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Research Paper

Dynamic associations between daily alternate healthy eating index, exercise, sleep, seasonal change and mental distress among young and mature men and women

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ABSTRACT

Background: Diet quality, exercise and sleep are dynamic modifiable factors that impact mental health. However, taking into consideration gender and age-groups as risk factors may be necessary to customize therapies. The purpose of the study was to assess the dynamic interactions between diet quality, and lifestyle factors in relation to mental distress in these sub-groups.
Method: A total of 52 adult participants provided 4 week-daily records using the Food-Mood questionnaire. Data were collected for 2 years during the summer and fall seasons. Spearman's correlation as well as multivariate and multilevel regression analyses were used to identify correlations and model the relationships, respectively, between the variables of interest.
Results: There was a mild negative correlation between AHEI and K-6 scores; r_s= -0.08 (95% confidence interval = [-0.14, -0.02]). Men and participants aged 30 years or older had lower K-6 scores than women (0.8 vs 1.8, $p < 0.001$), and younger adults (0.6 vs 1.9, $p < 0.001$), respectively. Lower K-6 scores associated with 20 min or more exercise compared to days without exercise or exercised less than 20 min (1.2 versus 1.9, $p < 0.001$). Seasonal changes were associated with alterations in diet quality and mental wellbeing ($P < 0.001$).
Limitations: A convenience sample was used.
Conclusion: Our results suggest that adjusting one modifiable factor may lead to improvement in others. In addition, these factors are age and gender dependent. Therefore, customization of dietary and lifestyle factors based on gender and age-groups is recommended to optimize mental wellbeing.

1. Introduction

Mental distress, namely anxiety and depression, is on the rise despite the increase in resource allocation. This disconnect suggests a need to revolutionize prophylactic and therapeutic approaches to improve mental health. There is a clear discrepancy in the prevalence of mental distress among young adults (18–29 years) in comparison to their older counterparts (30 years and older) (Begdache et al., 2019a). Additionally, women have higher prevalence of mental distress than men (Albert, 2015). Recent evidence proposed that age-groups and gender may require differential dietary and lifestyle factors to support mental wellbeing (Begdache et al., 2018; 2019a). This defined disparity is mostly due to the incomplete development of the prefrontal cortex (PFC) in young adults (Coutlee and Huettel, 2012), and the differential brain connectivity and cortical volume between men and women (Ritchie, 2018). Therefore, therapies based on age-groups and gender are necessary to improve prognosis.

A major factor to consider when assessing mental distress in relation to dietary and lifestyle factors is the age bracket, to reflect brain maturity . PFC is the last part of the human brain to develop. It is estimated that the brain completes its maturity between mid to late 20 s (Somerville, 2016). PFC regulates impulsive behaviors, emotions, rationalization of thoughts and decision making (Coutlee and Huettel, 2012). This explains the differential age-related emotional control and the higher frequency of risky behaviors among young adults. Among the modifiable risk factors, a good quality diet appears to be the first line of defense against anxiety and depression (Bourre, 2005, 2006; Kolb and Gibb, 2011). A healthy diet provides several macro- and micronu-

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trients that support the brain structurally and biochemically (Gu et al., 2015). Consequently, the brain of young adults requires a spectrum of nutrient-dense food that may work synergistically to support growth and operation of different brain structures. Therefore, young adults who experience nutritional deficiencies are more likely to suffer from mental distress with a potential long-lasting effect (Gomez-Pinilla and Nguyen, 2012). Based on imaging studies, men have larger brain volume in all subcortical regions, primarily as gray matter (GM) (Ritchie et al., 2018). Conversely, women have a larger volume of GM in the cortices and higher density of white matter (WM) between the frontal lobes, which include regions that control impulse and emotions (Ryman et al., 2014). WM comprises myelinated axons that embody brain connectivity. Therefore, the dimorphic state of the brain may require a differential repertoire of nutrients and lifestyle factors to support mental wellbeing. Traditionally, studies on the association between diet and mental distress have focused on single nutrients (McLean et al., 2011); however current trends in nutritional epidemiology research are pushing toward analyzing dietary patterns in relation to comorbidities. As a step further, analyzing the quality of food within a dietary pattern presents a precise picture. The Alternate Healthy Eating Index (AHEI) is currently used in nutrition research to evaluate quality of foods as predictive of chronic disease risk, including mental distress (Chiuve et al., 2012). AHEI-2015 is a revised version of the Healthy Eating Index that assesses diet quality based on the recommendations of the Dietary Guidelines for Americans.

Other known modifiable factors that affect mental health are sleep, exercise and seasonal changes that are associated with light-induced alterations in the circadian rhythm (Brainard et al., 2015). A good sleep quality resets brain functions through upregulation of the circadian clock genes (Stankiewicz et al., 2017), while regular exercise supports brain volume and associates with improved cognition and mental wellbeing (Raichlen and Alexander, 2017; Swain et al., 2003). Seasonal changes that affect length of daylight contribute to mood disorders (Adamsson et al., 2018) by modifying the circadian rhythm and consequently impacting brain chemistry (Coon et al., 1995).

