UiT The Arctic University of Norway

Faculty of Health sciences -Department of Community Medicine

The association between visceral fat and lifestyle factors in an adult population: The Tromsø Study 2015-2016.

Geraldine Wadzanai Kakuruwo

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Supervisor: Marie Wasmuth Lundblad

Co-supervisor: Jonas Johansson

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Abstract

Introduction: Visceral fat (VAT) is the most metabolically, harmful type of body fat. It is in the abdomen and it surrounds organs like kidneys, pancreas and liver and is associated with higher risk for morbidity. VAT is accurately measured by dual-energy X-ray absorptiometry (DXA). Due to the imbalance between energy intake and expenditure, excessive VAT accumulation occurs; therefore, a healthy lifestyle that emphasizes enhanced diet and physical activity can be advantageous for health management Diet is measured with a validated FFQ and Physical activity is measured with an Acti graph accelerometer. The aim of this study is to examine the association between VAT, diet, and objective measures of physical activity in a general adult population from the seventh survey of the Tromsø Study.

Methods: A cross sectional study design was used. Data was from the Tromsø7 study (2015-16) and a total of 21083 (65%) participants attended, aged 40-80+. A total of 1903 participants were included in the analysis. VAT was measured with DXA scan, diet data was collected from a validated food-frequency questionnaire (FFQ) and physical activity by an ACTi Graph accelerometer. Participants with missing data were excluded from the study. Descriptive analysis was used to describe the characteristics of the population and the compliance to NNR and World Health Organization (WHO) physical activity recommendation. To investigate the relationship between visceral fat and diet and physical activity, linear regression analysis was used. All analysis was performed in women and men separately and adjusted for potential covariates (age, education, and smoking status).

Results: The average daily energy intake of females was 8594 kilojoules, while that of males was 10122 kilojoules. The median total energy intake for women was 8232, while it was 9783.5 for men. Males were more physically active than women. Visceral fat was negatively associated with total energy intake, vegetables, fruits, carbohydrates, dietary fibre, sugar, alcohol, mild physical activity, and moderate to vigorous physical activity. Protein, total fat, saturated fat, and sedentary lifestyle were all associated with visceral obesity in a positive manner. Vegetables, carbohydrates, dietary fibre, and saturated fat compliance with Nordic nutrient recommendations was lower.

Conclusion: Visceral adipose tissue was negatively associated with diet and MVPA and LPA whilst positively associated with SL. Physical activity is associated with lesser VAT in comparison to diet.

Abbreviations

BMI	Body Mass Index
CT	Computerized Tomography
DXA	Dual energy Xray absorptiometry
FFQ	Food Frequency Questionnaire
LPA	Light physical activity
MRI	Magnetic Resonance Imaging
MVPA	Moderate Vigorous Physical Activity
NCDs	Non communicable diseases
NNR	Nordic Nutrition Recommendations
Q	Questionnaire
SL	Sedentary Lifestyle
UiO	University of Oslo
UiT	The Arctic University of Norway
VAT	Visceral adipose tissue
WHO	World Health Organization

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1 INTRODUCTION

Obesity is regarded as a major public health problem worldwide as it is reaching epidemic proportions (1). Obesity is a complex disease characterized by the accumulation of excess fat resulting in compromised health (2). Globally, the prevalence of obesity has been rising quickly since 1975 (2). According to World Health Organization (WHO) in 2016 around 650 million (13%) adults had obesity (2). Obesity is associated with premature death; in 2017, 4.7 million deaths worldwide were directly linked to obesity (3).

Body mass index (BMI) can be used to estimate the prevalence of obesity and risks associated with it in a population. BMI is a measurement of body fat based on height and weight and is commonly used to classify underweight, normal weight, overweight, and obese individuals (4). World health organisation (WHO) categorized BMI (kg/m^2) in three groups with BMI of 18.5 - 24.9 kg/m^2 as normal weight, BMI of 25 – 29.9 kg/m^2 classified as overweight and BMI of 30 kg/m^2 and above is classified as obesity (4). BMI is insufficient for assessing adiposity because it cannot differentiate between lean muscle and visceral tissue. However, it has been noted that some obesity-related health risks are more strongly associated with body fat location than total body fat (5). Subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT) are the two major compartments in which body fat is found. Even though both of these tissues are significant, visceral adiposity has garnered more attention due to its association with numerous medical pathologies (6). The visceral adipose tissue (VAT), which is stored in the abdomen, serves a crucial role in the progression of health risks because it is considered the most harmful fat deposit.

1.1 Visceral Adipose Tissue

VAT is detrimental intra-abdominal adipose tissue accumulation associated with an increased risk of morbidity and mortality (7). VAT is located in the abdomen and surrounds internal organs like the liver, pancreas, and kidneys. VAT serves as protective padding to the organs and is involved in fat metabolism (8). It is hard to determine how much visceral fat one has, but a protruding belly and large waist are considered as indicators of possible excess VAT. VAT is more metabolically active than other fat tissues and imposes a health threat through being involved in both releasing and regulating pro-inflammatory processes (9). Excess VAT is associated with decreased production of adiponectin, a metabolic and anti-inflammatory molecule derived from adipose tissue (10). The ability of VAT to generate free fatty acids impairs hepatic insulin clearance, resulting in insulin resistance, increased glucose production, and an increase in very low-density lipoprotein secretion (11). Visceral fat is more metabolically active than subcutaneous fat (SAT) because it produces more hormones and substances such as inflammatory proteins, which can be detrimental to health by increasing insulin resistance, blood fat levels, blood pressure, and systemic inflammation.

1.1.1 Health implications

VAT is associated with several non-communicable diseases (NCDs) like cardiovascular disease, insulin resistance, hypertension, kidney disease, non-alcoholic fatty liver diseases and predisposition to various types of cancers (colon, breast, and prostate) (12). NCDs are the leading cause of death and disability in the world (13). Some NCDs can be avoided by changing one's lifestyle and avoiding risky lifestyle choices like cigarette smoking, drinking too much alcohol, being inactive, and eating unhealthily. NCDs are the primary cause of death on a global scale and are associated with lifestyle factors such as obesity, physical inactivity, and a poor diet. Those who maintain an unhealthy lifestyle are at a greater risk of death. Typically, VAT is assigned near the portal vein, which transports blood from the gastrointestinal tract to the liver for processing (12) therefore posing a great health risk. Since VAT transfers fatty acids and inflammatory proteins to the liver, it is linked to liver inflammation and increased liver obesity. Insulin resistance and nonalcoholic fatty liver disease (NAFLD) are associated with VAT. (12).

1.1.2 VAT measurement

VAT is difficult to measure due to its location in the abdominal cavity, which is surrounded by abdominal organs (14). Consequently, the measurement of VAT necessitates the use of sophisticated radiology techniques and apparatus. However, there are numerous techniques for measuring or calculating VAT, such as computed tomography (CT), magnetic resonance imaging (MRI), and dual-energy X-ray absorptiometry (DXA). CT and MRI are most commonly used in hospitals and clinics; they can evaluate body composition and the anatomical distribution of fat (15).

However, using CT or MRI in large scale studies or in general populations is not feasible, due to cost, availability, and radiation exposure. More recently, the DXA-scans have been used to assess body composition as it is a clinically applicable imaging method with negligible radiation exposure that provides accurate measures of fat mass, bone mass, and lean tissue mass (16). DXA is a technique for measuring body composition in both research and clinical practice (17). VAT is estimated from fat mass located in the abdominal area by subtracting subcutaneous fat

(SAT) from the total android fat mass (18). In comparison with VAT measured by the gold standards CT and MRI, the DXA is shown to give a highly accurate measure of VAT (18).

