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Short Communication

Food addiction is strongly associated with type 2 diabetes

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A R T I C L E   I N F O

S U M M A R Y

Background & aims: Individuals can develop an addiction-like attraction towards highly processed foods, which has led to the conceptualization of food addiction, a phenotype linked to obesity. In this study, we investigated whether food addiction is associated with type 2 diabetes (T2D).
Methods: 1699 adults from the general population and 1394 adults from a population with clinically verified mental disorder completed a cross-sectional survey including the Yale Food Addiction Scale 2.0. Logistic regression was employed to examine the association between food addiction and T2D, the latter operationalized via Danish registers.
Results: Food addiction was strongly associated with T2D in the general population (adjusted odds ratio (AOR) = 6.7) and among individuals with mental disorder (AOR = 2.4) in a dose—response-like manner.
Conclusion: This is the first study to demonstrate a positive association between food addiction and T2D in a general population sample. Food addiction may be a promising target for prevention of T2D.
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1. Introduction

Exposure to highly processed foods can result in addictive-like eating [1,2]. This has led to the conceptualization of food addiction based on the DSM-5 criteria for substance use disorders, including continued intake of highly processed foods despite negative physical, mental, and social consequences; tolerance; and persistent unsuccessful attempts to cut down on food intake.

Food addiction is closely linked to obesity [2], which is an established risk factor for type 2 diabetes (T2D) [3]. This has led to studies showing food addiction to be prevalent among individuals with T2D [4—6]. However, the association between food addiction and T2D at the level of the general population remains to be established. Moreover, food addiction [7] as well as T2D [8] are known as prevalent comorbidities to mental disorders. Yet, studies

investigating the link between food addiction and T2D in this high-risk group are absent from the literature. Therefore, in this study, we investigated whether food addiction is associated with T2D (i) among adults from a general population, and (ii) in a population of adults with clinically verified mental disorder.

2. Materials & methods

The study is based on data from the Food Addiction Denmark (FADK) Project, a combined survey and register-based study carried out in Denmark in 2018 [9]. Specifically, a random sample of 5000 individuals aged 18—62 years was drawn from the Danish Civil Registration System [10], and 5000 individuals in the same age group were drawn from the Danish Psychiatric Central Research Register (DPCRR) [11]. In the latter sample, n = 625 individuals were randomly drawn from the following eight diagnostic categories according to the International Classification of Diseases 10th Revision (ICD-10): substance use disorders (F10—F19), psychotic disorders (F20—F29), affective disorders (F30—F33), anxiety and stress-related disorders (F40—F42, F43.1), eating disorders (F50),

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personality disorders (F60—F62.1), autism spectrum disorders (F84.0, F84.1, F84.5, F84.8) and attention-deficit/hyperactivity disorders (ADD/ADHD) (F90.0, F90.1, F90.8, F98.8). Only individuals registered in the DPCRR in the period from January 2013 through January 2018 were eligible for extraction in the latter sample. Moreover, having a valid Danish postal address and being born in Denmark was required to be eligible for extraction in both samples. The extraction was carried out by Statistics Denmark. Invitations to survey participation were sent to both samples via a secure electronic mail system used by the Danish public authorities (e-Boks). The invitation contained a personal link to a web-based questionnaire covering a number of self-reported rating scales, including the Yale Food Addiction Scale 2.0 (YFAS 2.0), a widely used measure of food addiction [1]. For further details on the FADK project, see Horsager et al., 2019 [9]. The YFAS 2.0 is a self-reported rating scale consisting of 35 items. The response can be interpreted either categorically (no, mild, moderate, or severe food addiction — in this study we combined the three latter categories into one food addiction group) or numerically discrete (a total food addiction symptom score ranging from 0 to 11). The YFAS 2.0 has consistently shown good psychometric properties across different settings and populations [1,2].

T2D was defined as either being registered with a hospital admission code with a primary ICD-10 diagnosis of E11 or E14 in the Danish National Patient Register in the period from 1994 to 2017 [12] or as having filled at least two prescriptions for an antidiabetic drug excl. insulin (Anatomical Therapeutic Chemical (ATC) code A10B), as registered in the Danish National Prescription Register, in the six months prior to the survey.

We used logistic regression to evaluate the association between food addiction (categorically and numerically, respectively) and T2D (yes/no) in both populations. In the population with mental disorder, we also ran stratified analyses in the eight diagnostic categories listed above. Both crude and adjusted (i) for sex and age, and (ii) for sex, age and self-reported BMI (calculated based on self-reported weight and height available from the survey data: weight/height^2 (kg/m^2)), respectively) odds ratios (OR) were computed. The covariates were chosen a priory. As BMI/obesity is a likely mediator in the hypothesized causal relationship between food addiction and T2D, the BMI-unadjusted OR are likely more representative of the "true" strength of the association between food addiction and T2D, while the difference between the BMI-unadjusted and BMI-adjusted OR will give an idea about the role BMI/obesity is playing in this association.