However, the association between diet, sleep, exercise, and seasonal changes in relation to mental distress is complex and multidimensional. These variables are intertwined in a way that a shift in one factor may alter directionality of others and, consequently, impact mood. Therefore, it is crucial to recognize the dynamic relationships between those lifestyle factors and mental distress to provide the groundwork necessary to improve prophylactic and therapeutic approaches. To our knowledge, no study has evaluated the kinetics of these combined factors in relation to mental distress among young and mature men and women. Hence, the purpose of this study was to assess the nature of the associations between daily AHEI scores, sleep quality, exercise, seasonal changes and mental distress among men and women based on age-groups- reflective of brain maturity- to potentially describe their intricate role in mental distress. Our findings may provide a foundation for the field of personalized treatment and mental health as they may present a framework for developing dietary and lifestyle interventions to support clinical and pharmacological therapies.

2. Method

2.1. Study design

The study protocol was reviewed and approved by the Institutional Review Board at Binghamton University prior to the start of the project (Protocol 00000587, Approval date 5/25/2018). Healthy adults of 18 years and older were invited to join the study. Participants were recruited from the online community. The inclusion criterion was defined as healthy adults aged 18 years or older. There was no prior diagnostic assessment as the aim of the study was to evaluate the relationship between diet and sleep quality as well as exercise in relation to different levels of mental distress. The social media announcement described the aims, procedures, risks, and benefits of the research and provided a contact information for those interested in joining the study. Interested participants who communicated with the research team were asked to provide their name, email, date of birth, and phone number, and in return were assigned a study code. The consent form was built into the questionnaire and participants consented to the study by accessing the survey. Data were recorded electronically on a daily basis for four weeks. Data were collected in 2018 and 2019 from June through December. To eliminate the diurnal effect, participants were asked to complete the survey before going to bed at night. The survey was built in Google forms that tracked date and time of records. The research assistants monitored daily entries and sent to participants, around 9:00 pm, a text message as a reminder to complete the form.

2.2. Dietary patterns and mental distress assessment

Dietary and nutrient consumption patterns were evaluated using a modified version of the validated Food-Mood Questionnaire (FMQ). FMQ is a 5-subscale item with an internal consistency, as reflected by Cronbach's alpha values ≥ 0.70 for all sub-scales. FMQ is a reliable tool (ICC 0.619–0.884; $P < 0.01$; CI 95%), which has an external validity as well (Begdache et al., 2019b). FMQ questions were modeled after the Food Frequency Questionnaire; however, FMQ collects a concise dietary intake based on food group consumption. Typically, food groups share common nutrients that have a direct effect on brain function (Gomez-Pinilla and Nguyen, 2012). The modified version of FMQ evaluates daily servings of nine different food groups: whole grain, fruits, vegetables, meat, beans and legumes, nuts, dairy, fish, and high glycemic index (HGI) foods. Answers ranged on a 6-level Likert scale (0 = none of the time to 6 = 5 times or more) a day. Questions on breakfast consumption, frequency of exercise (20 min or more), use of multivitamins and fish oil supplements, consumption of fast-food and caffeinated beverages were included. Exercise frequency was based on suggestions from the literature that exercising for at least 20 min a day improves mental wellbeing (Craft and Perna, 2004; Ströhle, 2009; Taylor et al., 1985). Mental distress was measured using Kessler Psychological Distress Scale-6 (K-6) questionnaire, which uses a 5-level Likert scale for each question. Sleep quality was evaluated qualitatively by asking participants to rate their sleep using a 5-level Likert scale (1 being the worst; 5 being the best). An overall wellbeing question was also included to take into consideration any physical ailments that may have contributed to participants' mental health. Answers were also on a 5-level Likert scale (1 being the worst; 5 being the best).

2.3. Statistical analysis

The demographic characteristics of the participants were summarized by mean and standard deviation for continuous variables and by counts and percentage for categorical variables. A daily AHEI was calculated for each participant by summing over the scores for the 9 different food groups plus the use of multivitamins, fish oil supplements, consumption of fast-food and caffeinated beverages recorded for a given day. Similarly, a daily K-6 score was calculated for each participant by summing over the 6 scores on nervousness, helplessness, restlessness, worthlessness, depression and feeling everything was an effort (Furukawa et al., 2003). The number of hours of sleep per night was totaled per participant. Both AHEI and K-6 scores were first summarized overall and then separately by demographics characteristics such as gender, age (18–29 years versus 30 years or older), season of recording (summer versus fall) and their combinations.

2.3.1. Correlational study

Spearman's correlations and the associated confidence intervals were estimated between AHEI and K-6 scores. The relationship among the number of hours of sleep, restfulness and overall wellbeing was explored against AHEI and K-6 scores. For the general US adults, the

Table 1
Description of demographics.