1.2 Lifestyle

Lifestyle refers to day-to-day behaviour and functions of individuals in their daily activities, and diet (19). Researchers define lifestyle as "the sum of health-related factors (tobacco, drugs, alcohol, fat, sugar and exercise) that might influence life or health" (20,21). WHO reports that 60% of individual health hazards and quality of life are attributable to lifestyle factors (22). A healthy lifestyle is a way of life that reduces the risk of developing significant illness or dying prematurely. Some diseases cannot be prevented; however, it is possible to avert death from cardiovascular diseases and lung cancer. A healthy lifestyle reduces the likelihood of becoming gravely ill or shortening one's life expectancy. The quantity of visceral adipose tissue and total body fat can be affected by several variables, including genetics, environment, and lifestyle choices, with lifestyle choices being the easiest to actively modify body composition. Excess accumulation of VAT is because of imbalance between energy intake and expenditure, therefore maintaining a healthy lifestyle which focuses on improved diet and physical activity, is good for health management (23). This thesis will focus on two lifestyle factors considered to have an association with VAT: diet and physical activity.

1.2.1 Diet

Diet refers to the total amount of food consumed by individuals and is influenced by factors such as environmental conditions, availability of food, religious beliefs, and socioeconomic status (24). There are no medication treatments for the prevention and treatment of obesity and excess abdominal obesity, so dietary management is used to maintain a healthy lifestyle. The considerable rise in obesity has been linked to overeating and consuming fast food, both of which promote the accumulation of excess adipose tissue (25). A healthy diet is shown to have direct and positive relation with well-being of an individual while a poor diet has negative consequences such as obesity (26).

A diet that is healthy is characterized by the consumption of a variety of foods in the proper proportions, without exceeding the recommended caloric intake. A healthy diet includes fruits, vegetables, carbohydrate foods, especially those that contain more fiber and nutrients, lean proteins (fish, eggs, and white meat), dairy foods (a good source of protein and calcium), and a restricted amount of unsaturated fat (27).

Dietary quantity and quality are the two most important factors in weight control. Governments and the health sector play a crucial role in promoting a healthy diet by creating an environment conducive to the formation and maintenance of healthy eating practices (27). Thus, some countries have come up with dietary guidelines, to provide food and beverage recommendations for their populations (28). These Food based dietary guidelines were developed to improve healthy eating habits. These recommendations have the aim to provide diet recommendations that meet the energy and nutrient requirements to prevent diseases that are related to diet like obesity (28). WHO diet guidelines recommends diet with lot of fruits and vegetables, reducing fat, sugar, and salt. WHO healthy eating plan encourages eating variety plant-based food than animals, eating food with more dietary fiber, control fat intake, low sugar, and low salt intake. There is no limit on alcohol consumption as the ideal solution is not taking in alcohol (29).

1.2.1.1 Norwegian dietary recommendations

Norway has food dietary guidelines and specific nutrients recommendations, to encourage consumption of healthy food to avoid health complications. The Norwegian National Action Plan for a Healthier Diet (2017-2021) is in line with WHOs Global Action Plan for the prevention and control of non-communicable diseases, it aims in achieving a healthy diet for the whole population (30). The Norwegian dietary guidelines and nutrient recommendations are based on the Nordic Nutrition Recommendations 2012 (31).

The Norwegian nutritional recommendations act as a guide for decision-makers, medical professions, and other fields involved in public health work. The nutrients recommendations are presented as energy percentage (E%) and vitamins and minerals as recommended total intake per day gram (g), milligram (mg) per day (31).

The Norwegian health directorate encourage an intake of less sugary food and drinks, less saturated fats, less salty food, and encourages a higher intake of whole grain food, fibre, fruits, and vegetables (31). The Norwegian dietary guidelines recommend intake of a varied diet with lots of vegetables, fruit and berries, whole grain foods, fish and limited amounts of processed meat, red meat, salt, and sugar (31). Nutrition recommendation focus on nutrient intake control by suggesting reduction of total fat, saturated fat intake, trans fats, carbohydrates and added sugar (31).

These prescribed guidelines provide individuals with the opportunity to choose a healthy lifestyle and the knowledge to avoid contracting certain diseases. Overconsumption of fat, saturated fat, and sugar raises the risk of health complications such as cardiovascular disease and cancer, whereas inadequate protein intake inhibits growth (32). Fiber is more advantageous for digestion and regulating blood pressure (32).

Table1: Recommended nutrients and food intake. The Nordic Nutrition Recommendations 2012

Nutrients	**Recommendation**
Carbohydrates	45-60 E%
Sugar	< 10 E%
Dietary fiber	≥25g for women/ ≥35g for men
Protein	10-20 E%
Fat	25-40 E%
Saturated fat	< 10 E%
Alcohol	< 5 E%
Vegetables and fruits	**Recommendation**
Vegetables	250g/day
Fruits and berries	250g/day

E%, proportion of total energy intake. g- grams

1.2.2 Physical Activity

Physical activity is defined by WHO as any bodily movement produced by skeletal muscles that requires energy expenditure (33). Therefore, physical activity refers to activities such as exercising, walking, and household duties. Physical activity is regarded as effective for preventing hypertension and sustaining a healthy body weight, and it can enhance overall health (including mental and quality of life). On the other hand of the spectrum are sedentary lifestyles, such as lying, sitting, and standing, which do not increase the energy expenditure meaningfully above resting levels. Physical inactivity is associated with poor health and development of chronic health conditions. Physical inactivity is associated with VAT accumulation especially in older ages, where levels of physical activity have decreased in comparison to younger people who engage in more physical activities (34).

The levels of intensity for physical activity are moderate, light, and vigorous. Guidelines suggest using Metabolic Equivalents of Tasks (METs) as absolute intensity reference thresholds by designating an intensity value to each specific activity (35). Frequently, vigorous intensity is recommended for greater calorie-burning benefits than moderate intensity, whereas mild intensity is preferable to inactivity.

The metabolic equivalent of task (METs) is the quantity of energy expended during any physical activity. METs are used to rate the intensity of physical activities and are typically categorized as light, moderate, or vigorous. High energy expenditure is required for vigorous physical activity, and the METs for these activities exceed 6.0 (35). Examples of vigorous physical activity include jogging, swimming, jumping rope, and sports like basketball and soccer. Moderate physical activity requires greater energy expenditure than mild physical activity. Included in moderate physical activity are activities such as moderate walking, water aerobics, tennis, and volleyball. Light physical activity requires less effort and energy than vigorous or moderate physical activity. Light physical activity consists of moderate walking, stretching, raising hand weights, light housework, and push-ups, and has an energy expenditure of less than 3.0 METs. Less than 1.5 METs are associated with a sedentary lifestyle. WHO recommends that adults from 18 years and older should at least have 150 - 300 minutes of moderate-intensity aerobic physical activity or at least 75 - 150 minutes of vigorous intensity aerobic physical activity per day (33). WHO also recommends that people reduce sedentary time, by encouraging adults to do more physical activity than the recommended time. The physical activity recommendations for adults and the elderly in Norway are similar to those of the World Health Organization. Vigorous activity is associated with significant reduction of visceral fat (33). Moderate-to-vigorous physical activity has a positive relationship with good health status, especially in older adults, and with risk reduction of many chronic diseases (33). Multiple studies have demonstrated a negative association between physical activity and VAT, indicating that for VAT to decrease, physical activity intensity must also increase (36-39). This has led to the recommendation of moderate-to-vigorous physical activity more than activities with lower intensity (36,40). In some studies, the results showed that sedentary lifestyle is associated with increase in VAT (37,41).

