# Detection thresholds for four different fatty stimuli are associated with increased dietary intake of processed high-caloric food

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# Abstract

BMI-specific differences in food choice and energy intake have been suggested to modulate taste perception. However, associations between body composition and fat taste sensitivity are controversial. The objective of this study was to examine the association between body composition, dietary intake and detection thresholds of four fatty stimuli (oleic acid, paraffin oil, canola oil, and canola oil spiked with oleic acid) that could be perceived via gustatory and/or textural cues. In 30 participants, fat detection thresholds were determined in a repeated measurements design over twelve days. Weight status was examined by measuring the participants’ BMI, waist circumference and waist-to-hip ratio. To evaluate differences in fat taste sensitivity due to BMI, participants were sub-classified into two groups (BMI <25kg/m2 and BMI ≥25kg/m2). The habitual food intake was assessed via several questionnaires and twelve, non-consecutive 24-hour food diaries. In this study, a negative correlation was found between fat detection thresholds and the intake of food rich in vitamins and fibre. Moreover, a positive correlation was identified between the intake of processed, high-fat food and fat detection thresholds. No differences in fat detection thresholds were observed due to variations in weight status or waist-to-hip ratio. These findings indicate that a regular intake of fatty foods might decrease an individuals’ perceptual response to fats which might lead to excess fat intake on the long term.

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Keywords: Fat taste, Fat perception, BMI, diet. [[1]](#footnote-1)

# 1. Introduction

Dietary fat is known to be a flavor carrier, to positively affect the texture of food and to increase the palatability and consumption of a meal (Drewnowski, 1997; Wolfram et al., 2015). However, without control of total energy intake, an elevated intake of the energy-dense dietary fat may increase the risk for the development of overweightness and obesity. Generally, the fat content of food is noticed through textural attributes such as creaminess and viscosity (Rolls, 2015; Sonne, Busch-Stockfisch, Weiss, & Hinrichs, 2014). However, several studies have shown that free fatty acids (FFAs) can be tasted in the oral cavity when visual, olfactory and textural cues are masked (Chale-Rush, Burgess, & Mattes, 2007; Mattes, 2009a, 2009b; J. Stewart, L. P. Newman, & R. S. Keast, 2011; Stewart et al., 2010). FFAs are the digestive break-down product of triacylglycerols (TAGs) that can be hydrolysed by human lipases and can interact with receptors located on taste buds, thereby evoking a pungent, rancid taste in the mouth to prevent the consumption of spoiled foods. Humans have been found to differ intra- and inter-individually in their sensitivity for these FFAs which can be affected by various factors (Heinze, Preissl, Fritsche, & Frank, 2015; Running, Mattes, & Tucker, 2013). The discussion on the association between BMI and fat sensitivity is currently controversial. While some studies observed increased fat detection thresholds (less sensitivity for low concentrations) in participants with increased BMI (Daoudi et al., 2015; Sayed et al., 2015; Stewart et al., 2010; Stewart & Keast, 2012; J. E. Stewart, L. P. Newman, & R. S. Keast, 2011; J. E. Stewart, R. V. Seimon, et al., 2011; R. M. Tucker, Edlinger, Craig, & Mattes, 2014), other studies did not find BMI-specific differences in their study populations (Alexy et al., 2011; Alexy et al., 2010; Chevrot et al., 2014; Mattes, 2011; R. M. Tucker, Laguna, L., Quinn, R., Mattes, R.D., 2013). A recent meta-analysis did not indicate that BMI was significantly associated with fat taste sensitivity (R. M. Tucker et al., 2017).

Apart from the BMI, it was observed that the fat content in the diet could affect fat detection thresholds. Study participants that were able to detect lower concentrations of the FFA oleic acid consumed significantly lower amounts of energy and fat compared to participants that were less sensitive for oleic acid (Stewart et al., 2010; J. E. Stewart, L. P. Newman, et al., 2011). Furthermore, it was shown that dietary changes could also have an impact on fat sensitivity. Several studies have shown that reducing the fat content in the diet resulted in improved fat sensitivity (Mattes, 1993; L. P. Newman, Bolhuis, Torres, & Keast, 2016; Stewart & Keast, 2012). However, BMI-specific differences on the effects of dietary changes were observed. A low-fat diet over four weeks resulted in significantly lower oleic acid detection thresholds compared to baseline measurements in normal weight, overweight, and obese participants. In contrast, compared to baseline, a four week high-fat diet led to increased detection thresholds in lean participants but no significant differences in overweight and obese participants (Stewart & Keast, 2012). Therefore, it was assumed that overweight and obese participants may have already adapted to a high-fat exposure in their habitual diet (Stewart & Keast, 2012).