	Males	Females	18–29 years	30 years and older	Summer enrollment	Fall enrollment
Number	15	37	37	15	34	18
Percentages	(29%)	(71%)	(71%)	(29%)	(65%)	(35%)

proportions of K-6 scores of 13 or above (considered as severe mental distress) is estimated to be 6% (Kessler et al., 1996), and of 5 or above (considered as moderate mental distress) is estimated to be about 28% (Prochaska et al., 2012). Accordingly, we expect most K-6 scores from our study group to be less than 5 and with some participants/observations having 5 or above and very few, if at all, having scores 13 and above at any given day. Hence, K-6 scores were dichotomized into an indicator describing whether the participant experienced at least a moderate mental distress (K-6 scores ≥ 5) on a given day (Prochaska et al., 2012).

2.3.2. Regression analyses

To effectively recognize the contribution of the variables to mental distress, two separate multivariate logistic regression models were used. A multivariate logistic regression model explored the pooled data in relation to mental distress, and a multilevel logistic regression model investigated the data based on inter-individual differences by accommodating the multiple observations obtained from each participant and the variations across participants. Therefore, the multivariate logistic regression model was first fitted with the dichotomized K-6 scores based on the pooled data to investigate the effects of various variables on the probability of a moderate mental distress. Next, a multilevel logistic regression model was fitted using the dichotomized K-6 scores as responses indicating at least a moderate mental distress. The comparisons of AHEI and K-6 scores between different groups were carried out both parametrically (t-tests or ANOVA) and non-parametrically (Mann-Whitney tests or Kruskal-Wallis tests), and the larger of p-value is reported. All statistical analyses were performed in R: A Language and Environment for Statistical Computing, version 4.0.2 (2020, Vienna, Austria)(R Core Team, 2020) . The packages used were reshape2 (Hadley, 2007) plyr (Hadley, 2011), ggplot2 (Hadley, 2016), gridExtra (Auguie, and Antonov, 2017) RAVideMemoire (Hervé, 2020) and lme4 (Bates et al., 2015).

3. Results

A total of 52 participants joined the study with 37 (71%) females and 15 (29%) males and provided a total of 1065 daily records with complete AHEI, K-6 scores, breakfast and exercise frequencies, sleep quality and overall wellbeing ratings. Thirty-seven (71%) were 18–29 years old and fifteen (29%) were 30 years or older. Thirty-four (65%) of them were enrolled in the summer, and 18 (35%) were enrolled in the fall (Table 1). The average number of days observed was 20 days with a standard deviation (s.d.) of 9.4 days (median 22 days, interquartile range (IQR) was 17 days) and 56% reported having exercised 20 min or more. The average AHEI score was 39.8 (with s.d. 10.1) with men having slightly higher AHEI scores than women (40.8 vs. 39.4, $p = 0.04$). Participants aged 30 years or older had higher AHEI scores than younger adults (18–29 years old) (42.7 vs. 38.5, $p < 0.001$). Participants enrolled in the summer had higher AHEI scores than participants enrolled in the fall (40.7 vs 37.8, $p < 0.001$). On average, the AHEI scores were higher on days with 20 or more minutes exercise compared to days without exercise or exercised less than 20 min (40.9 versus 38.4, $p < 0.001$). The average K-6 score was 1.5 (sd. = 2.6, median = 0). On average, men had lower K-6 scores than women (0.8 vs 1.8, $p < 0.001$), and participants aged 30 years or older had lower K-6 scores than those aged 18–29 (0.6 vs 1.9, $p < 0.001$). Participants enrolled in the summer had lower K-6 scores than those enrolled in the fall (1.1 vs. 2.3, $p < 0.001$). K-6 scores were lower for days with 20 min or more exercise compared to days without exercise or exercised less than 20 min (1.2 versus 1.9, $p < 0.001$). There was a mild negative correlation between AHEI and K-6 scores; and Spearman's correlation coefficient $r_s = -0.08$ (95% confidence interval = [−0.14, −0.02]). Among the 52 participants, the average proportion of exercising 20 min or more daily was 0.53 (median 0.55) with sd. = 0.3, that roughly translated into an average of 20 min of exercise, every other day, for each participant Most of the participants got mostly 6–8 h of sleep per night. However, the sleep patterns varied greatly from person to person (Fig. 1). Sleep quality and overall well-being were closely related to the hours of sleep reported (Fig. 2). As the hours of sleep increased, sleep quality and overall well-being also improved. In addition, our results revealed that better overall well-being was associated with higher AHEI values and lower K-6 scores (Fig. 3).

Using the dichotomized K6-score for the pooled data and the multilevel analyses, a score of 5 or above implies a moderate mental distress, while a score of less than 5 indicates low mental distress (Prochaska et al., 2012). The multilevel logistic regression model suggests that better overall well-being, which is typically asking about physical ailments, decreases the probability of having a moderate mental distress. Being a male and 30 years or older are associated with a lower probability of having a moderate mental distress. Although the effect is not significant, the summer season is associated with a lower probability of having a moderate mental distress compared to the fall season, and the effect is trending toward significant ($P = 0.132$). While the overall AHEI score does not have a significant effect on lowering the probability of having moderate mental distress, coffee consumption and fish oil intake seem to have an impact on the probability of having a moderate mental distress. Our results suggest that the higher the fish oil intake on the AHEI scale, the lower is the probability of having a moderate mental distress. Similarly, the higher the caffeine intake, as reflected in AHEI scores, the greater is the increase in mental distress. After accounting for overall well-being, gender, age, season, and coffee and fish oil consumptions, daily exercise of 20 min or more did not predict the probability of having a moderate mental distress, and therefore the variable was dropped in the final model. Details information on the final models' estimates is presented in Table 2.