1.2.2.1 Sedentary lifestyle

Sedentary lifestyle refers to physical inactivity for six or more hours per day, resulting in less energy expenditure (42). Sedentary lifestyles include sitting, home schooling, commuting, viewing television, and playing video games. In addition to increasing the risk of developing obesity, cancer, diabetes, high blood pressure, and heart disease, a sedentary lifestyle has been linked to a reduction in bone mineral density in other studies (42). In the absence of physical activity, the brain produces less serotonin, a mood-enhancing chemical. Consequently, sedentary lifestyles have a negative impact on mental health.

1.2.2.2 Physical Activity measurement

Physical activity is traditionally measured using self-reported methods such as questionnaires, although these may be influenced by recall bias, inability to quantify levels of physical activity and health status (43). Therefore, there has been an introduction of objective measurements of physical activity to limit such bias, like pedometers and accelerometers (44). The accelerometer is defined as an electromechanical instrument that can measure acceleration forces in three axes (45). It is also a movement sensor capable of measuring light, moderate, and vigorous physical activity in addition to sedentary lifestyle. Accelerometers are wearable instruments that measure accelerations of a body segment to which a monitor is affixed (46). Furthermore, the signal is filtered and pre-processed by the monitor to obtain activity counts (46). The use of accelerometers to determine physical activity and sedentary time has now become an alternative to self-report like questionnaires, which are characterized by poor reliability and validity (47). Accelerometers are triaxial, meaning they detect motion in three planes. Using resultant vectors of the 3 axes vector magnitude, data acquired with these models can be analysed separately for each axis (46).

1.3 Rationale

Lifestyle interventions like diet and exercise are associated with a decrease in VAT. Unhealthy diet and lack of physical activity are the leading global risks to health. Changing lifestyles leads to a shift in in dietary patterns, as people are now consuming more processed foods that are high in energy and fat, too much sugar and salt, lacking enough vegetables, fruits, and dietary fibre. Energy intake should have balance with energy expenditure to avoid excess fat storage.

In a previous study they found out that a combination of diet and physical activity significantly decreased visceral fat (48). A cross-sectional study found out that high level of physical activity was associated with lower VAT volumes (48). Results from prospective studies also demonstrated the high levels of physical activity are associated with less weight gain and lower abdominal adiposity (49). These results demonstrate that diet and exercise cause a negative energy balance, which is linked to considerable VAT reductions.

Previous studies investigating lifestyle changes such as dietary patterns (Mediterranean diet), physical activity and sedentary lifestyles, reported that adjusting lifestyle leads to lower abdominal fat accumulation (50-53). Currently, no other study has assessed the association between DXA-derived VAT, diet, and objectively measured physical activity together using the Tromsø7 study as a focal point. Consequently, this study will shed light on the association between VAT and lifestyle parameters (diet and objectively measured physical activity). The utilization of accelerometers and DXA scan will yield precise and reliable results. Additionally, it is necessary to comprehend how diet and physical activity independently relate to VAT. This study will shed light on the relationship between a healthy lifestyle and VAT, as well as the contribution of diet and physical activity in preventing health complications. This study will provide valuable information to promote healthy lifestyles and reduce mortality and morbidity risks associated with excessive VAT.

The objective of the study is to assess how VAT is associated with diet and physical activity in a general adult population from Tromsø municipality.

2 MATERIALS AND METHODS

2.1 The Tromsø Study

The Tromsø study is an ongoing population-based study conducted in the municipality of Tromsø in Northern Norway, with data collected in waves every 7-8 years (54). The Tromsø study focuses on the adult residents in Tromsø. The population of the municipality of Tromsø consists of both urban and rural territories and is largely representative of the general urban Norwegian population in terms of sex, age, and educational attainment (55). The Tromsø study has 7 completed surveys (Tromsø1 -Tromsø7) done from 1974 to 2015-16. The present study is based on the Tromsø7 study (2015-16). All adult residents of the Tromsø municipality who were 40 years of age or older (n=32591) were invited to take part in the Tromsø 7 study. The invitations were sent out once every week by mail between March 2015 and June 2016 to randomly selected participants. There were a total of 21083 (65%) attendees.

2.2 Data collection

The data collection consisted of comprehensive collection of health data from questionnaires, measurements, biological samples, and clinical surveys. The first visit consisted of a basic examination for all the participants who attended. The invitation was sent to randomly selected participants and it included detailed information about the Tromsø Study, an information brochure and a personal letter with a username and password for completion of three online questionnaires (54). Questionnaire 1 (Q1) had short general questions that could be filled in by hand on paper or online, Questionnaire 2 (Q2) consisted of long general questions and. On the first visit consent forms were signed, and check for the completion and submission for Q1 and Q2, the Food Frequency Questionnaire (FFQ). If any participants needed assistance due to disabilities, digital illiteracy, or translation technicians were available to help.

The second visit included extended examinations for a pre-marked subsample of the total invited sample (N=13 028) and 8346 (64 %) participants attended the extended examinations. Specially trained research technicians performed all examinations. Data for the second visit was collected through biological sampling, accelerometer, and body composition by DXA.

Data collection methods for diet mostly rely on self-reported information by the study participants. The methods of measuring habitual dietary intake include food records, food frequency questionnaires (FFQ) and 24-hour recalls (56). FFQ is a dietary assessment tool, which indicate the consumption of food and beverages over a period.

2.3 Food Frequency Questionnaire

An FFQ developed at University of Oslo (UiO), was used to measure food and beverage intake. The FFQ was validated for fruits, vegetables, and energy intake (57). On the first visit, at the examination site, participants were given FFQs to complete on-site or at home and return in a prepaid envelope. Study technicians provided motivational information to the participants in completing the FFQ. The cover page of the FFQ explained why data on food intake was essential, and the first page provided instructions on how to respond to the questionnaire (58). The FFQ contained 13 pages with questions about the average intake of 261 different types of food, dishes, dietary supplements, meals, and beverages including alcohol during the last year in the Norwegian population (58). Trained technicians manually inspected all the submitted FFQs , and any required adjustments were made according to UiO standards Before sending the data to UiO to compute food and nutrient intakes, the data was scanned for digital storage and the raw data was analysed for compliance with metadata requirements. The KBS (AE14 – KBS version 7.3) software at UiO was used for the computation of energy and nutrient intakes (58). All the dietary data was imported into Eutro at UiT. Eutro is an IT solution that gathers all data from the Tromsø Study into one database (59).

2.4 Physical Activity

Physical activity was measured using an ActiGraph wGT3X-BT(ActiGraph LLC, Pensacola, FL, USA) accelerometer, recording in three axes (axial, coronal, and sagittal).Before attaching the accelerometer to the participant's right hip with an elastic band, trained technicians gave them instructions on how to use the device. During water-based activities such as bathing and swimming, the accelerometer was to be removed. Participants (n = 6333, 93% of those invited) were instructed to wear the accelerometer for 8 days and nights, 24 hours per day. The accelerometer started recording at 00:00 on the day following the clinic visit. After the measurement time was over, the accelerometer was mailed back in a pre-paid envelope and the data downloaded. The ActiLife software (ActiGraph, LLC, Pensacola, USA) was used for the initialization and downloading of the data. Measurements were included if the participant had at least four days of 10 hours of physical activity per day.

2.4.1 Accelerometery data processing

Accelerometery data was screened to ensure that the included data were calibrated with a sampling rate of 100 Hertz. Using the default private filter of the ActiLife software, the raw acceleration files were filtered to epochs. The data was aggregated to a duration of 10 seconds.

Using a quality control and analysis instrument (QCAT), the data were analysed and processed. The axial axis was used to calculate the step count of the accelerometer. The acceleration units for the axial plane (vertical axis) are triaxial vector magnitude (VM) counts per minute (CPM) (the square root of the total number of squared activity counts). 60s epochs were added to the 10s epochs, and an epoch was designated as wear time if two out of the following three conditions were met: One epoch of less than 5 VM CPM, two if there were at least two epochs of less than 5 VM CPM in the preceding 20 minutes, three if its value was less than 5 VM CPM, and at least two epochs of less than 5 VM CPM in both the previous and following 20 minutes (60). If not, the motion was categorized as noise and non-wear time (61). Triaxial VM CPM cut points for different intensities are <150 VM CPM for sedentary lifestyle (62) and 150-2689 VM CPM for light physical activity (63) and while moderate and vigorous physical activity is between ≤2690 VM CPM.

