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Smoking status and abdominal obesity among normal- and overweight/obese adults: Population-based FINRISK study

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ABSTRACT

Several studies have reported direct associations of smoking with body mass index (BMI) and abdominal obesity. However, the interplay between them is poorly understood. Our first aim was to investigate the interaction between smoking status and BMI on abdominal obesity (waist circumference, WC). Our second aim was to examine how the association of smoking status with WC varies among normal and overweight/obese men and women. We examined 5833 participants from the National FINRISK 2007 Study. The interactions between smoking and BMI on WC were analyzed. Participants were categorized into eight groups according to BMI (normal weight vs. overweight/obese) and smoking status (never smoker, ex-smoker, occasional/light/moderate daily smoker, heavy daily smoker). The associations between each BMI/smoking status -group and WC were analyzed by multiple regressions, the normal-weight never smokers as the reference group. The smoking status by BMI-interaction on WC was significant for women, but not for men. Among the overweight/obese women, ex-smokers (β = 2.73; 1.99, 3.46) and heavy daily smokers (β = 4.90; 3.35, 6.44) had the highest estimates for WC when adjusted for age, BMI, alcohol consumption and physical activity. In comparison to never smoking overweight/obese women, the β-coefficients of ex-smokers and heavy daily smokers were significantly higher. Among men and normal weight women the β -coefficients did not significantly differ by smoking status. An interaction between smoking status and BMI on abdominal obesity was observed in women: overweight/obese heavy daily smokers were particularly vulnerable for abdominal obesity. This risk group should be targeted for cardiovascular disease prevention.

1. Background

Smoking and obesity constitute the leading causes of preventable death (Danaei et al., 2009, Stokes and Preston, 2016). Globally, tobacco use has killed 100 million people in the 20th century alone (Eriksen et al., 2015). Obese smokers live on average 13 years less than normal weight non-smokers (Peeters et al., 2003). Apart from a body mass index (BMI) 30 and above, abdominal obesity on its own is associated with higher mortality in all weight categories (Cerhan et al., 2014; Jacobs et al., 2010). Globally, approximately 30% of adult men and 6% of women are daily smokers (Ng et al., 2014), further 39% of the world's population are overweight (BMI ≥ 25 kg/m^2) and 13% are obese (BMI ≥ 30 kg/m^2) (WHO, 2015). It has been reported that 30% of daily smokers are overweight or obese (De Munter et al., 2015). Smoking alone or in combination with overweight or obesity poses the major public health burden in developed countries (Danaei et al., 2009; Eriksen et al., 2015).

Previous studies have reported on the relationship between smoking and weight. First, current daily smokers generally have lower BMIs than never smokers (Akbartabartoori et al., 2005; Audrain-Mcgovern and Benowitz, 2011; Berlin, 2008; Munafo et al., 2009; Pisinger et al., 2009; Sikorski et al., 2014; Sneve and Jorde, 2008). Second, during cessation, most of the quitters gain weight (Aubin et al., 2012; Filozof et al., 2004; Tian et al., 2015). Third, former smokers tend to be heavier than both never and current daily smokers (Akbartabartoori et al., 2005; Caks and Kos, 2009; Canoy et al., 2005). Fourth, some studies have reported that BMI among the smokers was positively associated with the number of cigarettes smoked per day (Bamia et al., 2004; Berlin, 2008; Chiolero et al., 2007; De Oliveira Fontes Gasperin et al., 2014; Pisinger et al., 2009) although other studies

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reviewed by Winslow et al. (2015) have found the opposite. However, many studies have shown that daily smokers weigh less than never smokers, but the body of knowledge about whether smokers have more abdominal obesity is controversial.

Specifically, current smokers have more abdominal obesity than never smokers (Berlin, 2008; Berlin et al., 2012; Morris et al., 2015; Pisinger and Jorgensen, 2007; Sikorski et al., 2014; Slagter et al., 2013; Yun et al., 2012) but other studies have not confirmed this association (Caks and Kos, 2009; De Oliveira Fontes Gasperin et al., 2014) or have even found the opposite (Clair et al., 2011; Lv et al., 2015; Onat et al., 2007; Onat et al., 2009; Sikorski et al., 2014). Yet other studies have reported that WC increases with increasing pack years among current daily smokers (Clair et al., 2011; Kim et al., 2012; Rom et al., 2015). The amount smoked daily by smokers have also been reported to be positively associated with abdominal obesity (Bamia et al., 2004; Barrett-Connor and Khaw, 1989; Clair et al., 2011). Moreover, a recent study that took a Mendelian randomization approach reported causal association. Morris et al. (2015) found that heavier smoking may lead to a relative increase in WC. Not only does current daily smoking increase the risk of elevated WC, former smokers also have more abdominal obesity compared with never smokers (Kwok et al., 2012; Lv et al., 2015; Sikorski et al., 2014; Yun et al., 2012), and also compared with current daily smokers (Akbartabartoori et al., 2005; Pisinger and Jorgensen, 2007). However, some studies have reported the opposite (Canoy et al., 2005; Yun et al., 2012). These contradictory findings show that the association still requires more attention.

