Master thesis

The influence of sugar intake on depressive mood and the mediating effect of body dissatisfaction

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Summary

Sugar consumption has increased over the past years and has surpassed the recommended amount. This has many negative consequences such as weight gain and chronic diseases, but it can also impact mental health. Studies found that sugar can increase depressive mood. These studies however only studied specific sugary products that are generally known to be unhealthy and high in sugar. By only focusing on these products, these studies could not conclude that sugar intake in general increases depressive mood, but only that the certain obviously sugary products they studied increase depressive mood. To answer this question, this study therefore studied if total sugar intake, both from obviously sugary products but also from products that seem healthy but still contain a high amount of sugar, called hidden sugars, also lead to depressive mood. It was expected that intake of total sugar, sugars from obviously sugary products and hidden sugars all increase depressive mood. It was also expected that body dissatisfaction would mediate this effect, since studies found that consuming sugary products can decrease body satisfaction, and low body satisfaction can cause depression. This effect is more prevalent for obviously sugary products so it was expected that the influence of sugar on depression would be larger for these products than for products with hidden sugar.

The hypotheses were tested among $N = 292$ participants. Sugar intake was measured with a Food Frequency Questionnaire, for depression the Hospital Anxiety and Depression Scale was used and for body satisfaction the Body Shape Questionnaire was used. Three multiple hierarchical regression analyses showed that intake of total sugar, sugar from obviously sugary products and hidden sugars all did not significantly predict depressive mood. Body satisfaction was not found to be a significant mediator in any of these analyses.

The results found in this study were contrary to the expectations and preceding studies. This might be due to how this study measured sugar intake and depression. Since this study did not find that sugar could increase depressive mood, no recommendations for people to reduce their sugar intake to improve their mood can be made. However, high sugar intake has many negative consequences that in the long term can also negatively impact mood. It is therefore still advised that people reduce their sugar intake. This can be done on policy level by providing knowledge and implementing a sugar tax. For future studies, it is suggested to perform a longitudinal study to look into the causal relationship of sugar intake and depressive feelings and also to look more into the difference between the influence of sugars from obviously sugary products and hidden sugars on depression. In these future studies, it is advised to let participants track their food intake and depressive feelings by use of a diary.

Introduction

Over the past decades, there has been an increase in people's sugar consumption (Powell et al., 2016). The WHO (2015) recommends that 5 to 10 percent of our daily caloric intake comes from sugar, however, a study from Newens and Walton (2016) found that currently, 13,5 to 24,6 percent of the daily caloric intake of adults around the world consists of sugar. This high sugar consumption has many negative consequences, like for example, weight gain (Te Morenga et al., 2013), dental problems (Moynihan, 2016) and chronic diseases such as type 2 diabetes (Imamura et al., 2016; Malik et al., 2010), cardiovascular diseases (Bray, 2012) and cancer (Port et al., 2012). But besides these physical consequences, recent studies suggest that consuming too much sugar might also influence mental health (Guo et al., 2014; Knüppel et al., 2017; Sachez-Villegas et al., 2018).

Besides the increase in sugar consumption over the last years, depression and anxiety also increased over the past years (Calling et al., 2017; Twenge et al., 2019). This led some researchers to investigate whether there is a link between sugar consumption and mental health problems. Knüppel et al. (2017) for example found that a high intake of sweet products such as cakes and frizzy soft drinks led to increased odds of common mental health disorders such as depression after five years. Similar studies also found that frequent drinking of sweetened beverages (Guo et al., 2014) and high added sugar consumption (Sachez-Villegas et al., 2018) led to increased risk of depression years later.

Most of these studies seem to have found evidence that the consumption of sugar can lead to mental health problems. These studies however only looked at foods and beverages that are generally known as unhealthy and high in refined sugar, such as candy, (Hu et al., 2019). In this study, sugars from such products will be called 'obvious sugars'. These preceding studies did not include diets which are generally high in sugar or products that seem healthy but still contain a large amount of sugar, like fruit juice and cereal (Voedingscentrum, 2020). The sugars in such products will be called 'hidden sugars'. A study by Healthline (2019) found that most people are aware of the amount of sugar in products with obvious sugars, such as cookies, but a lot less people are aware of the amount of sugar in products with hidden sugars, and often underestimated the amount of sugar in these products. The consumption of these hidden sugars therefore unknowingly causes some people to have diets higher in sugar than they anticipated. It is therefore important that a study on sugar and depression focusses on total sugar intake, from both hidden and obvious sugars. By only focusing on obvious sugars, preceding studies could not conclude that sugar intake in general

increases depressive mood, but only that the certain sugary products they studied increase depressive mood.

There are multiple possible explanations for why sugar intake could lead to mental health problems. Firstly, studies focussed on the brain derived neurotrophic factor (BDNF), which is a growth hormone (Dwivedi, 2009). A study found that BDNF levels are very low in people who suffer from major depressive disorder, and that treatment with antidepressants increased BDNF levels again (Sen et al., 2008). Diets high in added sugar were found to reduce BDNF (Molteni et al., 2002). BDNF could thereby be a mechanism through which a diet high in sugar could lead to depression. Secondly, sugar intake can potentially be addictive, and studies therefore suggests that sugar affects dopamine (Avena et al., 2008; Rada et al., 2005). Since dopamine was found to play a role in mood disorders (Dunlop & Nemeroff, 2007), Knüppel et al. (2017) state that the effect that sugar has on dopaminergic neurotransmission mechanisms might connect frequent sugar intake with depression. Thirdly, diets high in sugar can cause an exaggerated insulin response (Schwartz et al., 1987), which can cause low blood sugar and thereby influence hormone levels and potentially mood (Park et al., 2012). Lastly, according to Kendall-Tackett (2007), the primary risk factor for depression that underlies all other risk factors is inflammation. A diet high in sugar increases inflammatory processes in humans (Della Corte et al., 2018). Studies found that long-term inflammation decreases the immune system and thereby increases the risk of depression (Dantzer et al., 2008; Kivimaki et al., 2014).