A recent review by Cox et al. (2016) investigated whether normal and overweight/obese individuals differ in their sensitivity, hedonics and preference for basic tastes and fatty foods. They reported that decreased sensitivity and increased preference and liking for fat was associated with increased BMI. Nonetheless, a demand for future studies examining different adiposity measurements, the actual dietary intake and taste sensitivity and perception was acknowledged. The aim of the current study was to assess associations between body composition, food intake and perceptual recognition for four fatty stimuli. These four stimuli (oleic acid (a FFA), paraffin oil (mixture of hydrocarbons), canola oil (TAG-rich) and canola oil spiked with oleic acid (rich in TAGs and FFAs)) differ in their chemical composition and can be perceived orally via gustatory or textural cues. To investigate associations between body composition and perceptual recognition of fats, anthropometric measurements (BMI, waist and hip circumference, waist-to-hip-ratio (WHR)) were determined to refer to an individuals’ weight and visceral fat status. According to their BMI, participants were classified into two groups: one group included healthy weight participants with a BMI <25.0kg/m2, and due to the small number of overweight and obese participants enrolled in the current study, these participants were merged to form a group with a BMI ≥25.0kg/m2. It was hypothesized that participants with lower BMI and WHR would consume less fat in their habitual diet and have increased perceptual recognition (lower detection threshold) than participants with higher BMI and WHR. To study the effect of dietary behavior, participants were required to complete several eating behavior related questionnaires and to record their food intake over 24-hours on twelve non-consecutive days. It was expected that a higher fat content in the diet would be associated with an attenuated perceptual recognition of fat (higher detection thresholds).

# 2. Experimental Methods

## 2.1 Study Outline

The aim of this study was to examine whether body composition and habitual food intake were associated with the perceptual recognition of different fatty stimuli. Detection thresholds for four fatty stimuli (oleic acid, paraffin oil, canola oil, canola oil + oleic acid) were determined in three non-consecutive laboratory sessions per stimuli. Hence, participants were required to attend twelve sessions in total at the Deakin University Centre for Advanced Sensory Science. For each session, participants were required to fast overnight and to attend the laboratory at the same time in the morning for each of the twelve sessions. There was no strict time in which all sessions had to be completed. The maximum time taken to complete all sessions was ten weeks.

## 2.2 Participants

Participants with an age below 18 or above 55 years, being pregnant or lactating, suffering from lactose-intolerance or impaired smell or taste functions were excluded. The 30 participants included were recruited from Deakin University, Burwood, Victoria, Australia and provided written informed consent prior to participating in the study. The study was approved by the Deakin University Human Ethics Advisory Group (HEAG-H 89\_2016) and complied with the principles laid down in the Declaration of Helsinki.

## 2.3 Determination of fat detection thresholds

To expand the knowledge of human fat sensitivity, four fatty stimuli that could be detected via gustatory and/or textural cues were chosen. The FFA oleic acid was chosen based on an established procedure (Haryono, Sprajcer, & Keast, 2014) and to control for fat sensitivity associated with gustatory cues. Paraffin oil (mixture of hydrocarbons) was included to control for fat perception based on textural cues. Because paraffin oil does not contain FFAs nor TAGs, fatty taste sensations evoked by FFAs can be ruled out. In contrast, canola oil (TAGs-rich) can be perceived over two possible mechanisms. Firstly, it can be perceived by textural cues due to the high amount of TAGs that affect viscosity (Valeri & Meirelles, 1997) and secondly over the gustatory sensations due to the low concentration of FFAs that is naturally present in oils (1-2%) (Gunstone & Norris, 1983; Koriyama, Wongso, Watanabe, & Abe, 2002). Additionally, the amount of FFAs in canola oil can be increased by lingual lipases that hydrolyse TAGs into glycerol and FFAs (Pepino, Love-Gregory, Klein, & Abumrad, 2012; Voigt et al., 2014). Furthermore, canola oil spiked with oleic acid was included as mixed stimulus that could be perceived via gustatory and textural cues. By using increasing concentrations of canola oil spiked with a fixed amount of oleic acid (3.80mM, based on mean detection thresholds of previous studies (L. P. Newman, Keast, R.S.J., 2013; Stewart et al., 2010; Stewart & Keast, 2012)) it was expected that some participants would detect this stimulus due to gustatory sensations evoked by the addition of oleic acid, whereas other participants would refer to textural cues due to the TAG-rich canola oil.