4. Discussion

The purpose of this study was to assess the dynamic relationships between daily diet quality, as a function of AHEI scores, sleep, exercise and the effect of season on mental distress in young and mature men and women. Our findings revealed that mental distress is the product of a concoction of these factors. Taking into consideration the AHEI scoring alone, an improvement in diet quality enhanced mental well-being, as reflected by lower K-6 scores. A good sleep quality was associated with mental and overall wellbeing, as well as with higher diet quality and exercise frequency. Seasonal changes had an impact on diet quality and mental health. In fact, mental distress tends to be lower in the summer when compared to the fall. Seasonal changes were associated with alterations in diet quality and mental wellbeing. Men had higher AHEIs and lower K-6 scores than women, and mature adults (30 years or older) had higher AHEIs values and scored lower on the K-6 scale. Taken all together, our results confirmed the hypothesis that risk factors for mental distress are dynamic. They also suggest that improving one factor may positively impact all others. Additionally, our results support the notion of personalizing therapies based on gender and age-groups.

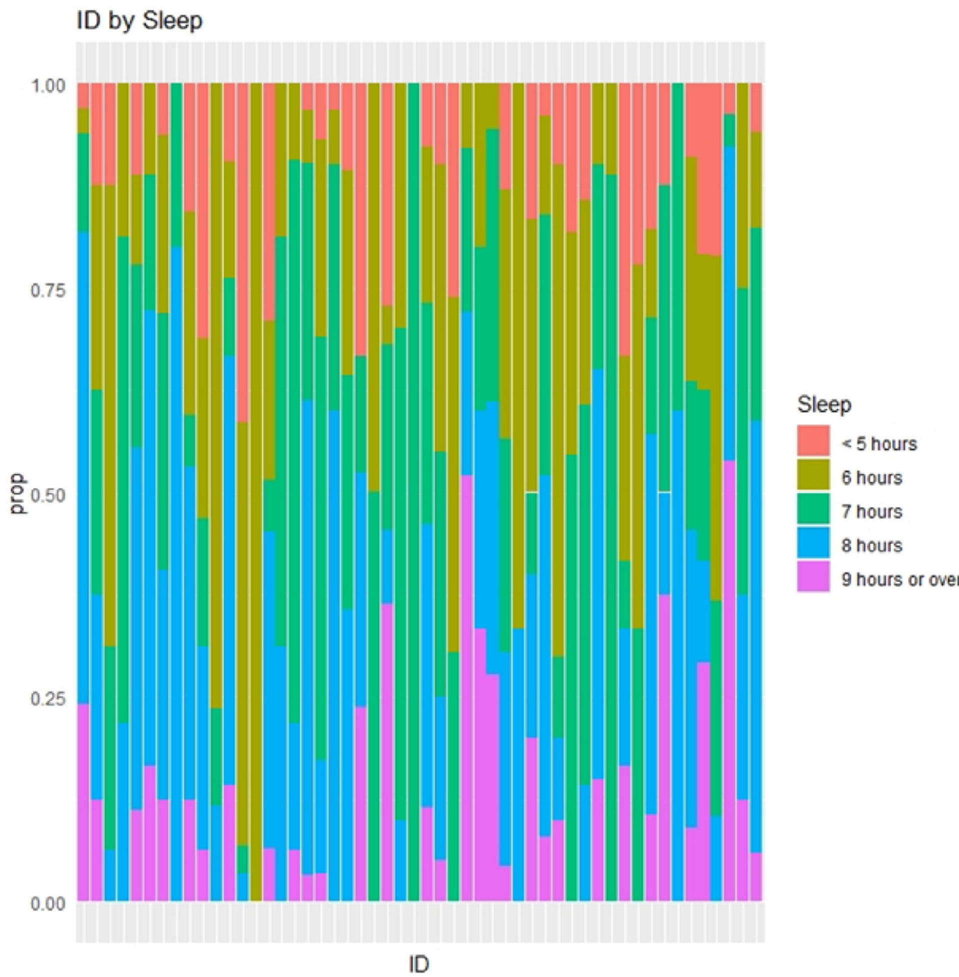

Fig. 1. The number of hours sleep per night summarized per participant.

Table 2
Regression models on variables predictive of a moderate mental distress.