Besides biological explanations, some studies also looked into psychological explanations. In Western society, being thin is the beauty standard and this causes a lot of people to fear to gain weight (Aruguete et al., 2006). Yamamoto (2003) found that certain types of food can influence perceived body satisfaction through this fear of becoming fat. Since it is commonly believed that foods high in sugar can lead to weight gain, eating these kinds of foods could lead to a more negative body image since especially these foods increase people's fear to gain weight. Vocks et al. (2007) studied this among participants with an eating disorder. They found that after participants consumed a milkshake, their body dissatisfaction was higher than that of the participants in the control group. According to studies (Barnes et al., 2020; Paxon et al., 2010; Stice et al., 2000), body dissatisfaction can be a predictor of depressive mood. Because of this, body satisfaction can be a mediator between sugar intake and depressive mood.

The goal of this study is to find out if the influence of sugar on depression is caused by the consumption of obvious sugars, hidden sugars or total sugar intake. This study will

therefore research if a diet high in total sugar leads to increased depressive mood. Our study will also look into the influence of hidden and obvious sugars on depressive mood separately. Since studies indicate that all kinds of sugars can lead to depression through biological reasons, it is expected that high total sugar, high obvious sugars and high hidden sugars will all lead to an increased score on depressive mood. However, since the effect of sugar on body satisfaction is largest for obvious sugars, it is expected that the effect of obvious sugar on depression will be larger than the effect of hidden sugar. It is therefore expected that the influence of sugar on depression is mediated by body satisfaction. If these influences are found, people's mood and body satisfaction can be improved by informing them about the consequences of too much sugar, and by guiding them to consume less sugar. If this study also finds that hidden sugars can lead to depressive mood, a way to guide people to consume less sugar can be by informing them about hidden sugars. Since most people are yet unaware of these risks (Healthline, 2019), there is still much to gain in this area.

Methods

Participants

The sample consisted of N = 292 participants who were eighteen years or older. N = 84 participants were male (M_{age} = 33,12, SD = 13,24) and N = 207 were female (M_{age} = 31,43, SD = 13,35). The sample consisted of participants from different nationalities, mostly Dutch (N = 140), Chinese (N = 109) and German (N = 35). They were recruited through a digital flyer (Appendix 1) which was shared on social media sites and through Sona Systems from Utrecht University.

Materials

This study is part of a project called 'The Food Mood Move Project', therefore, this survey also included questionnaires used by other researchers. All questionnaires were put together in one survey on Qualtrics. The whole survey was originally developed in English, but because this is a cross-national study, the survey was translated to Dutch, German and Chinese (Simplified). Our study project was ethically approved by the Faculty Ethics Review Board (FERB) of the Utrecht University.

Food Frequency Questionnaire

A Food Frequency Questionnaire (FFQ) was used to measure general food intake and sugar intake. The FFQ contained 51 items (Appendix 2) and was based on the Block Brief 2000 FFQ (Block et al., 2000) and a FFQ based on sugar intake (Boniface, 2013). For each item, participants firstly answered how often they consume a product, an example of such a question was "*How often do you eat eggs?*". Participants could choose one of the nine answer options with "*never*" as an option as well as options ranging from several times per month or per week to "*every day*". Secondly, if participants answered that they consume the product, they were asked about the amount of the product they consume each time that they consume the product. An example of such a question was "*How many eggs do you eat on average each time you eat eggs?*". The answer options were framed in portion sizes ranging from one to five portions and were accompanied with pictures of the portion sizes. Hidden and obvious sugar intake were also measured with the FFQ. Foods with hidden sugar were defined as foods that most people consider to be low in sugar, but that actually contain higher amounts of sugar than expected, like cereal or fruit yoghurt. The items which measured hidden sugar were 4, 7, 10, 13, 15, 20, 27, 38, 39 and 49. Foods with obvious sugar were defined as foods

of which people know that they contain a lot of sugar, like candy or soda. The items which measured obvious sugar were 8, 9, 11, 42, 46, 47, 48, 50 and 51 (Healthline, 2020; Queensland Government, 2017).

Body Shape Questionnaire

Body dissatisfaction was measured with a short version of the Body Shape Questionnaire (BSQ). The BSQ is a 34-item self-report questionnaire to measure concerns and dissatisfaction about body shape (Cooper et al., 1987). An 8-item version of the BSQ was used that consisted of item 5, 11, 15, 20, 21, 22, 25 and 28. This 8-item BSQ was found reliable ($\alpha = .88$) and has a significant concurrent validity ($r = .76$) and divergent validity ($r = .200$) (Da Silva et al., 2014). Participants answered on a 6-point Likert scale (1 = *never*, 6 = *always*).

Hospital Anxiety and Depression Scale

Depressive mood was measured using the Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith, 1983). The HADS is a 14-item self-report questionnaire to measure the main complaints of anxiety and depression, without measuring physical complaints. Since this study only looks at depression, only the depression items from the HADS were used. This were item 2, 4, 6, 8, 10, 12, 14. The depression part of the HADS was found reliable with a Cronbach's alpha between .84 and .86. The HADS also has good validity, with a concurrent validity of $r = .75$ and a divergent validity of $r = .20$ (De Croon et al., 2005). Participants answered on a 4-point Likert scale with varying answer options, for example 1 = *often* to 4 = *very seldom.*

Covariates

Potential confounders were chosen based on preceding studies with similar research questions (Guo et al., 2014; Knüppel et al., 2017; Sanchez-Villegas et al., 2017). All results were adjusted for gender and age. Socio-demographic variables that were adjusted for were the country where the participant lives, their highest attained level of education and their marital status. Health behaviours that were included as potential confounders were smoking status, alcohol consumption, duration of sleep, BMI, having diabetes, following a specific diet and physical activity. Given that the current Covid-19 pandemic has impacted people's mental health (Bueno-Notivo et al., 2021), the results were also adjusted for participants' worry about Covid-19.