Fat detection thresholds were determined using a 3-alternative forced choice test (3-AFC), based on the protocol of Haryono and colleagues (2014). Concentrations for oleic acid (Sigma-Aldrich Chemie GmbH, Steinheim, Germany) were also taken from this protocol, whereas the concentrations for paraffin oil (Sanofi Consumer Healthcare, Virginia, Queensland, Australia), canola oil (Coles, Hawthorn East, Victoria, Australia), and canola oil + oleic acid were based on pilot studies using 0.15 log steps with a starting point of 1.00% fat in the samples. Concentration steps 1 and 13 were extrapolated to ensure that all participants could perceive the stimuli in the milk-based samples.

*\*\*\*please include Table 1 here\*\*\**

All samples were freshly prepared on the morning of each testing day. For each of the four stimuli, a base solution containing the fat in an emulsified form was prepared by adding 5% w/v gum Arabic ((Tic Gums, Parramalta, New South Wales, Australia) to ultra-high-temperature processed non-fat milk (Devondale, Southbank, Victoria, Australia). When oleic acid or canola oil + oleic acid detection thresholds were measured, 0.01% EDTA (Titriplex ® III, Merck KGaA, Darmstadt, Germany) was added additionally to the base solution to prevent oxidation of the oleic acid. This base solution was then homogenized at 12000rpm for 30s per 100mL. Following this homogenization process, 13 beakers were filled with the respective amount of fat and filled up with base solution. For oleic acid concentrations, based on Haryono and colleagues (2014), 5% paraffin oil was added to each beaker to increase viscosity. Each of the 13 beakers was then homogenised at 12000rpm for 30s per 100mL again. Control samples were prepared in the same way but without adding oleic acid, paraffin oil, canola oil or canola oil + oleic acid, respectively.

To minimize sensory fatigue and to familiarize the participants with the fatty stimuli, a sensory training was conducted. The sensory training would start with concentration step 7 for all four stimuli, and could be followed by concentration steps 10 and 13 (Table 1), if no difference could be perceived. Concentration step 7 was chosen as starting point for the sensory training because participants that can perceive oleic acid below 3.80mM (concentration step 7) are classified as hypersensitive whereas those participants who need higher oleic acid concentrations for detection are classified as hyposensitive (Haryono et al., 2014). Participants were trained by receiving a labelled test and control sample. Both samples were tasted under red light and while wearing nose clips to avoid visual and olfactory cues. Participants were then asked whether they could perceive a difference between the test and the control sample. If a difference was perceived, the actual detection threshold was determined with a 3-alternative forced choice test. If they could not perceive a difference between the test and control sample, training continued with a higher fat concentration sample. Depending on the outcome of the sensory training, the 3-AFC would start at different concentrations to avoid sensory fatigue by exposing participants with samples below their individual fat sensitivity. If a difference at concentration step 7 was perceived, the 3-AFC would start at concentration step 1. Subsequently, a perceived difference at concentration step 10 was followed by a 3-AFC with concentration step 7 as starting point. If a difference between the labelled test and control sample was only detected at concentration step 13, the 3-AFC would start at concentration step 10. All participants were able to perceive a difference between the test and control sample in the sensory training. Within the 3-alternative forced choice test, participants were presented with a set of three samples, one test sample and two control samples, and instructed to identify “the odd one out”. Whenever they were incorrect, the fat concentration of the fatty test sample was increased. When participants identified the test sample correctly, they received another set of three samples, in which the test sample would contain the same fat concentration as in the previously correctly identified set. A detection threshold was defined as the fat concentration that was correctly identified three consecutive times among the control samples.

## 2.4 Associations between body composition and fat detection thresholds

To examine associations between an individuals’ body composition and fat detection thresholds, several anthropometric measurements were determined during the first laboratory session. A participants’ height (Seca, MedShop Australia, Fairfield, Victoria, Australia) and weight (Tanita Body Scan Composition Monitor Scales, Cloverdale West Australia, Australia) were measured to calculate the BMI. According to this BMI, participants were sub-classified into two groups. One group contained participants with a BMI <25.0kg/m2, the other those with a BMI ≥25.0kg/m2. These groups were used to examine BMI-specific differences in detection thresholds for the four stimuli. Furthermore, waist and hip circumference (Seca, MedShop Australia, Fairfield, Victoria, Australia) were collected according to the methodology of the World Health Organization (WHO, 2008). Both parameters were used to calculate the WHR as an indicator for visceral fat.