2.5 VAT

VAT mass (g) was assessed by a DXA scan, using the GE Lunar Prodigy Advance (GE Healthcare Medical Systems, Madison, Wisconsin). The participants were instructed to wear light clothes or were provided with hospital gowns during the scans, also all metal objects were to be removed. No instructions were given regarding food or water restrictions (non-fasting samples). Technicians were trained in standard operating procedures for using DXA scans in accordance with manufacturer recommendations. Each morning DXA scan systems were calibrated with a standard phantom as recommended by the manufacturer (8). Trained technicians performed a post-scanning inspection and potential corrections of images. From the 8346 who attended the extended examination, a total of 3683 (70%) participants attended the DXA scans. Eight of these were excluded for not having valid VAT measures. Thus, the included number of participants in this study are those with valid VAT measures (N= 3675).

2.6 Study sample and exclusion criteria

The inclusion process is presented in figure 1 below. Participants were firstly excluded based on the completeness of the FFQ and/or unrealistic energy intakes. Participants that completed less than 90% of the FFQ (n = 3487) were excluded. Also, the 1 % with the highest and lowest energy intake (below 3950 kJ and above 21300 kJ per day) were excluded from this study (n= 41). Participants with missing data on both Physical activity (n= 518) and DXA (n=2332) results were excluded from the study. All participants hat had missing data on education and smoking (n=49) were excluded. Finally, a total of 1903 participants were included in this study.

This is 9% of all the participants in the Tromsø study, 13% of all participants that returned the FFQ, and 23% of all that attended the second examination visit.

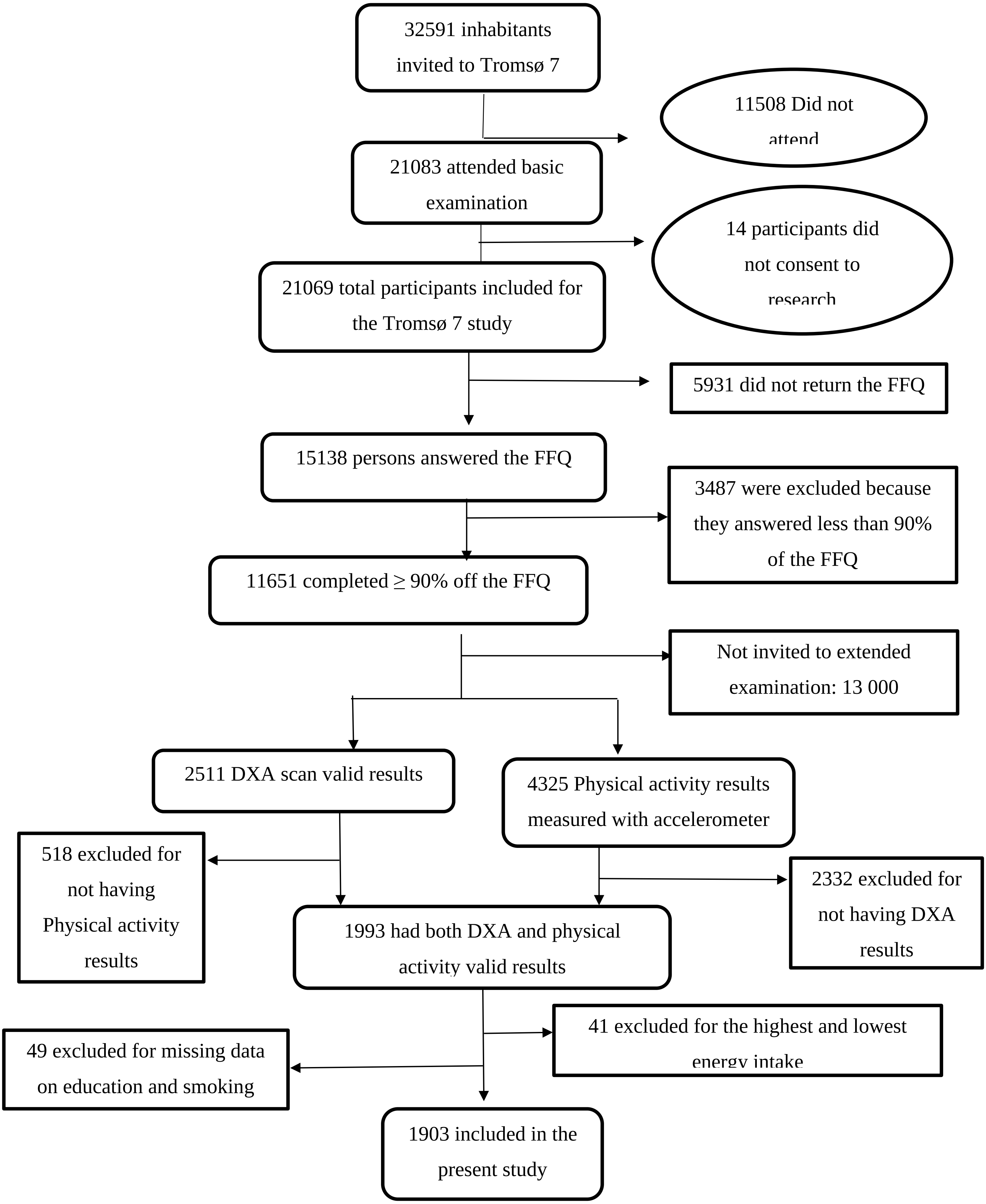

Figure 1:

Flowchart showing included and excluded participants

2.7 Variables

Exposure variables

An FFQ was used to capture data on diet, from which the following estimates were derived: daily energy in kJ, vegetables, fruits, and berries, protein, fat, and saturated fat, carbohydrates, dietary fiber, sugar, and alcohol. Total energy intake calories were quantified as kilojoules per day (kj/day), while energy percent intake (E%) was used to quantify the energy intake of specific nutrients.

An ActiGraph wGT3X-BT(ActiGraph LLC, Pensacola, FL, USA) accelerometer was used to measure physical activity. The levels of physical measured were Moderate to very vigorous minutes per valid day, Sedentary minutes per valid day, and Light minutes per valid day.

Outcome variable

VAT(g) was calculated using the GE Lunar Prodigy Advance DXA scan (GE Healthcare Medical Systems, Madison, Wisconsin). The scans were performed by trained technicians. The participants had light clothing and no shoes.

Covariates

Age, gender, smoking status, and educational attainment data were self-reported from Q1 (Table 1). Age was divided into 5 groups (40–49, 50–59, 60–69, 70–79, and 80–plus). Education levels were reported using the same four-level scale as Statistics Norway (Table 1). There were 4 educations categories primary/ partly secondary education up to 10 years of schooling, upper secondary education with a minimum of years, tertiary education less than 4years in a college or university and tertiary education with 4 or more years in college or university. Smoking was divided into 3 groups, those that never smoked, those that previously smoked and those that currently smoke.