	Pooled analysis			Multilevel Analysis		
	Estimate	Std. Error	P-value	Estimate	Std. Error	P-value
(Intercept)	−1.75	0.27	< 0.01	−2.14	0.53	<0.01
How you feel (center at 3)	−1.11	0.12	<0.01	−1.33	0.16	<0.01
Fall (Summer as reference)	0.46	0.25	0.07	0.9	0.6	0.13
Age 30 and above (18–29 as reference)	−1.16	0.43	0.01	−1.55	0.79	0.05
Male (Female as reference)	−0.98	0.42	0.02	−1.41	0.77	0.07
Caffeine (1–2 cups of coffee)	0.62	0.26	0.02	0.6	0.33	0.07
Fish Oil intake (in AHEI scale)	−1.18	0.52	0.02	−1.36	0.67	0.04

*One or two cups of coffee consumption and Fall season increases the probability of having a moderate mental distress, while better overall wellbeing, fish oil fish oil intake, older age, and being male decrease the probability of having a moderate mental distress after controlling for the individual-variation.

4.1. AHEI, K-6 and gender

Our results revealed that men have higher AHEI scores than women, and higher AHEI scores are associated with lower mental distress, which are consistent with several published reports. A large-scale study by McCullough et al. (McCullough et al., 2002) described that AHEI mean scores were higher among men and associated with lower risk of chronic diseases. Additionally, another report suggested that men are more likely to experience mental wellbeing unless they consume a poor quality diet; while women require a spectrum of nutrient-dense food, representing a high-quality diet, and exercise to achieve mental wellbeing (Begdache et al., 2018), which implicitly support our results. The lower AHEI scores among women could be explained by the likelihood of resorting to emotional eating as a way to cope with stressful events (Richardson et al., 2015; Papadakis et al., 2006). Since women produce less serotonin and exhibit lower serotonin kinetics, a consumption of a low-quality diet deprives the brain of a range of nutrients that contribute to brain chemistry in general and to stable serotonin levels in particular (Young, 2007; Jovanovic et al., 2008; Nishizawa et al., 1997). This gender-based response to stress is mostly attributed to the effects of the female sex hormones on the autonomic nervous system and the hypothalamic-pituitary adrenal (HPA) axis (Newhouse and Albert, 2015), which hyperactivation increases the risk of mental distress (Qin et al., 2016). Taking all together, consumption of a high-quality diet along with a healthy lifestyle may provide women with the resilience needed against mental distress.