Procedures

The participants got a link to the survey on Qualtrics where they could fill in the questionnaires online on their own device. Before the study started, the participants had to read the information letter in which the goal, method and background of the study were explained. It was also explained that our study is entirely voluntary and anonymous. The participants then needed to sign the informed content. After that, the survey started. The participants first had to answer some demographic questions. Then they could fill in the questionnaires. After finishing all questionnaires, the participants were thanked for their participation and asked if they wanted to leave their email address to participate in an allotment to win a coupon. If the participant was a Psychology student at the Utrecht University, they could also get 1 PPU for their participation.

Statistical analysis

Excel was used to calculate the results of participants' food and sugar intake and participants' score on the BSQ and HADS. IBM SPSS Statistics 24 was used to run the main analyses.

Pre-processing steps food and sugar intake

The percentage of sugar in participants' diets was calculated by firstly calculating the total calories in the participants' diets and the total amount of sugar in their diet. This was done by firstly calculating how many portions of a certain food a participant eats in a year, by multiplying the frequency that the participant consumes the product with how many portions they consume each time. The number of portions was multiplied with the number of calories that one portion contains (Voedingscentrum, 2021). After that, the calories for each product were added up for each participant separately. This way, the total amount of calories that the participant consumes in a year was calculated.

To find the total amount of sugar in the participants' diet, the number of portions was multiplied with the amount of calories in one portion consisting of sugar. This was calculated by multiplying the grams of sugar in one portion with four, since one gram of sugar contains four calories (Voedingscentrum, 2021). After that, the calories that consist of sugar for each product were added up for each participant separately. This way, the total amount of calories consisting of sugar that the participant consumes in a year was calculated. After these calculations, a percentage was calculated for each participant of the amount of calories consisting of sugar that where in their entire calory intake. The amount of hidden and obvious

sugar in the participants' diet was calculated the same way but the amount of sugar was then only calculated with the products that contain hidden or obvious sugar.

Pre-processing steps body shape and depression

The BSQ score was calculated by adding up the scores on all eight questions. The higher the score, the more dissatisfied the participant was with their body shape. The HADS score was also calculated by, after recoding some items, adding up the scores of all depression questions. The higher the score, the more depressive feelings the participant had.

Main analyses

The hypotheses were tested by performing three hierarchical multiple regression analyses. In all analyses, the independent variable was put in the first block, the covariates in the second block, the main effect of body dissatisfaction in the third block, and to test the mediating effect of body dissatisfaction, the interaction between body dissatisfaction and the independent variable were added in the fourth block.

Results

Descriptive statistics

The mean percentage of sugar in the participants' diets was 13,52% (*SD* = 5,60), their mean percentage of hidden sugar was 3,17% (*SD* = 2,88) and their mean percentage of obvious sugar was 5,03% (*SD* = 4,26). Participants' mean score on the HADS was 4,77(*SD* = 3,42). 229 (78,42%) participants scored 7 or below on the HADS which is within the normal range, 42 (14,38%) participants scored between 8 and 10 which suggest the presence of a depressive state, and 21 (7,19%) participants scored 11 or above, indicating probable presence of depression (Zigmond & Snaith, 1983). Participants' mean score on the BSQ was 16,49(*SD* = 6,05). 209 (71,58%) participants scored 18 or below on the BSQ which indicates no concern with body shape, 72 (24,66%) participants scored between 19 and 25 which indicates mild concern with body shape, 24 (8,22%) participants scored between 26 and 33 which indicates moderate concern with body shape, 3 (1,03%) participants scored above 33 which indicates marked concern with body shape (Da Silva et al., 2014). Descriptive statistics of all the variables can be found in Appendix 3.

Assumptions

Before running the analysis, a number of assumptions were tested and checks were performed. First, stem-and-leaf plots and boxplots indicated that each variable in the regression was normally distributed, but each variable did contain some outliers. Second, an inspection of the normal probability plot of standardised residuals and the scatterplot of standardised residuals against standardised predicted values indicated that the assumption of normality, linearity and homoscedasticity of residuals were met. Third, the Mahalanobis distance did exceed the critical X^2 for *df* =33 (at $\alpha = .001$) of 62.49 for some cases in the data file, indicating that there were some multivariate outliers. Finally, relatively high tolerances for all predictors in the final regression model indicated that multicollinearity would not interfere with the ability to interpret the outcome of the multiple regression analyses.

Regression analysis

Total sugar

A simple linear regression was run to predict depression based on sugar intake. A non significant regression equation was found, $F(1, 290) = 0.001$, $p = .98$.

A multiple hierarchical regression was then run to predict depressive feelings from sugar intake, while controlling for multiple variables. When all the variables were added to the model, the whole model explained 24.7% of the variance in depressive feelings, $R^2 = .25$, adjusted $R^2 = .14$, $F(34, 250) = 2.41$, $p < .001$. By Cohen's (1988) conventions, a combined effect of this magnitude can be considered small to medium ($f^2 = .33$). The regression coefficients for all variables, including the covariates, can be found in Appendix 4. The covariates that were controlled for were gender, age, country, education, marital status, smoking, alcohol consumption, sleep, BMI, diabetes, diet and physical activity. Sugar intake did not significantly predict depression $B = -.03$, $t(250) = -.28$, $p = .78$. Body dissatisfaction was not found to be a significant mediator $B = .00$, $t(250) = .02$, $p = .99$. Unstandardised (B) and standardised (β) regression coefficient, and squared semi-partial correlations (sr^2) for the independent variable and mediator on each step of the hierarchical multiple regression analysis are reported in Table 1. As seen in Table 1, none of the variables added significantly to the prediction in the final model.