Table 2: Description of variables included in the study

Variable	
Age in 10-year groups	40-49 50-59 60-69 70-79 80+

Sex	Male and female
Education 4 categories	Primary/ partly secondary education / (up to 10 years of schooling) Upper secondary education (a minimum of 3 years) Tertiary education, short: college/university less than 4 years Tertiary education, long: college/ university 4 years or more
Smoking	Never Yes, currently Yes, previously
Vegetables	Grams per day
Fruits and Berries	Grams per day
Protein	Energy Percent of total energy intake
Fat	Energy Percent of total energy intake
Saturated fat	Energy Percent of total energy intake
Carbohydrates	Energy Percent of total energy intake
Dietary fiber	Converted to grams – ≥ 25 for women and ≥35 for men
Sugar	Energy Percent of total energy intake
Alcohol	Energy Percent of total energy intake
SL minutes per day	Minutes per day (accelerometer measured)
LPA minutes per day	Minutes per day (accelerometer measured)
MVPA minutes per day	Minutes per day (accelerometer measured)

SL- sedentary lifestyle; LPA- light physical activity; MVPA- moderate to very vigorous physical activity.

2.8 Statistical analyses

All statistical analyses were performed utilizing IBM SPSS 28.0 (Windows). In the present sample, VAT measures with values of 0 grams (n = 5) were converted to the next lowest value (2 grams) (8). The dietary fibre data presented in energy percentage was converted to grams. Since it is believed that intake of nutrients for females and males vary, all analyses were performed separately for females and males to remove the effect of sex (64). All variables included in the study were subjected to a descriptive analysis to ascertain the demographic, dietary, physical activity, and VAT characteristics of the study participants. Table 2 presents categorical data as numbers (n) and percentages, and continuous variables as means and standard deviations (SD).

The participants were divided into three tertiles based on the amount of VAT they had: 33.3%, 66.6%, and 99.9%. There were 504 females and 131 males in the first tertile, 399 females and 234 males in the second tertile, and 180 females and 455 males in the third tertile. Compliance of nutrients with NNR (2012) recommendations were presented using descriptive analyses. Due to the fact that a small proportion of participants in the Tromsø study 2015-16 were below the recommended intake, it was determined to compare the intake only to the recommended intakes as opposed to the lower intake level, average requirement, recommended intake, and upper intake level combined (65). Physical activity was also examined for compliance with Nordic recommendations, which are identical to WHO recommendations. Median for moderate vigorous physical activity (MVPA), light physical activity (LPA) and sedentary lifestyle (SL) time was recorded.

Linear regression was used for each sex separately to find the association between VAT and diet and physical activity. The linear regression was carried out step by step: the crude, then secondly the model was adjusted for age and then finally adjusted for smoking and education. (table 5). The unstandardized beta (B) was reported, together with its corresponding 95% confidence interval (CI).

2.9 Ethical considerations

The Tromsø Study was performed according to the Helsinki declaration of 1964 and its later amendments. Data collection was approved by the Regional Committee of Medical and Health Research Ethics (REC North) and the Norwegian Data Protection Authority (NSD). FFQ data collection and analysis has been approved as a subproject in Tromsø 7 (REC North 10.02.2015 rf. 2014/940). An application was sent to the Tromsø Study Data and Publication Committee which approved this project and granted access to specified variables for the present project. All the participants gave informed written consent before participation in the study. Data obtained is anonymized to safeguard the privacy of participants. Some of the data is presented under categories like age, education, and smoking, but none of the data contains names or other details that can be used to identify participants. Data from participants that withdrew their consent for scientific research was excluded before data delivery from the Tromsø study. The data will be deleted after the completion of this project following the contract with the Tromsø study.

3 RESULTS

A total of 1903 participants were included in this study. The participants involved in this study consisted of more females (57%) than males (43%). Majority of the female participants were in the age group 60-69 (47.7%), whilst there were fewer participants in the 80 (4%) and above age group. Similarly, there were more male participants in the age group 60-69 (52.1%) and fewer participants in the 80 (3.8%) and above age group. Majority of the female participants either never smoked (41.3%) or previously smoked (47.1%), similar to males who also had participants that never smoked (36.2%) and previously smoked (54.6%).More women had primary and secondary education (33.2%) whilst a smaller group had education with less than four years of tertiary education (15.8%). The majority of male participants (30.5%) had upper secondary school, while fewer had more than four years of university education (19.5%) (Table 3).

Females consumed an average of 8594 kilojoules of energy per day, whereas males consumed 10122 kilojoules (Table 3). There was more intake of fruits and berries among both females and males compared to the intake of vegetables. Most of the average intake of nutrients and food intake was almost similar for females and males. VAT mean (and standard deviation) was 895.7g (604) for females and 1663.5g (915.7) for males. Females averaged 572.7 minutes per day of sedentary lifestyle, 416.8 minutes per day of light physical activity, and 37.9 minutes per day of moderate to very vigorous physical activity (Table 3). Males averaged 607,9 minutes per day of sedentary lifestyle, 374 minutes per day of light physical activity, and 42.8 minutes per day of moderate to very vigorous physical activity (Table 3).

Table3: Characteristics of study sample by sex. The Tromsø Study 2015-2016

	Female	Male	Total
% & N	57% (1083)	43% (820)	(100%) 1903
Energy kj/day median (SD)	8594 (2624)	10122(2955)	9252.5 (2872.29
Age, % (N)			
40-49	5.9% (64)	5.6% (46)	5.8% (110)
50-59	14.4% (156)	12.1% (99)	13.4% (255)
60-69	47.7% (517)	52.1 (427)	49.6% (944)
70-79	28% (303)	26.5 (217)	27.3% (520)
80+	4% (43)	3.8% (31)	3.9% (74)
Smoking, % (N)			
Yes, now	11.6% (126)	9.2% (75)	10.6% (201)
Previously	47.1% (510)	54.6 (448)	50.3% (958)
Never	41.3% (447)	36.2% (297)	39.1% (744)
Education, % (N)			
Primary & partly secondary	33.2% (359)	26.7% (219)	30.4% (578)
Upper secondary (3 years)	27.2% (294)	30.5% (250)	28.6% (544)
Tertiary education < 4years	15.8% (171)	23.3% (191)	19% (362)
Tertiary education > 4years	23.9% (259)	19.5% (160)	22% (419)
Vegetables g/day	245 (139.3)	185 (121.3)	219.1 (2872.2)
Fruits and berries g/day	353 (258.2)	334 (276.6)	344.5 (266.4)
Protein E%	18 (2.5)	18 (2.5)	17.8 (2.5)
Fat E%	34. (5.7)	34 (5.7	34.0 (5.6)
Saturated fat E%	13 (2.8)	12 (2.6)	12.5 (2.7)
Carbohydrate E%	42 (6.2)	42 (5.9)	42.3 (6.1)
Dietary fiber g/day	2.6 (0.63)	2.2 (0.55)	2.5 (0.63)
Sugar E %	5 (2.9)	6 (3.2)	5.4 (3.02)
Alcohol E%	3 (3.7)	4 (4.2)	3.4 (3.9)
VAT g	895.7 (604)	1663.5 (915.7)	1226.6 (844.5)
SL minutes/day	572.7 (95.2)	607.9 (104.7)	587.9 (100.9)
LPA minutes/day	416.8 (84.3)	379.4 (87.1)	400.7 (87.5)
MVPA minutes/day	37.9 (27.2)	42.8 (31.2)	40.07 (29.07)

SL- Sedentary lifestyle, LPA – Light physical activity, MVPA -Moderate to vigorous physical activity, .

Kj- kilojoules, E%- energy percentage, g-gram

Results are presented as percentage and number (n) for categorical variables or as mean and standard deviation (SD) **for continuous variables.**

Table 4: Dietary Intake and physical activity by sex, and non-compliance to the Nordic Nutrient Recommendations (NNR) 2012 in different tertile of VAT: The Tromsø Study 2015-2016.