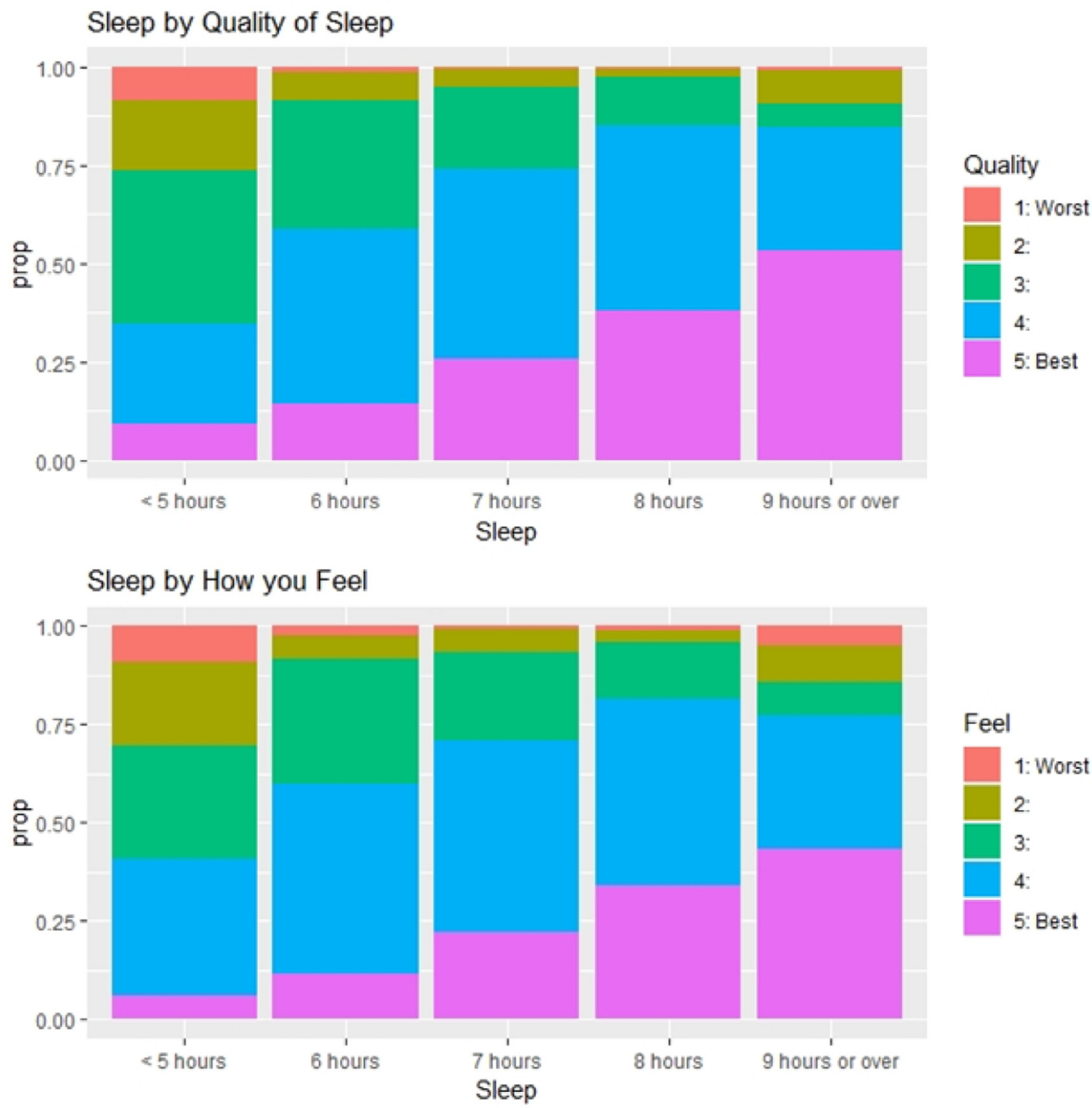

Fig. 2. Summaries of sleep quality and overall well-being by the number of hours sleep.

4.2. AHEI, K-6 and age-groups

Our results reveal that mature adults (30 years or older) had higher AHEIs values and lower K-6 scores compared to young adults (18–29 years), which support several findings from published reports (Charles and Piazza, 2009; Nashiro et al., 2012; Pelletier et al., 2014). With the incomplete maturity of the PFC, young adults are inclined to have an overactive limbic system (LS). LS typically generates high emotions and store their associated memories, while PFC rationalizes feelings and controls impulsive reactions. Additionally, young adults typically consume an imbalanced diet (Pelletier et al., 2014); which is likely to change the gene expression profile of the brain, (Bourre, 2006; Gómez-Pinilla, 2008). Similarly, a low-quality diet among mature adults promotes oxidative stress and disturbs neurotransmission (Briguglio et al., 2018). An international cross-sectional study comparing levels of mental distress among young versus mature adults reported that a differential dietary repertoire is associated with mental wellbeing in these subpopulations (Begdache et al., 2019a). Exercise and food that contribute to neurotransmitter precursors, needed for brain maturity, were positively associated with mental wellbeing in young adults; whereas food high in antioxidants were associated with mental wellbeing in mature adults (Begdache et al., 2019a).

4.3. Seasonal effect and mental distress

The purpose of assessing the effect of summer versus fall was to consider the potential impact of changes in the circadian rhythm on mental health. Others have reported independently on the effect of seasonal change on sleep, diet quality or overall wellbeing (Suzuki et al., 2019; van der Toorn et al., 2020). A recent published report revealed that the spring season, in comparison to winter, is associated with mental distress among young and mature women (Begdache et al., 2021), which supports the notion of mental distress being associated with light-induced alterations in the circadian rhythm. Our finding that the summer season is linked with mental wellbeing could be explained in part by the length of day which boosts brain serotonin levels (Vittinghoff and McCulloch, 2007).

4.3.1. Association between the circadian rhythm and mental distress

Mechanistically, a disturbance in the circadian rhythm along with shorter daylight stimulate the conversion of serotonin to melatonin