It has been reported that smoking affects fat distribution in the abdominal area by various biological mechanisms such as the dysregulation of the hypothalamic-pituitary-adrenal axis (Audrain-Mcgovern and Benowitz, 2011; Rohleder and Kirschbaum, 2006). Another biological mechanism between smoking and increased abdominal obesity is that smoking affects the regulation of the sex hormones (Chiolero et al., 2008). For example, lower levels of androgens in male smokers and an imbalance in estrogens and androgens levels in female smokers have been found to increase abdominal obesity (Audrain-Mcgovern and Benowitz, 2011; Chiolero et al., 2008). Moreover, smoking may increase insulin resistance (Audrain-Mcgovern and Benowitz, 2011; Cena et al., 2011).

It is well established that overweight and general obesity as defined by BMI are the most important risk factors for abdominal obesity or elevated WC. However, previously published studies have reported inconsistent and even controversial findings about the association of smoking with abdominal obesity.

Considering prior knowledge about smokers' abdominal obesity, we hypothesized an interaction between smoking status and BMI on abdominal obesity (WC). We further hypothesized that normal and overweight/obese participants show different abdominal obesity according to their smoking status. The first aim of this study was to investigate the interaction between smoking and BMI on WC in a Finnish cross-sectional population-based sample. The second aim was to examine ways in which the association of smoking status with abdominal obesity varies among normal and overweight/obese men and women.

2. Methods

2.1. Data source and sample

The National FINRISK 2007 Study was a population-based health examination survey in Finland, which was used as the data source for this study. FINRISK 2007 Study has been described in detail elsewhere (Vartiainen et al., 2010). In brief, a stratified random sample was drawn from the Population Register comprising 9957 men and women aged 25 to 74 years. Members of the sample received an invitation to a health examination and also a questionnaire to complete. Of those invited, 6258 participated (62.9%). The participants had their height, weight, and WC measured by trained nurses according to an internationally accepted protocol to ensure an internationally comparable standard (Tolonen et al., 2008). Pregnant women ($n = 16$) were excluded from the present study. This study comprised 5833 participants (2738 men, 47%; 3079 women, 53%) all of whom provided complete information for any of the analyzed variables. The participants filled in a self-administered questionnaire that covered, for example, smoking habits, alcohol consumption, physical activity, and a history of non-communicable diseases. All procedures involving participants were approved by the Ethics Committee of Helsinki and Uusimaa Hospital District and in accordance with the Helsinki Declaration of 1975. The participants gave their written informed consent for health examination procedures. The study protocol followed the recommendations of the World Health Organization Multinational monitoring of trends and determinants in cardiovascular disease (Borodulin et al., 2015).

2.2. Variables

We classified the participants of this study according to their smoking status and whether they were either normal weight or overweight/obese on the basis of the BMI cut-off point of 25. Participants were classified into four categories according to their smoking status as follows: 1) never smokers, 2) ex-smokers (those who had quit smoking at least one month ago), 3) occasional smokers and light/moderate daily smokers, and 4) heavy daily smokers. Smoking classification was ascertained by asking the following questions in the questionnaire: 1) "Have you ever smoked?" 2) "Have you ever smoked at least 100 cigarettes during your lifetime?" 3) "Do you smoke currently?" 4) "Have you ever smoked regularly (in at least one year period)?" 5) "When was the last time you smoked?" In brief, those who answered "no" to questions 1 and 2 were classified as never smokers. Those who answered "yes" for 1 and 2 and "no" for question 3 were classified as ex-smokers. Those who answered "no" for question 4 were classified as occasional smokers. Finally, those who answered "yes" for questions 1, 2, 3, and 4 were classified as current daily smokers. Daily smokers were divided into light/moderate and heavy smokers according to their response to the question "How many manufactured cigarettes or hand-rolled cigarettes do you smoke on average in a day?" Those who smoked 19 or fewer cigarettes per day (CPD) were classified as light/moderate smokers and those who smoked 20 or more CPD were classified as heavy smokers. The same classification light/moderate versus heavy smokers has been used elsewhere before (Rasouli et al., 2013).

Anthropometric measures were taken and recorded by a trained study nurse using international protocols (Tolonen et al., 2008). All anthropometric measures were assessed with the subjects wearing light clothing and bare footed. The measurement of weight was rounded-off to the nearest 0.1 kg and height rounded-off to the nearest 0.1 cm. BMI was calculated as the weight in kilograms divided by the squared height in meters (kg/m^2). The participants were divided into two groups according to their BMI values, (1) normal weight (BMI < 25 kg/m^2) and (2) overweight or obese (BMI ≥ 25 kg/m^2) (Prentice and Jebb, 2001).

Abdominal obesity was defined using measures of WC in centimeters. The participant's WC was measured midway between the lower rib margin and the iliac crest (Tolonen et al., 2008). The WC was used as a continuous variable and it was rounded-off to the nearest 0.5 cm.

Based on the earlier literature, the following variables were included as the covariates in the analyses: age, BMI, alcohol consumption and physical activity and were added to the models using a stepwise procedure (Dvorak et al., 2009; Morris et al., 2015; Oh and Seo, 2001; Shimokata et al., 1989). The level of alcohol consumption was assessed as the self-reported use of alcohol products in the previous week in ethanol grams and used as a continuous logarithmically transformed variable. The level of physical activity was assessed using self-reports on leisure-time activities, commuting and occupational physical activity that were combined to create a physical activity index and used as a continuous variable (Borodulin et al., 2016).