The survey data and data from the Danish registers were de-identified by Statistics Denmark. The use of data from the registers was approved by Statistics Denmark and the Danish Health Data Authority. The project was registered with record number 2008-58-0028 at the Danish Data Protection Agency. The invitees were informed that survey participation was voluntary and that their consent to participate could be withdrawn at any time.

3. Results

There were 1699 respondents from the general population sample (response rate of 34.0% - results of an extensive attrition analysis are published elsewhere [13]). Their mean age was 43.4 years, and 58.7% were female (see Table 1). Among these respondents, a total of 153 (9.0%) met the criteria for food addiction, and 52 (3.1%) had T2D according to the operationalization used in the present study. The crude OR for the association between food addiction and T2D was 4.9 (95% CI: 2.7; 9.1, p < 0.001), the sex- and

age-adjusted OR was 6.7 (95% CI: 3.5; 12.8, p < 0.001), and the sex-, age- and BMI-adjusted OR was 5.6 (95% CI: 2.7; 11.5, p < 0.001). In the dose—response-like model in which the association between the food addiction symptom score and T2D was examined, we found a crude OR of 1.2 (95%CI: 1.1; 1.4, p < 0.001) per point on the YFAS 2.0, an age- and sex-adjusted OR of 1.3 (95%CI: 1.2; 1.4, p < 0.001), and an age-, sex- and BMI-adjusted OR of 1.3 (95%CI: 1.1; 1.4, p < 0.001).

There were 1394 respondents from the sample of individuals with mental disorder (response rate of 27.9% - results of an extensive attrition analysis are published elsewhere [7]). Their mean age was 33.5 years and 66.6% were female. Among these respondents, a total of 369 (26.5%) fulfilled the criteria for food addiction, and 58 (4.1%) had T2D according to the operationalization used in the present study. For the association between food addiction and T2D, the crude OR was 2.4 (95% CI: 1.4; 4.0, p = 0.002), the age- and sex-adjusted OR was 2.4 (95% CI: 1.4; 4.2, p = 0.002), and the sex-, age- and BMI-adjusted OR was 1.8 (95% CI: 1.0; 3.5, p = 0.061). In the dose—response-like model, the crude OR was 1.2 (95% CI: 1.1; 1.2, p < 0.001) per point on the YFAS 2.0, the age- and sex-adjusted OR was 1.1 (95% CI: 1.1; 1.2, p < 0.001), and finally the age-, sex- and BMI-adjusted OR was 1.1 (95%CI: 1.0; 1.2, p = 0.034). The analyses stratified on the eight diagnostic categories (see Table 2) showed that all associations were positive, but not statistically significant (with the exception of the age- and sex-adjusted OR for anxiety of 4.9 (95% CI: 1.1; 22.8, p = 0.041), due to the small strata (a limitation of this study).

4. Discussion

This study is the first to demonstrate that there is a strong and intuitively meaningful positive association between food addiction and T2D, both in a sample from the adult general population and in a sample of adults with clinically verified mental disorder. Furthermore, in both samples, a dose—response-like relationship was found between the food addiction symptom score and the risk of T2D. As expected, the strength of the positive association between food addiction and T2D was somewhat attenuated following adjustment for BMI, suggesting that BMI/obesity may be a causal link in the association, but not the only one.

On the basis of the well-known association between mental disorder, obesity and T2D [8], it may seem surprising that the association between food addiction and T2D in individuals with mental disorder was found to be less strong than that observed for the general population sample. However, this is likely a consequence of a ceiling effect as food addiction "competes" with other risk factors for T2D that are common among individuals with mental disorder, such as sedentary lifestyle and use of psychotropic medication, making food addiction a *relatively* weaker risk factor for T2D in this specific population when compared with the general population. The higher prevalence of T2D observed in the population with mental disorder, despite it being almost 10 years younger, compared with that in the general population (4.1% vs. 3.1%), lends indirect support to this explanation.

The strong positive association between food addiction and T2D aligns well with studies finding food addiction to be prevalent in individuals with T2D [4—6]. When these two conditions co-occur, they are associated with higher BMI, T2D-related complications, and several psychological/psychiatric symptoms (depression, anxiety and reduced wellbeing) [5,6]. When taken together with the findings of the present study, this suggests that there should be awareness of both the risk of T2D in individuals with food addiction

Table 1
The association between food addiction and Type 2 Diabetes (T2D). Demographic characteristics of the general population and the population with mental disorder.