## 2.5 Associations between dietary intake and fat detection thresholds

The dietary behavior of the study participants was assessed via several questionnaires and food diaries. To assess a participants’ habitual food consumption, a Food Frequency Questionnaire (FFQ) that was adapted from the Australian National Nutrition Survey in 1995 was used (McLennan, 1999). The Dietary Guideline Index (DGI) was used to assess an individuals’ diet quality and adherence to Australian dietary guidelines (McNaughton, Ball, Crawford, & Mishra, 2008). Furthermore, participants were asked to rate their current physiological states such as hunger, satiety, and fullness on visual analogue scales (VAS) prior to the detection thresholds assessment. Data was collected using Compusense Cloud Software as part of the Compusense Academic Consortium. To examine the habitual food intake, participants were required to complete 24-hours food diaries on the day before each of the twelve laboratory sessions. Participants were asked to record the food and drinks they consumed for each meal, along with the quantity, the cooking method (e.g. fried, steamed, raw) and whether they added something to their food (e.g. sugar, salt, butter, dressing). The food diaries were analysed using FoodWorks 2015 software, version 8 (Xyris software, Highgate Hill, Australia) and the AUSNUT 2011-13 food composition data base. To examine differences between participants with higher or lower perceptual response to fat, we conducted a tertile split, subdividing the 30 study participants into ten participants per group with high, moderate or low perceptual response to fat, respectively. Analyses including the 20 participants with the highest or lowest mean detection thresholds for each stimuli revealed significant differences and associations with their dietary behavior.

## 2.6 Statistical analysis

Data was analysed using the software SPSS, version 22 (IBM®SPSS®, Armonk, NY, USA). To evaluate associations between fat detection thresholds, body composition and dietary parameters, Spearman correlations were used. Differences over repeated measurements were assessed with Friedman-Tests. To determine day-to-day differences, Wilcoxon signed rank tests were used. To assess group differences according to variations in BMI (<25.0kg/m2 or ≥25.0kg/m2) or performance in fat detection thresholds (10 participants with the lowest or highest detection thresholds) Mann-Whitney-U-Tests were performed. To assess the consistency of the fat detection thresholds over repeated measurements intraclass correlations were calculated. Significance was accepted at p-values <0.05. Values are expressed as means ± standard error of the mean (SEM).

# 3. Results

## 3.1 Baseline characteristics

Thirty-three participants were recruited to participate in this study. Three participants dropped out because of time issues. A total of 30 participants completed the study (six males, age: 29.17 ± 3.67 years (range 20-41 years), BMI: 24.14 ± 1.10kg/m2 (range 21.0-28.80kg/m2), WHR: 0.80 ± 0.02 (range 0.7-0.9), 24 females, age: 28.04 ± 1.36 years (range 18-46 years), BMI: 24.02 ± 0.91kg/m2 (range 17.5-36.7kg/m2), WHR: 0.76 ± 0.02 (range 0.6-1.0)).

## 3.2 Fat detection thresholds

Mean fat detection thresholds over all three sessions were as followed: oleic acid: 0.15 ± 0.03%, paraffin oil: 17.24 ± 2.07%, canola oil: 11.66 ± 1.75%, canola oil spiked with oleic acid: 5.57 ± 1.27% Associations within and between the detection thresholds for these four stimuli are described elsewhere (Reference of first manuscript (currently submitted at Chemical Senses)).

## 3.3 Associations between body composition and fat detection thresholds

In general, no significant associations between anthropometric measurements and detection thresholds for oleic acid, paraffin oil, canola oil, and canola oil spiked with oleic acid were found. To examine BMI-specific differences in fat detection thresholds and dietary behavior, the participants were classified into two groups, one with participants with a BMI <25kg/m2 (N=21, 4 males, age: 27.14 ± 1.19 years (range 19-40 years), BMI: 21.89 ± 0.42kg/m2 (range 17.5-24.7kg/m2), WHR: 0.74 ± 0.02 (range 0.6-0.9)) and the other with participants with a BMI ≥25.0kg/m2 (N=9, 2 males, age: 30.89 ± 3.23 years (range 18-46 years), BMI: 29.07 ± 1.15 kg/m2 (range 25.0-36.7kg/m2), WHR: 0.84 ± 0.02 (range 0.7-1.0)). The two groups did not differ in age. Concerning the three detection threshold measurements per stimuli and their mean, no significant differences between both groups on each of the three measurements were found (Table 2). However, over the course of the three measurements, it was observed that canola oil + oleic acid detection thresholds were significantly different in participants with a BMI ≥25.0kg/m2 (p=0.010) (Table 2). Detection thresholds for this stimulus were significantly decreased on the second measurement (p=0.046) and third measurement (p=0.018) compared to the first measurement. Moreover, canola oil + oleic acid detection thresholds were significantly lower on the third measurement than on the second measurement in this group (p=0.046). In contrast, no differences over repeated measurements were found in participants with a BMI <25.0kg/m2.