Table 1

Unstandardised (B) and Standardised (β) Regression Coefficients, and Squared Semi-Partial (sr^2) for Each Predictor Variable on Each Step of a Hierarchical Multiple Regression Predicting Depression (N = 292)

Variable	B [95% CI]	β	sr^2
Step 1			
Total sugar	0.00 [-0.07, 0.07]	0.00	0.00
Step 2			
Total sugar	-0,02 [-0.1, 0.06]	-0.03	0.00
Step 3			
Total sugar	-0.03 [-0.10, 0.05]	-0.04	0.00
Body dissatisfaction	0.18 [0.10, 0.26]*	0.32	0.07
Step 4			
Total sugar	-0.03 [-0.28, 0.17]	-0.05	0.00
Body dissatisfaction	0.18 [0.10, 0.35]	0.32	0.01
Total sugar X body dissatisfaction	0.00 [-0.11, 0.11]	0.00	0.00

Note. CI = confidence interval.
* p < .001

Hidden sugar

A simple linear regression was run to predict depression based on hidden sugar. A non significant regression equation was found, $F(1,290) = 0.05$, $p = .83$.

A multiple hierarchical regression was then run to predict depressive feelings from hidden sugar intake, while controlling for multiple variables. When all the variables were added to the model, the whole model explained 25.1% of the variance in depressive feelings, $R^2 = .25$, adjusted $R^2 = .15$, $F(34, 250) = 2.46$, $p < .001$. By Cohen's (1988) conventions, a combined effect of this magnitude can be considered small to medium ($f^2 = .34$). The regression coefficients for all variables can be found in Appendix 4. Hidden sugar intake did not significantly predict depression $B = -.27$, $t(250) = -1.19$, $p = .24$. Body dissatisfaction was not found to be a significant mediator $B = -.02$, $t(250) = 1.37$, $p = .17$. Table 2 again shows the unstandardised (B) and standardised (β) regression coefficient, and squared semi-partial correlations (sr^2). As seen in this table, only body dissatisfaction added significantly to the prediction in the final model and on step 3.

Table 2

Unstandardised (B) and Standardised (β) Regression Coefficients, and Squared Semi-Partial (sr^2) for Each Predictor Variable on Each Step of a Hierarchical Multiple Regression Predicting Depression (N = 292)

Variable	B [95% CI]	β	sr^2
Step 1			
Hidden sugar	0.01 [-0.13, 0.16]	0.01	0.00
Step 2			
Hidden sugar	-0,04 [-0.19, 0.11]	-0.03	0.00
Step 3			
Hidden sugar	-0.02 [-0.17, 0.12]	-0.02	0.00
Body dissatisfaction	0.18 [0.11, 0.25]*	0.32	0.07
Step 4			
Hidden sugar	0.27 [-0.17, 0.71]	0.22	0.00
Body dissatisfaction	0.23 [0.13, 0.33]*	0.41	0.06
Hidden sugar X body dissatisfaction	-0.02 [-0.04, 0.01]	-0.26	0.01

Note. CI = confidence interval.
* p < .001

Obvious sugar

A simple linear regression was run to predict depression based on obvious sugar. A non significant regression equation was found, $F(1,290) = 1.75$, $p = .19$.

A multiple hierarchical regression was then run to predict depressive feelings from obvious sugar intake, while controlling for multiple variables. When all the variables were added to the model, the whole model explained 24.6% of the variance in depressive feelings, $R^2 = .25$, adjusted $R^2 = .14$, $F(34, 250) = 2.40$, $p < .001$. By Cohen's (1988) conventions, a combined effect of this magnitude can be considered small to medium ($f^2 = .33$). The regression coefficients for all variables can be found in Appendix 4. Obvious sugar intake did not significantly predict depression $B = -.02$, $t(250) = .17$, $p = .87$. Body dissatisfaction was not found to be a significant mediator $B = .00$, $t(250) = .10$, $p = .92$. Table 3 again shows the unstandardised (B) and standardised (β) regression coefficient, and squared semi-partial correlations (sr^2). As seen in this table, only body dissatisfaction added significantly to the prediction in the final model and on step 3.

Table 3

Unstandardised (B) and Standardised (β) Regression Coefficients, and Squared Semi-Partial (sr^2) for Each Predictor Variable on Each Step of a Hierarchical Multiple Regression Predicting Depression (N = 292)

Variable	B [95% CI]	β	sr^2
Step 1			
Obvious sugar	0.07 [-0.03, 0.16]	0.09	0.01
Step 2			
Obvious sugar	0,04 [-0.06, 0.15]	0.05	0.00
Step 3			
Obvious sugar	0.03 [-0.07, 0.13]	0.04	0.00
Body dissatisfaction	0.18 [0.11, 0.25]**	0.31	0.07
Step 4			
Obvious sugar	0.02 [-0.22, 0.26]	0.03	0.00
Body dissatisfaction	0.18 [0.07, 0.28]*	0.31	0.03
Obvious sugar X body dissatisfaction	0.00 [-0.01, 0.01]	0.02	0.00

Note. CI = confidence interval.
* p < .005
** p < .001

Discussion

This study looked at the influence of sugar on depressive mood and also made a distinction between hidden and obvious sugar. Contrary to our expectations, the amount of sugar in participants' diet was not a significant predictor of depressive mood. Similarly, both hidden and obvious sugars were not significant predictors of depressive mood. This was inconsistent with preceding studies on sugar intake and depression (Guo et al., 2014; Knüppel et al., 2017; Sachez-Villegas et al., 2018). The reason for why we found different results compared to preceding studies might be because our study measured depression differently than the preceding studies. The preceding studies all measured depression based on a depression diagnosis by a clinician. Our study used the HADS which is an instrument to screen for who presumably has depression. This instrument however cannot make a distinction between who has depression and who does not have depression (Spinhoven, 1997). It is therefore unclear how the percentage of participants with a depression diagnoses in this study compared to the preceding studies. Another reason for why we found different results compared to preceding studies might be, as will be explained in the next paragraph, due to our flaws in measuring participants' sugar intake.