	General population	Population with mental disorder	P-value for comparison between groups[a]
Response rate (%)	1699 (34.0)	1394 (27.9)	–
Age (years)[b]			
Mean (SD)	43.5 (12.8)	33.5 (12.6)	<0.001
BMI			
Median (IQR)	24.9 (5.2)	24.5 (7.9)	0.296
Female sex (%)[b]	997 (58.7)	929 (66.6)	<0.001
Marital status (%)[b]			
Married or cohabiting	1210 (71.2)	629 (45.2)	
Single	489 (28.8)	764 (54.9)	
			<0.001
Educational level (%)[c]			
Lower secondary school	297 (17.5)	588 (42.2)	
Upper secondary school	199 (11.7)	236 (16.9)	
Vocational or short-cycle higher education	612 (36.0)	304 (21.8)	
Medium-cycle higher education including bachelor	376 (22.1)	191 (13.7)	
Long-cycle higher education	212 (12.5)	71 (5.1)	
Missing (n = 7)			
			<0.001
Occupation status (%)[d]			
In the labor force	1290 (75.9)	377 (27.0)	
Unemployment, sick pay, leave of absence	42 (2.5)	51 (3.7)	
Disability pension, social security benefit	121 (7.1)	504 (36.2)	
Enrolled in education	210 (12.4)	366 (26.3)	
Missing	36 (2.1)	96 (6.9)	
			<0.001
Personal income (%)[e]			
Quintiles			
< 21,906 euro	299 (17.6)	650 (46.6)	
21,906 euro − 38,145 euro	283 (16.7)	480 (34.4)	
38,146 euro − 48,914 euro	338 (19.9)	139 (10.0)	
48,915 euro − 63,329 euro	376 (22.1)	80 (5.7)	
>63,329 euro	401 (23.6)	44 (3.2)	
			<0.001
Degree of urbanization (%)[f]			
Densely populated	537 (31.6)	456 (32.7)	
Intermediate populated, largest town with ≥40,000 inhabitants	281 (16.5)	231 (16.6)	
Intermediate populated, largest town with <40,000 inhabitants	300 (17.7)	234 (16.8)	
Intermediate populated, largest town with <15,000 inhabitants	37 (2.2)	32 (2.3)	
Thinly populated, largest town with ≥15,000 inhabitants	205 (12.1)	187 (13.4)	
Thinly populated, largest town with <15,000 inhabitants	339 (20.0)	254 (18.2)	
			0.704
Region of residence (%)[b]			
Capital	483 (28.4)	416 (29.9)	
Central Jutland	409 (24.1)	365 (26.2)	
Northern Jutland	204 (12.0)	153 (11.0)	
Zealand	250 (14.7)	169 (12.1)	
Southern Denmark	353 (20.8)	290 (20.8)	
			0.173

[a] P-values from Chi^2 tests except for the comparison of age where the two-sample t-test was used and the comparison of BMI where the nonparametric Mann–Whitney test was used with medians and interquartile range (IQR) reported.
[b] Obtained from the Danish Civil Registration System.
[c] Obtained from the Register on Personal Level of Education. Medium-cycle higher education including bachelor degrees refers to, e.g., nurses, teachers, physiotherapists, and midwifes. Long-cycle higher education refers to master level and PhD degrees obtained at universities.
[d] Obtained from the Registers on Personal Labor Market Affiliation.
[e] Obtained from the Income Statistics Register.
[f] Based on EUROSTAT's DEGURBA categorization (https://www.dst.dk/en/Statistik/dokumentation/nomenklaturer/urbaniseringsgrad–degurba−−danmarks-statistik).

and the potential presence of food addiction among individuals with established T2D.

Having established a strong association between food addition and T2D, the logical next step is to investigate whether this association represents a causal chain going from food addiction to T2D, likely with substantial mediation via overweight and outright obesity [1,3]. Unfortunately, due to its cross-sectional assessment of food addiction, the present analysis is not very informative with regard to causal inference. Furthermore and relatedly, potential

selection- and response biases may have affected the survey part of the study providing data for this analysis. The ideal method to more firmly establish whether the association between food addiction and T2D is causal, and, if so, the direction of this causality, is so-called Mendelian randomization, which is based on data from genome-wide association studies (GWAS). However, unlike the very large GWAS of T2D [14], the only available GWAS of food addiction [15] is too small to allow for Mendelian randomization analysis, but the future will likely change this.

Table 2
The association between food addiction and Type 2 Diabetes (T2D).

