-term intake of dietary fat and risk of ulcerative colitis and Crohn's disease. Gut 2014;63:776–84.
51 Ricciotti E, FitzGerald G. Prostaglandins and inflammation. Arterioscler Thromb Vasc Biol 2011;31:986–1000.
52 Fernstrom JD, Fernstrom MH. Tyrosine, phenylalanine, and catecholamine synthesis and function in the brain. J Nutr 2007;137:1539S.
53 National Health Research Institute. 2017. *Phenylalanine*. [cited 28 Apr 2017]. Available from: http://apjcn.nhri.org.tw/server/info/books-phds/books/foodfacts/html/data/data2e.html.

54 Burke SN, Barnes CA. Neural plasticity in the ageing brain. Nat Rev Neurosci 2006;7:30–40.
55 Hashimoto K, Shimizu E, Iyo M. Critical role of brain-derived neurotrophic factor in mood disorders. Brain Res Rev 2004;45: 104–14.
56 Ribeiro JA, Sebastião AM, de Mendonça A. Adenosine receptors in the nervous system: pathophysiological implications. Prog Neurobiol 2002;68:377–92.
57 Simen AA, Bordner KA, Martin MP, Moy LA, Barry LC. Cognitive dysfunction with aging and the role of inflammation. Ther Adv Chronic Dis 2011;2:175–95.
58 Cribbs DH, Berchtold NC, Perreau V, Coleman PD, Rogers J, Tenner AJ, *et al.* Extensive innate immune gene activation accompanies brain aging, increasing vulnerability to cognitive decline and neurodegeneration: a microarray study. J Neuroinflamm 2012;9:179.
59 Pfeifer MA, Weinberg CR, Cook D, Best JD, Reenan A, Halter JB. Differential changes of autonomic nervous system function with age in man. Am J Med 1983;75:249–58.
60 Soreq L, Rose J, Soreq E, Hardy J, Trabzuni D, Cookson MR, *et al.* Major shifts in glial regional identity are a transcriptional hallmark of human brain aging. Cell Rep 2017;18(2):557–70.
61 Basta G, Schmidt AM, De Caterina R. Advanced glycation end products and vascular inflammation: implications for accelerated atherosclerosis in diabetes. Cardiovasc Res 2004;63:582–92.
62 Dooren FE, Pouwer F, Schalkwijk CG, Sep SJ, Stehouwer CD, Henry R, *et al.* Advanced glycation end product (age) accumulation in the skin is associated with depression: the Maastricht study. Depress Anxiety 2017;34:59–67.
63 Smith AP. Breakfast and mental health. Int J Food Sci Nutr 1998;49:397–402.
64 Bergendahl M, Vance ML, Iranmanesh A, Thorner MO, Veldhuis JD. Fasting as a metabolic stress paradigm selectively amplifies cortisol secretory burst mass and delays the time of maximal nyctohemeral cortisol concentrations in healthy men. J Clin Endocrinol Metab 1996;81:692–9.
65 Witbracht M, Keim NL, Forester S, Widaman A, Laugero K. Female breakfast skippers display a disrupted cortisol rhythm and elevated blood pressure. Physiol Behav 2015;140:215–21.
66 Lanou AJ. Should dairy be recommended as part of a healthy vegetarian diet? Counterpoint. Am J Clin Nutr 2009;89(5): 1638S–42S.
67 Weaver CM. Should dairy be recommended as part of a healthy vegetarian diet? Point. Am J Clin Nutr 2009;89(5):1637S.