*\*\*\*Please include Table 2 here\*\*\**

A positive correlation between oleic acid detection thresholds and canola oil + oleic acid detection thresholds was found in participants with a BMI <25.0kg/m2 (R=0.496, p=0.022). Additionally, a trend for a positive correlation between oleic acid and paraffin oil detection thresholds was observed in this group (R=0.416, p=0.061). In contrast, no significant correlations between the average detection thresholds for oleic acid, paraffin oil, canola oil and canola oil spiked with oleic acid were found in the group with a BMI ≥25.0kg/m2. Whereas intra-class correlation coefficients (ICC) reached significance in participants with a BMI <25.0kg/m2 (oleic acid: ICC=0.494, p<0.001, paraffin oil: ICC=0.364, p=0.004, canola oil: ICC=0.336, p=0.006, canola oil + oleic acid: ICC=0.359, p=0.004), ICCs were not found to be significant in participants with a BMI ≥25.0kg/m2. Hence, it seems that participants with a BMI <25.0kg/m2 had smaller differences in their detection thresholds over repeated measurements and these thresholds resembled each other more compared to participants with a BMI ≥25.0kg/m2  who showed larger differences in fat detection thresholds.

## 3.4 Associations between dietary intake and fat detection thresholds

To evaluate associations between fat detection thresholds and dietary behavior, the detection thresholds were correlated with the outcomes of the VAS, FFQ, and DGI. As anticipated, no significant differences in the physiological state (hunger, satiety, fullness) over the twelve days was observed. Apart from these questionnaires, associations between fat detection thresholds and a participants’ habitual food intake were examined via twelve food diaries that were completed on the day before each of the twelve measurements. Over the course of twelve days, no significant variations between energy, fat, protein, carbohydrate, vitamin and mineral intake were found. Therefore, associations between the mean of the twelve food diaries and the mean of the fat detection thresholds were examined. We conducted a tertile split among our study population and only included the ten participants with the lowest and the ten participants with the highest mean detection thresholds for each stimulus in the following analyses (Table 3). Hence, we could examine whether variations in the dietary intake might explain the observed differences in oral fat perception.

*\*\*\*Please include Table 3 here\*\*\**

In general, elevated fat detection thresholds were associated with an increased intake of processed, high-fat food. Canola oil detection thresholds correlated positively with the mean frequency of consumption of savoury, high-fat food including fried fish, pizza, and hamburger (R=0.589, p=0.006) (Figure 1). It was observed that the ten most sensitive participants for canola oil consumed significantly less savoury, high-fat foods compared to the ten least sensitive participants (p=0.015). Detection thresholds for canola oil spiked with oleic acid showed the tendency to also correlate positively with the intake of savoury, high-fat food (R=0.391, p=0.088) and with the consumption of so called ‘extra’ food (R=0.413, p=0.070), defined in the DGI as food that is not essential to provide nutrients (e.g. fast food, sweet and savoury snacks, alcohol). Moreover, canola oil detection thresholds correlated positively with the average frequency of consumption of meat products (mixed dishes with beef, lamb or poultry, sausage, bacon, luncheon meats, etc.) (R=0.590, p=0.006). In line with this observation, paraffin oil detection thresholds correlated positively with the servings of processed meats (R=0.501, p=0.025). Considering the consumption of sweet, high-fat foods (e.g. ice cream, sweet pies, desserts) a positive correlation with canola oil detection thresholds was found (R=0.464, p=0.039).

*\*\*\*please include Figure 1 here\*\*\**

**Figure 1.** Association between mean canola oil detection thresholds and the frequency of consumption of savoury, high-fat food (fried fish, pizza, hamburger) per month.

In contrast, an increased intake of food rich in vitamins and fibre was associated with lower detection thresholds. With regards to the habitual food intake, the number of servings of wholegrain products (R=−0.496, p=0.026) was negatively associated with canola oil detection thresholds (Figure 2). The intake of beta carotene which can be found in many fruits and vegetables was negatively associated with detection thresholds for oleic acid (R=−0.449, p=0.047), paraffin oil (R=−0.420, 0.065), and canola oil spiked with oleic acid (R=−0.524, p=0.018).

*\*\*\*please include Figure 2 here\*\*\**

**Figure 2.** Association between mean canola oil detection thresholds and the number of wholegrain servings over the course of twelve days.