General population (N = 1699)	Odds ratio	SE	z-value	95% CI	P-value
Food addiction (y/n) crude	4.9	1.54	5.07	2.7; 9.1	<0.001
Food addiction adjusted for sex and age	6.7	2.21	5.70	3.5; 12.8	<0.001
Food addiction adjusted for sex, age & BMI (N = 1506)	5.6	2.06	5.25	2.7; 11.5	<0.001
YFAS 2.0 symptom score (per point) crude	1.2	0.06	4.72	1.1; 1.4	<0.001
YFAS 2.0 symptom score (per point) adjusted for sex and age	1.3	0.06	5.39	1.2; 1.4	<0.001
YFAS 2.0 symptom score (per point) adjusted for sex, age & BMI (N = 1506)	1.3	0.07	4.25	1.1; 1.4	<0.001
Population with mental disorder (N = 1394)					
Food addiction (y/n) crude	2.4	0.64	3.15	1.4; 4.0	0.002
Food addiction adjusted for sex and age	2.4	0.67	3.12	1.4; 4.2	0.002
Food addiction adjusted for sex, age & BMI (N = 1157)	1.8	0.60	1.87	1.0; 3.5	0.061
YFAS 2.0 symptom score crude	1.2	0.04	3.99	1.1; 1.2	<0.001
YFAS 2.0 symptom score adjusted for sex and age	1.1	0.04	3.85	1.1; 1.2	<0.001
YFAS 2.0 symptom score (per point) adjusted for sex, age & BMI (N = 1157)	1.1	0.05	2.13	1.0; 1.2	0.034
Diagnostic categories of mental disorders					
Substance use disorders (F10) (N = 110)[a]	–	–	–	–	–
Psychotic disorders (F20) (N = 150)					
Food addiction (y/n) crude	2.3	1.35	1.48	0.8; 7.2	0.140
Food addiction adjusted for sex and age	1.8	1.10	0.94	0.5; 6.0	0.347
Food addiction adjusted for sex, age & BMI (N = 127)	1.3	1.00	0.36	0.3; 5.9	0.715
Affective disorders (F30) (N = 193)					
Food addiction (y/n) crude	1.6	1.18	0.61	0.4; 6.8	0.543
Food addiction adjusted for sex and age	1.6	1.18	0.59	0.4; 6.8	0.555
Food addiction adjusted for sex, age & BMI (N = 170)	0.5	0.48	−0.69	0.1; 4.3	0.488
Anxiety disorders (F40) (N = 186)					
Food addiction (y/n) crude	3.5	2.52	1.70	0.8; 14.4	0.090
Food addiction adjusted for sex and age	4.9	3.85	2.05	1.1; 22.8	0.041
Food addiction adjusted for sex, age & BMI (N = 149)	6.0	6.20	1.73	0.8; 45.6	0.084
Eating disorders (F50) (N = 239)					
Food addiction (y/n) crude	3.1	2.61	1.33	0.6; 16.2	0.185
Food addiction adjusted for sex and age	2.8	2.40	1.19	0.5; 15.0	0.232
Food addiction adjusted for sex, age & BMI (N = 199)	4.6	5.21	1.34	0.5; 42.5	0.179
Personality disorders (F60) (N = 175)					
Food addiction (y/n) crude	2.1	1.22	1.27	0.7; 6.6	0.204
Food addiction adjusted for sex and age	2.2	1.31	1.32	0.7; 7.1	0.188
Food addiction adjusted for sex, age & BMI (N = 148)	0.8	0.64	−0.28	0.2; 3.8	0.782
Autism spectrum disorders (F84) (N = 137)[a]	–	–	–	–	–
Attention deficit disorders (F90) (N = 137)					
Food addiction (y/n) crude	2.7	3.36	0.79	0.2; 31.0	0.428
Food addiction adjusted for age	–	–	–	–	–
Food addiction adjusted for sex, age & BMI	–	–	–	–	–

[a] The model was violated as too few individuals had both exposure (food addiction) and outcome (T2D).

5. Conclusion

This study is the first to show that there is a strong, positive association between food addiction and T2D, both in a sample from the adult general population and in a sample of adults with clinically verified mental disorder. Future studies should address which role sedentary lifestyle and use of psychotropic medication plays in the association between mental disorder, food addiction and T2D. If further studies support that food addiction causes T2D, treating food addiction would be a promising avenue for prevention of T2D.

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Author contributions

The study was designed by CH, MBL and SDØ. The data were analyzed by CH and EF. The results were interpreted by CH, JMB, SH, MBL and SDØ. The manuscript was drafted by CH and SDØ, and revised critically for important intellectual content by JMB, EF, SH and MBL. The final version of the manuscript was approved by all authors prior to submission.

Data availability

In accordance with Danish legislation, the original (individual-level) data cannot be shared due to its personal sensitive nature.

Conflicts of interest

SDØ received the 2020 Lundbeck Foundation Young Investigator Prize. Furthermore, SDØ owns/has owned units of mutual funds with stock tickers DKIGI, IAIMWC, SPIC25KL and WEKAFKI, and has owned units of exchange traded funds with stock tickers BATE,

TRET, QDV5, QDVH, QDVE, SADM, IQQH, USPY, EXH2, 2B76 and EUNL.

The remaining authors declare no conflicts of interest.

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