It was expected that body dissatisfaction would mediate the influence of sugar on depressive mood. However, this mediating effect was not found, which was not in line with preceding studies (Barnes et al., 2020; Paxon et al., 2010; Stice et al., 2000; Vocks et al., 2007). The reason for why this result was inconsistent with preceding studies might be because the preceding study which stated that sugar consumption could decrease body image was obtained from a sample of eating disorder patients (Vocks et al., 2007). This study however looked at the general population. Although body dissatisfaction was not found to be a mediator, our study did find that body dissatisfaction on itself significantly predicted depressive mood, which is consistent with preceding studies on body dissatisfaction and depressive mood (Barnes et al., 2020; Paxon et al., 2010; Stice et al., 2000).

Strengths and limitations

The strength of this study was that, contrary to preceding studies that only focused on certain obviously sugary products, we looked at total sugar intake, both from hidden and obvious sugars. The obviously sugary products that the preceding studies focused on are not the only foods that contain sugar. By only focusing on these products, these studies could not conclude that sugar intake in general leads to increased depressive mood, but only that the certain

sugary products they studied increase depressive mood. Our study therefore looked at the total sugar intake, to be able to answer this question.

However, this study also had a few limitations. Firstly, this study used a self-report FFQ to measure food and sugar intake. A study by Ravelli and Schoeller (2020) however found that memory-based self-reporting of diet is often not accurate, and people tend to underestimate how much they consume. This was also seen in our study, some participants reported very low or high total calorie and sugar intake, which did not seem realistic. This assessment strategy was chosen since the preceding studies also used this strategy. These preceding studies however used the whole FFQ, and not a short version like we did. Studies however indicate that shorter versions of the FFQ are just as reliable and valid as the full versions (Bredin et al., 2019; Mannato et al., 2015; Shaw et al., 2021). Secondly, the FFQ is an instrument developed in Western society. Participants in this study however were not all from western countries. Being from a western or non-western country however did not have an influence on the results, as seen in Appendix 4.

Practical implication

Since this study did not find that sugar could increase depressive mood, no recommendations for people to reduce their sugar intake to improve their mood can be made, based on this study. However, the increased sugar intake of people over the last years has many negative consequences, as was explained in the introduction. In the long term, this could also negatively impact mood (Guthrie, 1966; McDaniel et al, 1955; Turner & Kelly, 2000). The WHO (2015) therefore recommends that adults and children reduce their daily sugar intake to less than 10% of their total energy intake.

Reducing people's sugar intake can be accomplished the best on policy level, since policy makers have various measures to induce behavior change, like providing knowledge, setting up campaigns or even changing laws (Diepeveen et al., 2013). According to Diepeveen et al., more intrusive interventions like changing laws are effective in changing people's behavior, however, there is not a lot of support for such interventions by the public. Less intrusive interventions like providing knowledge are less effective but there is more support for these kind of interventions. Although not sufficient, education is a necessary component for behavior change (Arlinghaus & Johnston, 2018). It therefore seems like a good idea to start reducing people's sugar intake by providing them with knowledge about their sugar intake and its negative consequences. Providing education is most effective when it is focused on increasing personal awareness of why people need to change their behavior, and

also provides them with specific information on how they can change their behavior (Arlinghaus & Johnston, 2018).

Another very effective but more drastic intervention could be to implement a tax on products high in sugar. Multiple studies found that a sugar tax can decrease sugar intake and generate substantial health gains (Hangoma et al., 2020; Lee et al., 2020; Powell et al., 2013; Phulkerd et al., 2020). According to the WHO (2020), an increase of 20% on the price of sugary products can lead to a reduction in consumption of around 20%, and thus decreasing obesity and diabetes. In the Dutch population, there is a high support for the implementation of a sugar tax (Eykelenboom et al., 2020). A sugar tax could therefore be an interesting intervention to reduce the population's sugar intake.

Although body dissatisfaction was not found to be a mediator, our study did find that body dissatisfaction on itself significantly predicted depressive mood. Simbar et al. (2020) therefore advice that health policies also focus on improving the population's body image, to promote mental health. The Mental Health Foundation (2019) recommends that governments do this by regulating the commercial sector to use 'idealized' images to promote their products, or by setting up campaigns that promote diversity in body types. Such interventions were found effective in improving well-being (Guest et al., 2019).

Future studies

For future studies, we suggest performing a longitudinal study to look into the causal relationship of sugar intake and depressive feelings. It is also advised to look more into the difference between the influence of hidden and obvious sugar on depression. The results could thereby give a more precise advice to people on if and how they could perhaps change their sugar intake to improve their mood.

In these future studies, it is advised to let participants track their food intake and their depressive feelings by use of a diary, instead of using memory-based self-reports. Additionally, several technological applications have been developed to help participants record their dietary intake, like apps to record food and beverage intake (Shriver et al., 2010). This way, a more accurate assessment of participants' calory and sugar intake can be made (Marques-Vidal et al., 2011).