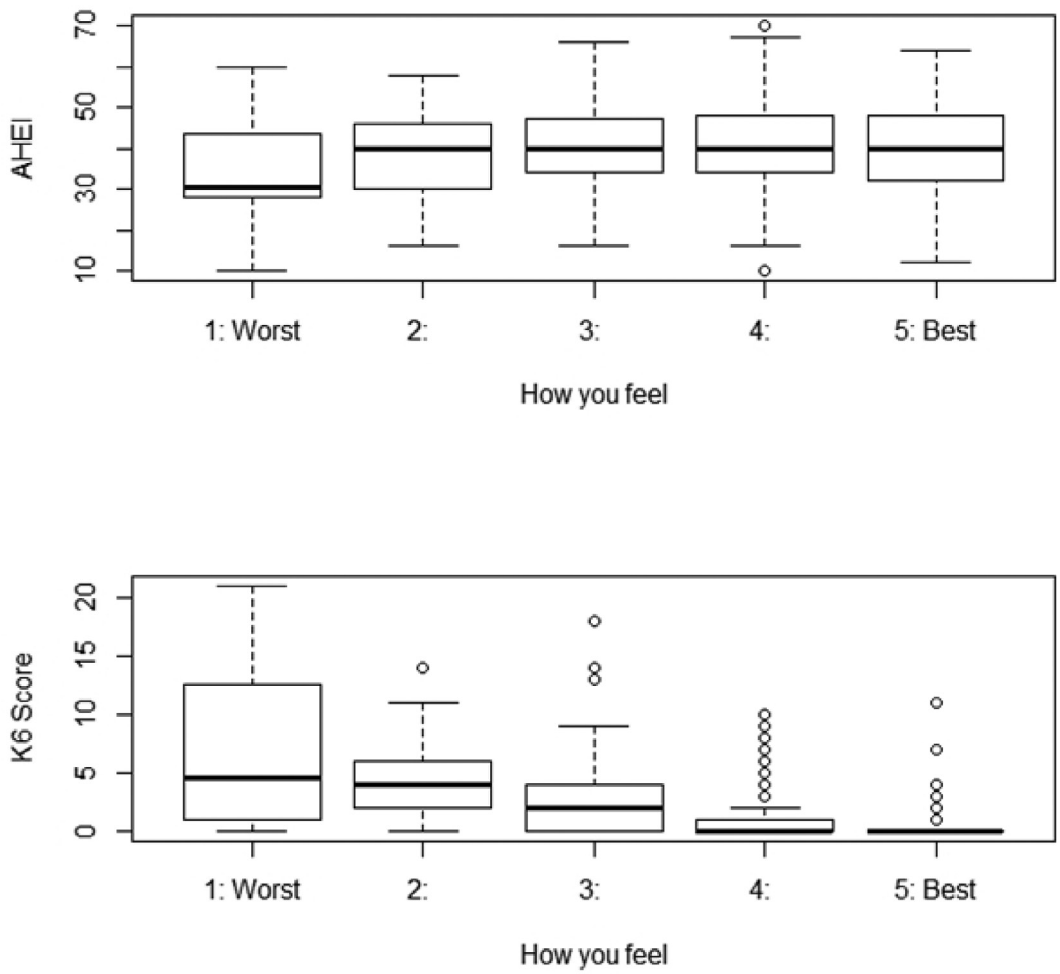

Fig. 3. The relationships between overall wellbeing and AHEI index and K6-scores, respectively.

(Salva & Hartley, 2012), which implies that melatonin production during the dark phase leads to a lower mood. The rate of melatonin synthesis is dictated by the length of the day/night cycle. Its biosynthesis declines with daylight and surges during the dark phase, which explains why seasonal affective disorder (SAD) is prevalent in the fall and winter (Lundt, 2004). Hence, light therapy is often used during these two seasons to combat mood disorders (Pail et al., 2011). The alteration in serotonin levels influences the feeding centers in the hypothalamus, Consequently, mood and diet quality are impacted, an association that was depicted in our study. In fact, an imbalanced diet further affects the serotonin/melatonin cycle (Donovan and Tecott, 2013; Peuhkuri et al., 2012) producing a vicious cycle of low mood and a poor quality diet.

4.3.2. Serotonin biosynthesis and diet quality

Serotonin synthesis in the brain is reliant on the influx of its precursor, tryptophan (Trp), an essential amino acid that needs to be supplied by the diet. The transport of Trp to the brain is insulin-dependent (Young, 2007). Therefore, fluctuations in blood insulin secondary to a high glycemic diet cause oscillation in brain serotonin levels. In addition, a high protein diet causes Trp to compete with other large neutral amino acids (LNAAs) for the common carrier protein lowering the amount of Trp entering the brain. (Fernstrom and Wurtman, 1972; Markus, 2008). In essence, an imbalanced diet, typically producing low AHEIs, affects the kinetics of Trp transport to the brain and leads to changes in mood.

4.4. Sleep, diet, mental distress, exercise, and overall well-being

Our results suggest that sleep duration is positively associated with sleep quality, which is linked to an overall well-being. In addition, the latter is positively correlated with AHEI values and inversely associated with K-6 scores. Exercising frequently for over 20 min a day was associated with higher AHEI scores and lower K-6 scores. These intricate relationships suggest that mental wellbeing results from a combination of these lifestyle factors. Chaput (Chaput, 2014) described that a low sleep quality was correlated with poor dietary habits and obesity, and unhealthy eating associated with a poor sleep pattern. Enhanced sleep quality has evolutionarily contributed to the cognitive faculties in modern humans (Hunter, 2016). Likewise, a higher quality diet led to the evolution of the human brain (DeCasien et al., 2017; Hunter, 2008). Evidence also suggests that complex scavenging tasks, equivalent to the modern exercise, were physically and mentally taxing, which supported the evolution of the human brain (Raichlen and Alexander, 2017). Therefore, the disagreement between the contemporary lifestyle factors and the evolutionary requirements of the brain is potentially triggering cognitive and mental ailments.

4.5. Predictive model of a moderate mental distress assessing the role of diet, exercise, sleep and overall wellbeing based on interindividual differences

The multilevel modeling approach is typically used to handle grouped data with repeated measures, especially when time and number of measurements vary from one subject to another. Additionally, this modeling approach goes beyond the regression analysis that illustrates the relationship between predictors with outcome variables, to describe the variability of these relationships. This model was used to assess the interindividual differences in dietary intake, sleep, exercise and overall wellbeing to identify predictors of mental distress. According to the multilevel model, positive predictors of moderate mental distress are physical ailments, consumption of caffeine and the fall season. Negative predictors of moderate mental distress are high consumption of fish oil, being over 30 years, and being a male. Caffeine and fish oil intake were the only two variables depicted as significant in the model, after adjusting for age, and gender.