# 4. Discussion

The aim of the current study was to investigate effects of body composition and food intake on detection thresholds for oleic acid, paraffin oil, canola oil, and canola oil spiked with oleic acid. In general, no associations between body composition (assessed via parameters such as BMI and WHR) and fat detection thresholds, nor a significant difference in fat detection thresholds between participants with a BMI below or above 25.0kg/m2 were found. Concerning the habitual food consumption, associations between an increased intake of processed high-fat food and an impaired perceptual recognition of fat was found. In contrast, an elevated intake of fibre- and vitamin-rich foods was associated with increased fat sensitivity and thus lower detection thresholds.

The effect of body composition on fat sensitivity is controversial. In the current study, parameters such as BMI, waist circumference and WHR were not associated with detection thresholds for oleic acid, paraffin oil, canola oil and canola oil spiked with oleic acid. This observation is in line with previous studies (Chevrot et al., 2014; Martinez-Cordero, Malacara-Hernandez, & Martinez-Cordero, 2015; Mattes, 2011; L. P. Newman, Torres, Bolhuis, & Keast, 2016; R. Tucker, Nuessle, Garneau, & Mattes, 2015; R. M. Tucker, Laguna, L., Quinn, R., Mattes, R.D., 2013) and a recent meta-analysis (R. M. Tucker et al., 2017). In contrast, other studies found a positive association between BMI and fat detection thresholds (Daoudi et al., 2015; Sayed et al., 2015; Stewart et al., 2010; Stewart & Keast, 2012; J. E. Stewart, L. P. Newman, et al., 2011; J. E. Stewart, R. V. Seimon, et al., 2011; R. M. Tucker et al., 2014). One possible explanation for the discrepancy in the BMI-associated results could be differences in the dietary intake. In two studies, Stewart and colleagues (J. Stewart et al., 2011; Stewart et al., 2010) reported that participants that were less sensitive for oleic acid had a greater BMI but also consumed more energy, saturated fat and fatty foods compared to participants that were able to detect lower concentrations of oleic acid. In the current study no associations between BMI and fat detection thresholds were found. Similarly to the results of Stewart and colleagues, we also observed positive correlations between the intake of processed high-fat food and elevated fat detection thresholds. However, we observed that detection thresholds for canola oil spiked with oleic acid decreased significantly over the course of the three measurements in participants with a BMI ≥25.0kg/m2 but not in participants with a BMI <25.0kg/m2. This might be explained by some kind of learning effect since participants with a BMI ≥25.0kg/m2 started with higher detection threshold at the first measurement compared to participants with a BMI <25.0kg/m2 which was probably mainly driven by one participant struggling to identify this particular fat type when tested for the first time. Apart from the BMI, Fernandez-Garcia and colleagues (2017) observed negative correlations between taste function and fat mass, fat-free mass and visceral fat rating that was assessed with an impedaciometer. In general, differences in fat sensitivity are mainly found between normal weight and obese participants (Daoudi et al., 2015; Sayed et al., 2015; R. M. Tucker et al., 2014). In the current study, only two BMI-specific groups were examined. One group contained 21 normal weight participants with a BMI <25kg/m2, and the other group included overweight (N=7) and obese (N=2) participants with a BMI ≥25kg/m2. Although participants of the group with the higher BMI tended to consume more fat, no differences in detection thresholds for the four fatty stimuli were found.

A recent review revealed a lack of studies that evaluate the relationship between taste attributes and dietary intake (Cox et al., 2016). To increase the knowledge of the relationship between fat sensitivity and dietary intake, the current study assessed food intake and preferences via several questionnaires but also with multiple 24-hour food diaries. Moreover, fat sensitivity was examined by determining fat detection thresholds for different fat types that were perceivable via gustatory or textural cues. Oleic acid was expected to be perceived via gustatory pathways due to the presence of FFAs. In contrast, paraffin oil, in which neither FFAs nor TAGs are present, was detectable by textural sensations only. Canola oil, with TAGs as the predominant form of fat but also 1-2% FFAs (Gunstone & Norris, 1983; Koriyama et al., 2002), was assumed to be perceivable via gustatory and textural cues. In comparison to canola oil alone, for canola oil spiked with oleic acid a shift towards gustatory sensations was assumed. As described elsewhere, we observed that fat detection thresholds decreased with an increasing concentration of FFAs (Reference of first manuscript (currently submitted at Chemical Senses)). Examining the relationship between perceptual recognition of fat and food intake, we observed that the influence of dietary intake might be more pronounced when the fat type is perceived via textural rather than gustatory cues. Oleic acid detection thresholds were relatively unaffected by the intake of sweet or savoury high-fat food but were found to be negatively associated with the average beta carotene intake. Similar negative correlations were also found between beta carotene intake and detection thresholds for canola oil spiked with oleic acid and paraffin oil. Additionally, it was observed that the higher the intake of fibre-rich food, the lower the detection threshold for canola oil. It can be speculated whether the intake of food rich in vitamins such as beta-carotene and fibre may lead to slower gastric emptying, increased satiety, and delayed return of hunger (Benini et al., 1995; Yu, Ke, Li, Zhang, & Fang, 2014) that might decrease the consumption of processed high-fat foods as it is often found in snacks. In contrast to those negative correlations between fat detection thresholds and the intake of food rich in vitamins and fibre, we also found positive correlations with processed, sweet and savoury high-fat foods. Paraffin oil detection thresholds were associated with the consumption of processed meats and canola oil detection thresholds correlated positively with the average consumption of savoury but also sweet high-fat food. Detection thresholds for canola oil spiked with oleic acid showed a trend to be positively associated with savoury, high-fat foods and the intake of ‘extra food’ that is not essential to provide nutrients such as sweet and savoury snacks but also alcohol. In general, the results of the current study led to the assumption that the higher the intake of sweet or savoury high-fat foods, the higher the fat detection thresholds. In contrast, we suggest that with an increased intake of food rich in vitamins and fibre, fat detection thresholds are decreased.