Females

Nutrients	**NNR 2012**	**Median**	**VAT (lowest tertile) Not in compliance %**	**VAT middle tertile Not in compliance %**	**VAT tertile (highest tertile) Not in compliance %**
Energy kj/day median		8232	8285	8243	8041
Vegetables g/day	250 g/day	222.7	55	60	59
Fruits and berries g/day	250 g/day	305	38	38	39
Protein E%	10 – 20 E%	17.8	14	13	15
Fat E%	25 – 40 E%	34	10	7.5	17
Saturated fat E%	<10E%	12.5	78	82	85
Carbohydrate E%	45 – 60 E%	42.6	64	63	71
Dietary fiber g/day	≥25g/day	2.6	37	47	46
Sugar E%	<10 E%	4.8	5	7	4
Alcohol E%	< 5 E%	1.8	5	5	5

Physical Activity	**Median**	**VAT (lowest tertile) Not in compliance (median)**	**VAT middle tertile Not in compliance (median)**	**VAT tertile (third tertile) Not in compliance (median)**
SL mins/day	569.7	556.7	571.9	605.6
LPA mins/day	413.4	429.9	408.6	378.
MVPA mins/day	32.63	43.1	30.3	20

Males

Nutrients	NNR 2012	Median	VAT (lowest tertile) Not in compliance %	VAT (middle tertile) Not in compliance %	VAT tertile (highest tertile) Not in compliance %
Energy kj/day (median)		9783.5	10395	10007	9502
Vegetables g/day	250 g/day	160.7	77	73	74
Fruits and berries g/day	250 g/day	275.6	39	43	45
Protein E%	10 – 20 E%	17.5	7	11	16
Fat E%	25 – 40 E%	33.7	15	9	3.5
Saturated fat E%	<10 E%	12.1	86	76	74
Carbohydrate E%	45 – 60 E%	42.7	60	60	65
Dietary fiber g/day	≥35 g/day	2.2	99	97	97
Sugar E%	<10 E%	4.9	9	9	8
Alcohol E%	< 5 E%	2.8	5	7	8.5

Physical Activity	Median	VAT (lowest tertile) Not in compliance (median)	VAT middle tertile Not in compliance (median)	VAT tertile (third tertile) Not in compliance (median)
SL mins/day	607.9	596	588.9	623.1
LPA mins/day	374.1	404.4	396.9	358.7
MVPA mins/day	36.4	44.14	41.35	30.6

E% -proportion of energy intake, g-grams per day

SL – Sedentary lifestyle, LPA- light physical activity, MVPA – moderate vigorous physical activity

Median intake for Total energy and physical activity

The median intake of total energy for females was 8232, while it was 9783.5 for males. The median intake for sedentary lifestyle was 569.7 and 607.9, for light physical activity it was 413.4 and 374.1, and for moderate to vigorous physical activity it was 32.6 and 36.4, females and males, respectively. For physical activity most participants spent more hours sedentary and doing light physical activity. A greater percentage of males were more physically active than women, with participants (both females and males) with higher volume of VAT being less active.

Compliance with recommendations

Almost 60% of participants and 40% of females did not consume the recommended amount of fruits and berries and vegetables, respectively. Nearly 77% and 45% of males did not consume the recommended amount of fruits and berries and vegetables, respectively. Females (47%

severe non-compliance) had a higher intake of dietary fiber than men (99.5 extreme non-compliance). Almost 85% of participants of both sexes did not adhere to the recommended intake of saturated fat. The majority of participants consumed less than the recommended intake of 45E% carbohydrates, indicating that a large number were not in compliance with carbohydrate consumption. Less than 10% of both sexes of the participants in the study did not adhere to the NNR recommendations for sugar and alcohol.

Table 5: The association between visceral fat and diet and physical activity: linear regression analysis. **The Tromsø Study 2015-2016**

Female

	Crude *R*(CI)	**Age adjusted (CI)**	**Fully adjusted ***
Energy kj /day	-0.009 (-0.023; 0.005)	-0.005 (-0.018; 0.009)	-0.003 (-0.016; 0.011)
Vegetables g/day	-0.162 (-0.421; 0.096)	-0.131 (-0.386; 0.124)	-0.002 (-0.259; 0.254)
Fruits and berries g/day	-0.037 (-0.177; 0.102)	-0.054 (-0.191; 0.084)	-0.017 (-0.154; 0.120)
Protein E%	14.181 (-0.186; 28.548)	13.474 (-0.681; 27.628)	12.457 (-1.527; 26.440)
Fat E%	4.575 (-1.779; 10.929)	6.427 (0.145; 12.708)	6.331 (0.123; 12.538)
Saturated fat E%	9.151 (-3.940; 22.243)	8.983 (-3.912; 21.878)	7.584 (-5.163; 20.332)
Carbohydrates E%	-4.210 (-10.020; 1.600)	-6.727 (-12.498; - 0.956)	-8.510 (-14.286; -2.733)
Dietary fibre g/day	-65.339 (-122.735; -7.943)	-74.967 (-131.541; -18.392)	-56.932 (-113.594; -0.269)
Sugar E%	-2.120 (-14.533; 10.293)	-3.474 (-15.708; 8.759)	-8.064 (-20.243; 4.114)
Alcohol E%	-3.456 (-13.171; 6.258)	-0.391 (-10.017; 9.236)	4.279 (-5.538; 14.096)
SL min/day	0.927 (0.553;1.301)	0.954 (0.586; 1.323)	0.995 (0.629; 1.361)
LPA min/day	-1.545 (-1.963; -1.128)	-1.433 (-1.847; -1.018)	-1.448 -1.856 -1.039
MVPA min/day	-7.439 (-8.690; -6.188)	-6.890 (-8.197; -5.582)	-6.439 -7.775; -5.103

Male

	Crude (CI)	**Age adjusted (CI)**	**Fully adjusted ***
Energy kj/day	-0.032 (-0.053; -0.011)	-0.029 (-0.050; - 0.008)	-0.029 (-0.050; - 0.007)
Vegetables g/day	0.102 (-0.416; 0.620)	0.081 (-0.436; 0.598)	0.153 (-0.368; 0.674)
Fruits and berries g/day	-0.064 (-0.291; 0.164)	-0.074 (-0.305; 0.148)	-0.060 (-0.287; 0.168)
Protein E%	87.364 (63.027; 111.700)	87.600 (63.338; 111.862)	85.967 (61.578; 110.356)
Fat E%	-13.581 (-24.840; -2.322)	-11.931 (-23.280; -0.582)	-12.632 (-23.985; -1.280)
Saturated fat E%	-28.822 (-52.769; -4.874)	-27.773 (-51.678; -3.868)	-29.794 (-53.728; -5.86)0
Carbohydrates E%	-14.411 (-25.068; -.3.754)	-16.560 (-27.283; -5.837)	-16.767 (-27.55;9 -5.976)
Dietary fiber g/day	-43.644 (-157.465; 70.177)	-67.520 (-182.511; 47.471)	-53.330 (-169.442; 62.781)
Sugar E%	-35.926 (-55.614; -16.237)	-36.781 (-56.419; -17.143)	-36.90 (-56.550; -17.253)
Alcohol E%	21.681 (6.760; 36.602)	22.250 (7.367; 37.133)	24.733 (9.639; 39.827)
SL min/day	1.609 (1.019; 2.199)	1.608 (1.020; 2.196)	1.664 (1.074; 2.253)
LPA min/day	-3.220 (-3.906; -2.533)	-3.17 (-3.856; -2.477)	-3.33 (-4.019; - 2.636)
MVPA min/day	-8.679 (-10.601; -6.757)	-8.528 (-10.484; -6.571)	-8.577 (-10.573; - 6.581)

**Fully Adjusted for age, smoking, and education. CI- confidence interval 95%.*
Abbr: kj; kilojoules, E%; energy percentage, G; grams, MVPA; moderate to very vigorous physical activity

4 DISCUSSION

4.1 Main findings

This study aimed to investigate the relationship between VAT and diet and physical activity using the data from Tromsø7 study. This study measured diet with an FFQ, physical activity with an accelerometer, and visceral fat with a DXA scan. The research found a correlation between the NNR-recommended diet and WHO-recommended physical activity levels and a lower volume of VAT. With the exception of protein, fat, saturated fat, and alcohol, diet that adheres to the NNR recommendations was found to be inversely related to VAT.