4.5.1. Caffeine and mental distress

Caffeine emerged as a positive predictor of mental distress as caffeinated beverages are commonly consumed. Caffeine is a xanthine alkaloid, which is a central nervous stimulant. Sporadic or low doses of caffeine (50–300 mg) increase brain activity and improve mood. Additionally, low-to-moderate consumption of caffeine promotes alertness and increases energy as well as focus. However, higher amounts have been linked to restlessness, insomnia, and tachycardia (Chaudhary et al., 2016; Klatsky et al., 2011). High caffeine intake is also associated with risk of anxiety, and mood disorders (Hughes and Hancock, 2017) by antagonizing the function of the adenosine A_1 and A_{2A} receptors. The latter are in brain regions that process threat, fear, and anxiety (Hughes and Hancock, 2017; Svenningsson et al., 1997). In addition, caffeine elevates glucocorticoid levels, which stimulate the HPA axis and increase risk of mental distress (Lin et al., 1997; Nicholson, 1989). Therefore, chronic high consumption of caffeine leads to a heightened stress response and mood disorders (Richards and Smith, 2015).

4.5.2. Fish oil and mental distress

Fish oil is typically high in eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) that contribute substantially to brain health. Deficiencies of these polyunsaturated fatty acids are associated with mental distress (Bazinet and Layé, 2014). These omega-3 fatty acids are natural Peroxisome Proliferator-Activated Receptors γ (PPARγ) agonists, a family of nuclear receptors that regulate a myriad of genes involved in brain homeostasis (Dyall, 2015). EPA plays a significant role in maintaining functional integrities of brain structures. It mediates neuroprotective functions through a cascade of cellular events that culminate in the production of anti-inflammatory molecules (Serhan et al., 2015). DHA controls a wide spectrum of neurophysiological processes such as neurotransmitter release, intracellular signaling, axon myelination, neuroinflammation, and neuronal differentiation (Kawakita et al., 2006; Orr and Bazinet, 2008). Additionally, EPA promotes proliferation of progenitor neural cells while DHA stimulates their differentiation (Crupi et al., 2013; Dyall, 2015). Collectively, these two fatty acids provide the cellular and physiological foundations for optimal brain function.

4.6. Future direction

Our study confirmed that differential diet qualities associate with mental distress among young and mature men and women. Taking into consideration brain maturity and gender-differences in brain morphology, the next step is to identify the minimum AHEI scores that correlate with mental wellbeing among the subgroups. In addition, there is a need to establish the specific repertoire of nutrients that are associated with mental wellbeing among these sub-populations.

4.7. Strengths and limitations

This study has several strengths and limitations. The number of records for the pooled data analysis is a strength. The fact that several of our results were previously reported by other studies suggests that these results could be generalizable. However, the small convenience sample size is a limitation. The multilevel regression model identified caffeine and fish oil as the only dietary predictors of mental distress. Few possible suggestions may explain this phenomenon. Because this modeling approach operates at multiple levels, the number of participants may have not been enough to detect the subtle interindividual variations attributed to diet alone after adjusting for age and gender differences. This is mostly because diet quality is also related to age and gender. The broad variability in the diet among participants may have contributed as well. In addition, the age distribution in the sample is unbalanced, mostly lower 20 s and 40 and above, which may have affected the results after adjusting for age. Although the multivariate logistic regression model identified “exercising 20 min or more” and the “daily overall wellbeing” as prognostic of mental distress, the daily indicator of “exercising 20 min or more” in the multilevel regression model was not predictive of mental distress after taking other variables into account. We suspect that the effect of exercise has been absorbed into “overall well-being” and did not surface as a predictor when the overall well-being was included in the model. In addition, the participants in this study were overall physically active, on average they exercised at least every other day, which represented a limited spectrum of exercising patterns. For future work, a large sample with a more diverse physical activity patterns are needed.

5. Conclusion

There is a clear interweaved relationship between diet quality, sleep, exercise, overall wellbeing, seasonal change, and mental distress. The current study suggests that mental distress is a product of a complex repertoire of modifiable lifestyle factors. These results imply that adjusting one factor may lead to improvement of others. Gender and age-groups have clearly differential quality of diets and mental distress levels. Therefore, our results reinforced the emerging concepts that personalization of mental distress therapies based on gender and age-groups is recommended. Positive predictors of mental distress include experiencing physical ailments, consumption of caffeine and the fall season. Negative predictors of mental distress include being a male and over 30 years of age as well as fish oil consumption. These results suggest that a move toward a customized approach to improve prognosis of mental health may be necessary.

Declaration of Competing Interest

All the authors have no conflict of interest.

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CRediT authorship contribution statement

Lina Begdache: Conceptualization, Data curation, Investigation, Methodology, Project administration, Visualization, Writing - original draft, Writing - review & editing. Mei-Hsiu Chen: Formal analysis, Software, Writing - original draft, Writing - review & editing. Validation, Visualization Cassey McKenna: Data curation, Investigation, Project administration, Writing - review & editing. Dylan Witt: Data curation, Investigation, Resources, Writing - review & editing.

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