Up to now, it is unknown whether impaired fat sensitivity is a cause of excessive weight or a predisposition for the development of obesity and overweight. In the current study, no associations between body composition and fat detection thresholds were observed. However, a diet rich in high-fat processed foods was associated with increased fat detection thresholds, whereas a diet rich in vitamins and fibre correlated with decreased fat detection thresholds. Individuals that are less sensitive for fatty food cues might be more prone to an excessive fat intake. In highly processed food, which are often rich in sugar, salt and fat, this overconsumption could be even more pronounced because the fat content was shown to be masked by other taste sensations such as salty (Bolhuis, Costanzo, Newman, & Keast, 2016) and sweet (Drewnowski, Shrager, Lipsky, Stellar, & Greenwood, 1989).

As a limitation of this study, it has to be acknowledged that the result of no significant relationship between weight status, visceral fat and detection thresholds for four different fat types is based on an uneven group size and only a small number of obese participants.

# 5. Conclusion

This study investigated associations between body composition, dietary intake and oral fat perception. In line with two recent reviews (Cox et al., 2016; R. M. Tucker et al., 2017), no significant relationship between weight status and detection thresholds for oleic acid, paraffin oil, canola oil, and canola oil spiked with oleic acid was found. Concerning dietary intake, an increased consumption of processed high-fat foods was associated with increased detection thresholds and deteriorated fat sensitivity. In contrast, an elevated intake of food rich in vitamins and fibre was associated with decreased detection thresholds and improved fat sensitivity. Subsequently, the intake of fruits, vegetables and wholemeal products might not only decrease the energy and fat intake in general, but might also increase the sensitivity for and thus prevent an overconsumption of processed high-fat food.

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**Table 1.** Fat concentrations for the four stimuli.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Oleic Acid** | | **Paraffin Oil** | | **Canola Oil** | | **Canola Oil + Oleic Acid** | |
|  | **mM** | **%** | **mM** | **%** | **mM** | **%** | **mM** | **%** |
| **1** | 0.02 | 0.001 | 5.41 | 0.30 | 9.90 | 0.30 | 9.90 + 3.80 | 0.30 + 0.119 |
| **2** | 0.06 | 0.002 | 17.88 | 1.00 | 32.69 | 1.00 | 32.69 + 3.80 | 1.00 + 0.119 |
| **3** | 1.00 | 0.032 | 25.21 | 1.41 | 46.09 | 1.41 | 46.09 + 3.80 | 1.41 + 0.119 |
| **4** | 1.40 | 0.044 | 35.76 | 2.00 | 65.37 | 2.00 | 65.37 + 3.80 | 2.00 + 0.119 |
| **5** | 2.00 | 0.063 | 50.42 | 2.82 | 92.18 | 2.82 | 92.18 + 3.80 | 2.82 + 0.119 |
| **6** | 2.80 | 0.088 | 71.15 | 3.98 | 130.10 | 3.98 | 130.10 + 3.80 | 3.98 + 0.119 |
| **7** | 3.80 | 0.119 | 100.47 | 5.62 | 183.70 | 5.62 | 183.70 + 3.80 | 5.62 + 0.119 |
| **8** | 5.00 | 0.158 | 141.95 | 7.94 | 259.54 | 7.94 | 259.54 + 3.80 | 7.94 + 0.119 |
| **9** | 6.40 | 0.202 | 200.59 | 11.22 | 366.75 | 11.22 | 366.75 + 3.80 | 11.22 + 0.119 |
| **10** | 8.00 | 0.250 | 283.37 | 15.85 | 518.10 | 15.85 | 518.10 + 3.80 | 15.85 + 0.119 |
| **11** | 9.80 | 0.309 | 400.29 | 22.39 | 731.87 | 22.39 | 731.87 + 3.80 | 22.39 + 0.119 |
| **12** | 12.00 | 0.380 | 565.30 | 31.62 | 1033.58 | 31.62 | 1033.58 + 3.80 | 31.62 + 0.119 |
| **13** | 20.00 | 0.631 | 893.90 | 50.00 | 1634.37 | 50.00 | 1634.37+ 3.80 | 50.00 + 0.119 |