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Appendixes

Appendix 1. Flyer

Appendix 2. Food Frequency Questionnaire

1. How often do you eat eggs?
   How many eggs do you eat on average each time you eat eggs?
2. How often do you drink milk (e.g., Cow milk, Soy milk, Flavoured milk, etc.)?
   How much milk do you drink on average each time you drink milk?
3. How often do you eat plain yoghurt (not sweetened/fruit yoghurt)?
   How much plain yoghurt do you eat on average each time you eat plain yoghurt?
4. How often do you eat sweetened/fruit yoghurt?
   How much sweetened/fruit yoghurt do you eat on average each time you eat sweetened/fruit yoghurt?
5. How often do you drink coffee?
   How much coffee do you drink on average each time you drink coffee?
6. How often do you drink caffeinated tea?
   How much tea do you drink on average each time you drink tea?
7. How often do you drink fruit juice (fresh juice and store-bought juice)?
   How much fruit juice do you drink on average each time you drink fruit juice?
8. How often do you drink soft drink with the exception of coke (e.g., Fanta, Sprite, Dr Pepper, etc.) (**not** 'diet' or 'zero' soft drinks)?
   How much soft drink do you drink on average each time you drink soft drink?
9. How often do you drink coke (**not** 'diet', 'zero' or 'caffeine-free' coke)?
   How much coke do you drink on average each time you drink coke?
10. How often do you drink sports drink (e.g., Aquarius, Iso drink, AA drink, etc.) (**not** Energy drink)?
    How much sports drink do you drink on average each time you drink sports drink?
11. How often do you drink energy drink?
    How much energy drink do you drink on average each time you drink energy drink?
12. How often do you drink beer?
    How much beer do you drink on average each time you drink beer?
13. How often do you drink wine?
    How much wine do you drink on average each time you drink wine?
14. How often do you drink liquor (e.g., Vodka, Rum, Tequila, Whisky, Cognac, etc.)?
    How much liquor do you drink on average each time you drink liquor?
15. How often do you drink cocktails (e.g., Mojito, Margarita, Cosmopolitan, Tequila sunrise, etc.)?
    How many cocktails do you drink on average each time you drink cocktails?
16. How often do you eat potatoes (e.g., Boiled potato, Baked potato, Sweet potato, etc.) (**not** Fried potatoes)?
    How many potatoes do you eat on average each time you eat potatoes?
17. How often do you eat rice?
    How much rice do you eat on average each time you eat rice?
18. How often do you eat fries?
    How many fries do you eat on average each time you eat fries?
19. How often do you eat bread?
    How much bread do you eat on average each time you eat bread?
20. How often do you eat jam or honey on your bread?
    How much jam or honey do you eat on average each time you eat jam or honey?
21. How often do you eat cheese?
    How much cheese do you eat on average each time you eat cheese?

22. How often do you eat lunch meats/cold cuts (e.g., Ham, Sausage, Salami, Turkey, etc.)?
    How much lunch meats/cold cuts do you eat on average each time you eat lunch meats/cold cuts?
23. How often do you eat pasta or noodles?
    How much pasta do you eat on average each time you eat pasta?
24. How often do you eat pizza?
    How much pizza do you eat on average each time you eat pizza?
25. How often do you eat a cracker or rice cake?
    How many crackers or rice cakes do you eat on average each time you eat crackers or rice cakes?
26. How often do you eat oatmeal/porridge?
    How much oatmeal/porridge do you eat on average each time you eat oatmeal/porridge?
27. How often do you eat cereal?
    How much cereal do you eat on average each time you eat cereal?
28. How often do you eat wraps/tortillas?
    How many wraps/tortillas do you eat on average each time you eat wraps/tortillas?
29. How often do you eat white meat like chicken or turkey (**not** goose or duck)?
    How much chicken or turkey do you eat on average each time you eat chicken or turkey?
30. How often do you eat white meat like duck or goose (**not** chicken or turkey)?
    How much duck or goose do you eat on average each time you eat duck or goose?
31. How often do you eat red meat like beef, pork, lamb or mutton?
    How much red meat do you eat on average each time you eat red meat?
32. How often do you eat tofu, tempeh, or meat replacements?
    How much tofu, tempeh, or meat replacements do you eat on average each time you eat tofu, tempeh, or meat replacements?
33. How often do you eat oily fish (e.g., Salmon, Mackerel, Sardines, etc.)?
    How much oily fish do you eat on average each time you eat oily fish?
34. How often do you eat whitefish (e.g., Cod, Haddock, Pollock, etc.) or shellfish (e.g. Shrimp, Oysters, Lobster, etc.)?
    How much whitefish or shellfish do you eat on average each time you eat whitefish or shellfish?
35. How often do you eat legumes?
    How many legumes do you eat on average each time you eat legumes?
36. How often do you eat vegetables?
    How many vegetables do you eat on average each time you eat vegetables?
37. How often do you eat fresh fruit?
    How much fresh fruit do you eat on average each time you eat fresh fruit?
38. How often do you eat canned fruit?
    How much canned fruit do you eat on average each time you eat canned fruit?
39. How often do you eat dried fruit?
    How much dried fruit do you eat on average each time you eat dried fruit?
40. How often do you use oil while cooking (e.g., Olive oil, Palm oil, Coconut oil, etc.)?
    How much oil do you use on average each time you use oil?
41. How often do you use butter?
    How much butter do you use on average each time you use butter?
42. How often do you use sugar, honey or syrup?

How much sugar, honey or syrup do you use on average each time you use sugar, honey or syrup?