The participants included in this study had more compliance with NNR recommendations in nutrients such as protein, total fat, alcohol, and sugar than for vegetables and fruits and berries. Dietary energy restriction has been the primary method for determining the impact of weight loss on VAT. The results from the present study are consistent with previous cross-sectional studies that examined the relationship between other diets and VAT and found a negative correlation (66).

VAT was negatively correlated with MVPA and LPA, whereas SL was found to be positively correlated with greater VAT volume. In a previous cross-sectional study, adherence to the Mediterranean Diet was not substantially associated with VAT, while physical activity has a negative relationship with VAT and, they found out is was positively associated with energy expenditure (67). Furthermore, A longitudinal study found out that reduced energy intake facilitated by prescribing portion-controlled entrees, in addition to increased physical activity resulted in greater loss of VAT (68). Diet and physical activity are complementary in maintaining low levels of VAT, as demonstrated by these findings. To gain a better understanding of the contribution of specific nutrients to cardiometabolic risk, additional research is required to determine whether various diets and total energy intake are differentially associated with VAT volumes.

4.2 Dietary intake

Vegetables, fruits, and berries

The findings of the present study indicate that vegetable, fruit, and berries intake has a negative correlation with VAT accumulation; however, in this study population, there was a low intake of these foods. A significant proportion of the participants did not consume the daily recommended amount of fruits and vegetables (250g each). In contrast to male participants, female participants exhibit a negative correlation between vegetable consumption and VAT. The lowest consumption of vegetables was found, particularly among male participants. However, those with higher levels of VAT in both sexes tended not to adhere more to daily intake recommendations. Our findings are consistent with those of a previous study, which discovered that a diet rich in fruits, vegetables, and plant-based fats and oils was associated with lower visceral obesity (69). A study of Latino adolescents concluded that the consumption of non-starch vegetables was associated with less liver fat deposition, while the consumption of dark green or brilliant orange vegetables was associated with less visceral fat and enhanced insulin sensitivity. Similarly, this population consumes less fruits and vegetables (70). Vegetables and fruits are consumed less frequently, this may be attributed to a preference for highly processed foods, a dislike of their texture, or deteriorating health resulting in a decreased appetite.

Protein

A diet high in protein has benefits for accelerating metabolism and sustaining weight loss and visceral fat loss in the body (71), however, in this study, there is a positive correlation between protein intake and VAT deposits. Even though the majority of participants adhered to the recommended protein intake range of 10–20% E%. This is probably due to the fact that the protein nutrient is grouped and not specific to what is consumed. The results of this study can be explained by the fact that excess protein consumption can lead to weight gain over time (72). Another study discovered that protein-rich diets are often high in fat, making it difficult to determine the benefits of consuming more fat (73).

Total Fat and Saturated fat

Excessive fat consumption is associated with negative health effects. Increased cholesterol is associated with excessive consumption of saturated fat, which increases the risk of cardiac disease (74). The majority of participants adhered to the recommended total fat intake guidelines (25–40E%), but men had better adherence compared to women. There was a marginally positive association between total fat intake and VAT in female participants, whereas there was a significantly negative association between total fat intake and VAT in male participants.

The majority of participants did not meet the NNR requirements because they consume more saturated fat than is recommended. The consumption of saturated fat exceeded the required 10

E% threshold. Due to its negative effects on health and the likelihood of developing excess visceral fat and other health concerns, a low intake of saturated fat is recommended. Limiting total fat intake results in a beneficial increase in the consumption of micronutrients and dietary fiber. Further reduction in dietary fat intake is associated with a reduction in body weight, and a reduction in a population's intake of saturated fatty acids results in lower total fat and low-density lipoprotein cholesterol levels (75). Reduced consumption of saturated fat results in decreased consumption of dietary cholesterol (75). In comparison to countries like Denmark, where total fat consumption (as a percentage of total energy) is 36% for both men and women, Norway's total fat intake (as a percentage of total energy) is 34% for both men and women (75).

Carbohydrates

There was a negative association between carbohydrates intake and VAT in both females and males. Both females and males exhibited a negative association between carbohydrate consumption and VAT. The participants had a slightly reduced carbohydrate intake, falling short of the NNR-recommended range of 45-60 E%. Similarly, in a prospective study involving a cohort of obese senior adults, researchers discovered that improvements in dietary carbohydrate quality over the course of a year were associated with significant changes in visceral fat deposition. The association was primarily driven by the ratio of dietary fiber to whole grains (76). In another study, a diet with a low carbohydrate intake, a high total energy intake, and a low added sugar intake significantly reduced the volume of VAT. In addition, they suggested different dietary profiles for individuals with intra-abdominal obesity based on personal preferences, without the need for strict energy restriction, in order to accomplish clinically significant and long-term fat loss (77). Studies have shown that diets low in carbohydrates are beneficial in lowering the amount of visceral fat that is stored in the body. (78). In an 8-week study involving 69 overweight participants, researchers discovered that those who followed a low carbohydrate diet lost 10% more visceral fat and 4.4% more total fat than those who followed a low-fat diet (78). The low carbohydrate intake of the participants in the Tromsø study prevented the accumulation of visceral fat.

Dietary Fibre

The results of this study are barely significant for females but not for males. Male findings are inconclusive. There may be an association for women, but more research is required to demonstrate it. Most of the female participants did not consume the recommended amount of dietary fiber, whereas the majority of male participants did not adhere to the recommendation. There are different dietary fiber recommendations for females (25g/day) and males (35g/day). Fiber is effective in suppressing appetite and has an effect on lessening VAT accumulation and overall weight (79). A study of 114 people found that simply increasing soluble intake by 10 grams daily reduced the risk of visceral fat gain by up to 3.7%, meaning that those who follow diets that are high in fiber tend to have less visceral fat than those who do not (80). The consumption of dietary fiber reduces the likelihood of developing chronic diseases. However, excessive consumption of fiber can cause bloating, gastrointestinal cramps, constipation, diarrhoea, and nausea (81).

Sugar

There was a negative correlation between sugar consumption and VAT for all participants. Participants in this trial consumed less sugar and food that was sweetened with sugar, which led to a large compliance rate in the sugar consumption measure. Consuming excessive amounts of sugar and sugary beverages is hazardous and causes weight gain and excess visceral fat. Therefore, it is recommended that individuals consume less sugar and consume more nutritious foods. This is consistent with a study conducted on 41 adolescents aged 9 to 18 in which scientists replaced fructose with starch containing the same number of calories. They discovered that VAT fell by 10.6 percent in just 10 days (82). People are encouraged to limit their consumption of sweetened foods and beverages to preserve their health.

Alcohol

A substantial proportion of participants adhered to the recommended alcohol intake. Females had a negative association between alcohol consumption and VAT, while males had a positive association. Higher levels of visceral were associated with increased alcohol consumption in both females and males. This study also revealed that men typically consume more alcohol than women. It has been confirmed that males consume more alcohol than women worldwide. In our current investigation, however, there is no distinction regarding the type of alcohol consumed; the results generalize on all types of alcohol. However, alcohol consumption has negative effects on health., Some studies indicate that excessive alcohol consumption promotes visceral fat storage (83).

Similarly, the findings are consistent with a study which found that men who consume more alcohol have higher levels of VAT (84). A high alcohol intake is positively correlated with a high VAT volume, which may result in fatty liver, insulin resistance in the liver, and further weight gain (85, 86) . In a study of 450 Japanese men, excessive drinkers had substantially higher VAT than those who abstained (87). The women in this study who consumed more alcohol had more VAT than their counterparts who drank less.