**Table 2.** Fat detection thresholds for participants with a BMI<25.0kg/m2 or BMI≥25.0kg/m2.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **1st Measurement** | **2nd Measurement** | **3rd Measurement** | **Mean of all measurements** |
| **Oleic Acid (%)** | | | | |
| <25.0kg/m2 | 0.20 ± 0.05 | 0.16 ± 0.05 | 0.10 ± 0.03 | 0.16 ± 0.04 |
| ≥25.0kg/m2 | 0.16 ± 0.07 | 0.16 ± 0.07 | 0.13 ± 0.07 | 0.15 ± 0.05 |
| **Paraffin Oil (%)** | | | | |
| <25.0kg/m2 | 18.47 ± 3.90 | 20.17 ± 3.66 | 14.49 ± 3.49 | 17.71 ± 2.80 |
| ≥25.0kg/m2 | 16.24 ± 5.63 | 17.82 ± 5.52 | 14.35 ± 4.78 | 16.14 ± 2.46 |
| **Canola Oil (%)** | | | | |
| <25.0kg/m2 | 12.71 ± 2.44 | 11.30 ± 3.46 | 11.23 ± 2.57 | 11.75 ± 2.14 |
| ≥25.0kg/m2 | 14.83 ± 7.02 | 9.97 ± 3.73 | 9.60 ± 3.27 | 11.47 ± 3.22 |
| **Canola Oil + Oleic Acid (%)** | | | | |
| <25.0kg/m2 | 5.47 ± 1.52 | 5.19 ± 1.79 | 4.99 ± 2.57 | 5.22 ± 1.52 |
| ≥25.0kg/m2 | 12.27 ± 5.14a,b | 4.94 ± 2.15a,c | 1.92 ± 1.17b,c | 6.38 ± 2.44 |

No significant differences between participants with a BMI<25.0kg/m2 or ≥25.0kg/m2 were found. a Detection thresholds for canola oil + oleic acid of participants with a BMI ≥25.0kg/m2 are significantly lower on the second than the first measurement (p=0.046). b Detection thresholds for canola oil + oleic acid are significantly lower on the third compared to the first measurement (p=0.018). c Canola oil + oleic acid detection thresholds are significantly lower on the third compared to the second measurement (p=0.046). Data are shown as % of fat in the samples and depicted as mean ± SEM.

**Table 3.** Participants with the highest/lowest mean detection threshold for each stimulus

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Lowest**  **detection threshold** | **Highest**  **detection threshold** | **p-value** |
| **Oleic Acid (%)** | 0.04 ± 0.003 | 0.34 ± 0.04 | <0.001 |
| **Paraffin Oil (%)** | 7.53 ± 1.16 | 29.94 ± 3.19 | <0.001 |
| **Canola Oil (%)** | 2.32 ± 0.44 | 23.78 ± 1.36 | <0.001 |
| **Canola Oil + Oleic Acid (%)** | 0.53 ± 0.11 | 13.42 ± 2.22 | <0.001 |

The perceptual recognition of fat is significantly different between the ten participants with the highest and the ten participants with the lowest detection thresholds. Data are shown as % of fat in the samples and depicted as mean ± SEM.

1. Abbreviations: 3-AFC: 3-alternative forced choice method CanO: Canola Oil, CanOOleA: Canola Oil spiked with Oleic Acid, CD36: Cluster of differentiation 36, EDTA: Ethylenediaminetetraacetic acid, FFA: free fatty acid, FFQ: Food Frequency Questionnaire, FLDQ: Food Like-Dislike Questionnaire, GPR120: G-protein coupled receptor 120, ICC: intra-class correlation coefficient, OleA: Oleic Acid, ParO: Paraffin Oil, TAG: triacylglycerol, TFEQ: Three factor eating questionnaire, VAS: visual analogue scales, WHR: waist-to-hip ratio. [↑](#footnote-ref-1)