43. How often do you eat nuts?
    How many nuts do you eat on average each time you eat nuts?
44. How often do you eat peanuts or peanut butter?
    How many peanuts or how much peanut butter do you eat on average each time you eat peanuts or peanut butter?
45. How often do you eat crisps?
    How many crisps do you eat on average each time you eat crisps?
46. How often do you eat chocolate or chocolate spread?
    How much chocolate or chocolate spread do you eat on average each time you eat chocolate or chocolate spread?
47. How often do you eat cookies?
    How many cookies do you eat on average each time you eat cookies?
48. How often do you eat bakery wares (e.g., Cake, Muffins, Brownies, Donuts, Waffles, etc.)?
    How many bakery wares do you eat on average each time you eat bakery wares?
49. How often do you eat granola bars?
    How many granola bars do you eat on average each time you eat granola bars?
50. How often do you eat ice cream?
    How much ice cream do you eat on average each time you eat ice cream?
51. How often do you eat candy (e.g., Gummies, Lollipops, Hard candies, Toffee, etc.)?
    How much candy do you eat on average each time you eat candy?

Appendix 3. Descriptives

Descriptive statics of the variables in the model

Covariates	n(%)	M(SD)
Gender		
Female	207(70,9)	
Male	84(28,8)	
Other	1(0,3)	
Age		31,88(13,31)
Country currently living		
The Netherlands	140(47,9)	
Germany	35(12,0)	
China	109(37,3)	
Austria	1(0,3)	
Sweden	2(0,7)	
Ireland	2(0,7)	
Lesotho	1(0,3)	
Spain	1(0,3)	
Belgium	1(0,3)	
Highest education		
Less than high school	2(0,7)	
Highschool diploma	64(21,9)	
College degree	168(57,5)	
Master's degree	56(19,2)	
Doctorate	2(0,7)	
Marital status		
Married	91(31,2)	
Divorced	13(4,5)	
Living together	19(6,5)	
In a relationship, but not living together	79(27,1)	
Single	88(30,1)	
Widow	2(0,7%)	
BMI		22,63(3,70)
Worry about Covid-19		
Very worried	21(7,2)	
Worried	120(41,1)	
Neutral	88(30,1)	
Not worried	55(18,8)	
Very much not worried	8(2,7)	
Smoking		
Never smoked	206(70,5)	
Current smoker	41(14,0)	
Former smoker	45(15,4)	
Alcohol consumption		
Yes	162(55,5)	
No	130(44,5)	
MET per day		441,68(543,86)

Duration of sleep		7,75(6,49)
Special diet		
Yes	62(21,2)	
No	229(78,4)	
Diabetes		
Yes	4(1,4)	
No	288(98,6)	
Depression		4,77(3,42)
Body dissatisfaction		16,49(6,05)
Percentage sugar in food		13,52(5,60)
Percentage hidden sugar in food		3,17(2,88)
Percentage obvious sugar in food		5,03(4,26)

Appendix 4. Regression coefficients

Total sugar

Unstandardised (B) and Standardised (β) Regression Coefficients, and Squared Semi-Partial (sr^2) for Each Predictor Variable on The Last Step of a Hierarchical Multiple Regression Predicting Depression (N = 292)

Variable	B [95% CI]	*β*	sr^2
Step 4			
Total food	-0.03 [-0.23,0.17]	-0.05	0.00
Gender			
Male	0.73 [-0.26,1.73]	0.10	0.01
Age	-0.03 [-0.07,0.01]	-0.11	0.01
Country			
Germany	2.70 [1.32,4.09]*	0.26	0.04
China	0.31 [-0.98,1.60]	0.04	0.00
Austria	1.36 [-5.08, 7.80]	0.02	0.00
Sweden	1.31 [-3.26, 5.89]	0.03	0.00
Ireland	-1.26 [-5.99, 3.47]	-0.03	0.00
Lesoto	-1.90 [-8.89, 5.09]	-0.03	0.00
Spain	0.31 [-6.48, 7.11]	0.01	0.00
Belgium	9.06 [2.50, 15.62]	0.16	0.02
Education			
Less than high school	2.66 [-2.45, 7.78]	0.07	0.00
High school	0.19 [-0.89, 1.27]	0.02	0.00
Master's degree	0.39 [-0.63, 1.41]	0.05	0.00
Doctorate	4.64 [-0.12, 9.40]	0.11	0.01
Marital status			
Divorced	-1.64 [-4.02, 0.74]	-0.10	0.01
Living together	-0.41 [-2.10, 1.29]	-0.03	0.00
Relationship	-0.41 [-1.68, 0.87]	-0.05	0.00
Single	0.48 [-0.71, 1.66]	0.06	0.00
Widow	3.43 [-1.35, 8.22]	0.08	0.01
BMI	-0.06 [-0.18, 0.06]	-0.06	0.00
Covid worry			
Very worried	0.60 [-1.18, 2.37]	0.05	0.00
Worried	-0.69 [-1.68, 0.31]	-0.10	0.01
Not worried	-0.53 [-1.68, 0.62]	-0.06	0.00
Very much not worried	-0.78 [-3.24, 1.67]	-0.04	0.00
Smoking			
Current smoker	1.07 [-0.14, 2.29]	0.11	0.01
Former smoker	1.11 [-0.22, 2.45]	0.12	0.01
Alcohol			
No	1.01 [-0.04, 2.07]	0.15	0.01
MET	0.00 [-0.00, 0.00]	-0.07	0.00
Duration of sleep	-0.04 [-0.10, 0.02]	-0.08	0.01
Special diet			

Yes	-0.60 [-1.62, 0.41]	-0.07	0.00
Diabetes			
Yes	0.98 [-3.06, 5.01]	0.03	0.00
Body dissatisfaction	0.18 [0.10, 0.35]	0.32	0.01
Total sugar X body dissatisfaction	0.00 [-0.01, 0.01]	0.00	0.00

Note. CI = confidence interval.
* p < .001

Hidden sugar

Unstandardised (B) and Standardised (β) Regression Coefficients, and Squared Semi-Partial (sr^2) for Each Predictor Variable on The Last Step of a Hierarchical Multiple Regression Predicting Depression (N = 292)