4.3 Physical activity

High level of physical activity was associated with lower VAT in both men and women, according to the results of this study. The results are consistent with a cross-sectional study which found a similar association between physical activity and reduced VAT volume in both sexes (84). This is further supported by prior prospective studies that have consistently shown that higher physical activity levels are associated with less weight gain and lower VAT (88, 89). In a separate study of middle-aged women and men, overall physical activity was associated with less visceral fat, whereas sedentary time was associated with greater visceral fat. Another research concluded that, visceral fat was found to increase with age and more in men than in women (90). In other studies, however, there was no association between age, gender, and VAT, indicating that they may have an indifferent association (67).

In this study the results show that objectively measured MVPA was associated with lower levels of VAT, in both female and males. A previous study found that MVPA was related with lower levels of visceral adipose tissue (VAT), and that replacing 30 minutes of sedentary time with MVPA was associated with lower levels of visceral fat (91). Participating in regular physical activity is an effective strategy for reducing visceral fat and preventing its accumulation. The most effective way to lower VAT is to engage in physical exercise of a moderate to high level. In a study involving 82 obese adults and objectively measured levels of sedentary time and physical activity, there was a faint positive correlation between moderate physical activity and visceral fat (92). It has been shown in a number of research that there is a correlation between physical activity and a reduction in visceral fat. (93). A prospective study of fat loss suggested that the association between physical activity and visceral adipose is due to a preferential reduction in response to exercise training (34).

Female average VAT was found to be lower than male average VAT; similar to the Pittsburgh site study of the prostate, lung, colorectal, and ovarian cancer screening trial (PLCO). There were 65 females and 106 males within the age range of 64.5 ± 5.2 years (94). They discovered that physical inactivity was independently associated with an increase in visceral adipose, and that there appears to be a threshold beyond which an increase in physical activity ceases to reduce visceral adipose (94). It is necessary to provide further support for the public health recommendations to increase physical activity in order to prevent the negative health effects that can result from increasing abdominal obesity in older females and males.

Sedentary Lifestyle

In the present study, there was a positive correlation between VAT and sedentary lifestyle. Female participants had an average of 572.7 minutes of sedentary time, while male participants averaged 607.9 minutes, with a median of 569.7 and 607.9 in females and males, respectively. These results showed that the participants spent more time sedentary, especially males. Participants who had more VAT depots recorded more sedentary time than their counterparts with less VAT. In a previous study of the National Health and Nutrition Examination Survey (NHANES) more sedentary time was associated with more VAT accumulation, furthermore men and women between the ages of 40-59, spent an average of 509 and 498 minutes per day sedentary respectively (95). In contrast to the previous study, the present study, participants spent more of their time sedentary. However, the data for sedentary time can be conflicting, in a 6-year follow-up study of adult men and women who reported sedentary lifestyle at baseline, there was no association between sedentary lifestyle or change in sedentary lifestyle and longitudinal in VAT (96). In a large cohort study, an association between sedentary time and VAT was not observed; therefore, it is unclear whether VAT accumulation is a factor linking sedentary lifestyle to cardiometabolic risk (97). The majority of older adults engage in an average of 9.4 hours of sedentary lifestyle per day, according to reports (98). In the current study the participants spent an average of 572.7 (9.5 hours) and 607.9 (10 hours) minutes while being sedentary for females and males, respectively. According to previous research, older individuals find physical activity incompatible with their self-perceptions and doubt the utility of physical activity; as a result, they do not engage in any physical activity (99). The elderly are more likely to have more VAT accumulation, because as they age, they become less physically active and adopt a sedentary lifestyle.

4.4 Limitations

The study's cross-sectional design makes it challenging to establish a cause-and-effect relationship. The findings of this study are supported by the findings of several other prospective studies that have revealed a cause-and-effect relationship between exercise and the decrease of visceral adiposity (34). The fact that the FFQ was self-administered means that it is susceptible to recall bias as well as measurement error; this is yet another drawback of the study. The nutrients and food groups were combined, but because they cover such a broad range, they could include both good and unhealthy foods, which would cause the results to be influenced by this combination. There is also no evidence that the quantity that was consumed can be determined. Nonetheless, a significant proportion of participants were excluded from the sample due to a lack of DXA scan or accelerometer-measured physical activity data, extreme or low energy consumption values, or failure to complete more than 90% of the FFQ. These exclusions result in selection bias, as some participants are omitted and may have an effect on the findings. Our cohort is only representative of the Norwegian adult population, so it cannot be applied to other ethnic groups. Another limitation of the study is that accelerometer-measured PA does not differentiate between recreational and occupational PA.

4.5 Strengths

This study's major strength was its use of a large random sample of older men and women. Visceral fat was measured using a DXA scan, which is a reliable and accurate method for determining VAT. The accelerometer objectively measured physical activity for more precise measurements. Typically, PA relies on self-report, resulting in recall bias. Another asset of the study is that it focuses on two lifestyle factors that are directly associated with body weight change. Adjusting for several potential confounding variables assists in determining the association with VAT.

4.6 Conclusion

In conclusion, based on data Tromsø7 study, dietary intake and objectively measured physical activity were negatively associated with VAT, whereas a sedentary lifestyle was positively associated with VAT. Compliance with NNR dietary and an increase in physical activity intensity were found to be beneficial in reducing VAT accumulation. However, physical activity is more associated with less VAT, than with diet. Diet and physical activity go hand-in-hand for enhanced results in reducing excessive VAT and maintaining healthy lifestyle. More research is required to expand the body of knowledge.

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Appendix 1: Decision from the Tromsø Study Data and Publication Committee

UiT Norges arktiske universitet

Avtale

mellom

Tromsøundersøkelsen, Institutt for samfunnsmedisin,

UiT Norges arktiske universitet

og

Marie Wasmuth Lundblad, Institutt for samfunnsmedisin, Universitetet i Tromsø - UiT

om utlevering av forskningsdata fra Tromsøundersøkelsen

Prosjektnummer EUTRO: **8030.00554**

Prosjekttittel:

The association between visceral fat and lifestyle factors in adult population: The Tromsø study 2015-2016

Avtalen bygger på skriftlig søknad med prosjektbeskrivelse og publikasjonsplan, samt godkjenning i Data og Publikasjonsutvalget for Tromsøundersøkelsen. Det forutsettes at arbeidet med data skjer i henhold til *Retningslinjer for tilgang til forskningsdata fra Tromsøundersøkelsen*, datert 6.2.2013.

En avidentifisert datafil utleveres til **Marie Wasmuth Lundblad, UiT.** Prosjektleder kan la samarbeidspartnere som er nevnt i prosjektsøknaden få analysere data, så fremt arbeidet holder seg innenfor rammen for prosjektbeskrivelsen og publikasjonsplanen. Prosjektleder har ansvar for datasikkerheten og at data oppbevares forsvarlig i hht lover og forskrifter.

Retten til data gjelder til **31.01.2024**. Når analysene er fullført, skal datasettet slettes og bekreftelse om dette sendes skriftlig til Tromsøundersøkelsen. Dette skal ikke skje senere enn **31.01.2024** med mindre ny avtale om forlengelse er inngått. Eventuelle nye data skal tilbakeføres til Tromsøundersøkelsen, jfr. pkt. 10 i retningslinjene. Pris for å benytte seg av data i henhold til ovennevnte avtale er som følger: kr. 0,-

Sted, dato	Sted, dato
______________________	Tromsø, 18.01.2023
______________________	Tom Wilsgaard
Prosjektleder	For Tromsøundersøkelsen

Tromsø-undersøkelsen