Variable	B [95% CI]	*β*	sr^2
Step 4			
Hidden sugar	0.26 [-0.17,0.71]	0.22	0.00
Gender			
Male	0.74 [-0.25,1.72]	0.10	0.01
Age	-0.03 [-0.07,0.01]	-0.13	0.01
Country			
Germany	2.67 [1.31,4.02]*	0.25	0.04
China	0.34 [-0.96,1.64]	0.05	0.00
Austria	1.44 [-4.97, 7.86]	0.03	0.00
Sweden	1.60 [-2.98, 6.18]	0.04	0.00
Ireland	-1.32 [-6.03, 3.40]	-0.03	0.00
Lesoto	-1.74 [-8.69, 5.22]	-0.03	0.00
Spain	0.30 [-6.49, 7.09]	0.01	0.00
Belgium	8.97 [2.43, 15.51]	0.16	0.02
Education			
Less than high school	2.54 [-2.57, 7.65]	0.06	0.00
High school	0.01 [-1.08, 1.11]	0.00	0.00
Master's degree	0.37 [-0.65, 1.38]	0.04	0.00
Doctorate	4.59 [-0.16, 9.34]	0.11	0.01
Marital status			
Divorced	-1.66 [-4.03, 0.71]	-0.10	0.01
Living together	-0.37 [-2.06, 1.32]	-0.03	0.00
Relationship	-0.37 [-1.65, 0.91]	-0.05	0.00
Single	0.44 [-0.76, 1.62]	0.06	0.00
Widow	3.41 [-1.40, 8.21]	0.08	0.01
BMI	-0.06 [-0.18, 0.07]	-0.06	0.00
Covid worry			
Very worried	0.69 [-1.07, 2.45]	0.05	0.00
Worried	-0.77 [-1.76, 0.22]	-0.11	0.01
Not worried	-0.55 [-1.69, 0.59]	-0.06	0.00

Very much not worried	-0.60 [-3.06, 1.85]	-0.03	0.00
Smoking			
Current smoker	1.15 [-0.06, 2.36]	0.12	0.01
Former smoker	1.13 [-0.19, 2.45]	0.12	0.01
Alcohol			
No	1.06 [0.00, 2.11]	0.15	0.01
MET	0.00 [-0.00, 0.00]	-0.07	0.00
Duration of sleep	-0.05 [-0.10, 0.01]	-0.09	0.01
Special diet			
Yes	-0.66 [-1.68, 0.41]	-0.08	0.00
Diabetes			
Yes	1.01 [-3.02, 5.04]	0.03	0.00
Body dissatisfaction	0.23 [0.13, 0.33]*	0.41	0.06
Hidden sugar X body dissatisfaction	-0.02 [-0.04, 0.01]	-0.26	0.00

Note. CI = confidence interval.
* p < .001

Obvious sugar

Unstandardised (B) and Standardised (β) Regression Coefficients, and Squared Semi-Partial (sr^2) for Each Predictor Variable on The Last Step of a Hierarchical Multiple Regression Predicting Depression (N = 292)

Variable	B [95% CI]	*β*	sr^2
Step 4			
Obvious sugar	0.02 [-0.22,0.26]	0.03	0.00
Gender			
Male	0.78 [-0.20,1.76]	0.10	0.01
Age	-0.03 [-0.07,0.01]	-0.12	0.01
Country			
Germany	2.50 [1.10,3.90]*	0.24	0.04
China	0.37 [-0.94,1.68]	0.00	0.00
Austria	1.47 [-4.97, 7.91]	0.03	0.00
Sweden	1.23 [-3.34, 5.81]	0.03	0.00
Ireland	-1.39 [-6.12, 3.35]	-0.03	0.00
Lesoto	-1.57 [-8.61, 5.48]	-0.03	0.00
Spain	0.48 [-6.32, 7.28]	0.01	0.00
Belgium	9.25 [2.69, 15.81]	0.16	0.02
Education			
Less than high school	2.73 [-2.38, 7.85]	0.07	0.00
High school	0.16 [-0.92, 1.24]	0.02	0.00
Master's degree	0.38 [-0.63, 1.40]	0.05	0.00
Doctorate	4.54 [-0.23, 9.30]	0.11	0.01
Marital status			
Divorced	-1.59[-3.97, 0.79]	-0.10	0.01

Living together	-0.29 [-2.01, 1.42]	-0.02	0.00
Relationship	-0.40 [-1.67, 0.88]	-0.05	0.00
Single	0.53 [-0.66, 1.72]	0.07	0.00
Widow	3.55 [-1.25, 8.36]	0.09	0.01
BMI	-0.06 [-0.18, 0.06]	-0.06	0.00
Covid worry			
Very worried	0.43 [-1.30, 2.15]	0.03	0.00
Worried	-0.70 [-1.69, 0.29]	-0.10	0.01
Not worried	-0.48 [-1.63, 0.67]	-0.06	0.00
Very much not worried	-0.72 [-3.18, 1.74]	-0.04	0.00
Smoking			
Current smoker	1.09 [-0.12, 2.30]	0.11	0.01
Former smoker	1.07 [-0.29, 2.42]	0.11	0.01
Alcohol			
No	1.00 [-0.06, 2.06]	0.15	0.01
MET	0.00 [-0.00, 0.00]	-0.08	0.00
Duration of sleep	-0.05 [-0.10, 0.01]	-0.09	0.01
Special diet			
Yes	-0.58 [-1.59, 0.44]	-0.07	0.00
Diabetes			
Yes	0.95 [-3.08, 4.99]	0.03	0.00
Body dissatisfaction	0.18 [0.07, 0.28]*	0.31	0.03
Obvious sugar X body dissatisfaction	0.00 [-0.01, 0.01]	0.02	0.00

Note. CI = confidence interval.
* $p < .001$