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Associations of visceral fat, physical activity and muscle strength with the metabolic syndrome

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ABSTRACT

Objective: We investigated the association of visceral fat with the metabolic syndrome (MetS) and its separate components; the associations of both physical activity and muscle strength with the MetS and its separate components independent of visceral fat. Furthermore, we studied these associations within participants with low and high amounts of visceral fat.

Study design: 400 men (aged 40–80 years) were recruited into a cross-sectional study.

Main outcome measures: Logistic regression models were used to study the individual associations in all participants (OR). The associations of physical activity (active vs inactive) and muscle strength (high vs low) within participants with low and high levels of visceral fat (assessed by ultrasonography) were tested using Univariate Analysis of Variance (difference in mean levels of the separate components of MetS) and logistic regression (risk on MetS).

Results: High levels of visceral fat were significantly associated with increased risk of MetS (OR 1.7 95%CI 1.5;1.9) and its separate components ($p < 0.05$). We did not find strong individual associations for physical activity or muscle strength, neither within men with low or high levels of visceral fat.

Conclusions: High body fat levels were associated with an unhealthier metabolic risk profile and a higher risk of the MetS. Our cross-sectional data do not indicate associations for physical activity or for muscle strength with the MetS independent of visceral fat. Also no differential associations of physical activity or muscle strength in men with low or high levels of visceral fat were found.

1. Introduction

The metabolic syndrome (MetS) is related to a 2-fold increased risk of all-cause mortality, as well as a 2-fold increased risk of cardiovascular mortality, while risk of type 2 diabetes is increased 3-fold [1–4]. MetS is defined as having 3 or more of the following 5 metabolic risk factors: abdominal obesity, elevated triglycerides, reduced high-density lipoprotein (HDL) cholesterol, elevated blood pressure, and/or elevated fasting glucose [5,6]. Among adults in Western society, the prevalence of the me MetS is around 25% and is increasing [6–8].

High body fat levels are associated with an increased risk on the MetS [5]. High levels of physical activity are associated with lower levels of total body fat and abdominal fat [9–16]. Therefore, high levels of physical activity might lower the risk of the MetS. However, it is not clear if this effect is also observed in obese people, who have a higher risk on the MetS.

According to previous studies, physical inactivity is known to increase the incidence of several chronic diseases or considered risk factors for chronic diseases [17,18]. However, whether these effects of physical activity are independent of visceral fat is not clear yet.

So far, only a few studies investigated the effects of physical activity, muscle strength or physical fitness on metabolic risk factors independently of body fat [19–23]. These were mainly done in young participants and results were inconclusive. Some found an independent effect of physical fitness on LDL cholesterol levels [21,22] or on triglyceride levels [21], or an independent effect of physical activity on the MetS [23], whereas others reported no effect [19,20].

Here, we studied the association of visceral fat with the metabolic syndrome (MetS) and its separate components; the associations of both physical activity and muscle strength with the MetS and its separate components independent of visceral fat. Furthermore, we studied these associations within participants with low and high amounts of visceral fat. For this purpose, we used a population-based sample of 400 Dutch men aged between 40 and 80 years.

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2. Methods

2.1. Study population

The study is a cross-sectional, single-centre study in 400 independently living men aged 40–80 years [24]. The men were recruited by contacting former (female) participants of studies conducted by the Julius Center (University Medical Centre Utrecht, The Netherlands). 770 women were sent letters asking if they knew men, aged between 40 and 80 who might be interested in taking part in the study. This resulted in 240 men volunteering to participate. Furthermore, 1230 invitation letters were sent to randomly selected male inhabitants of Utrecht, The Netherlands, aged 40–80 years. From this group, 390 men volunteered for participation (participation rate of 31.7%). From the 630 volunteers, those who did not live independently and subjects who were not physically or mentally able to visit the study centre independently were excluded ($n = 16$). No additional health-related eligibility criteria were used. Of the remaining 614 men, eventually 400 men were randomly selected to participate, 100 in each age decade. All participants gave written informed consent. All measurements were taken in a standardized way by a medical doctor.

2.2. Visceral fat

Ultrasonography of the abdomen was performed to determine the amount of abdominal visceral fat. Validation against computed tomography (CT) and magnetic resonance imaging (MRI) showed that abdominal ultrasound is a reliable and reproducible method to assess the amount of abdominal visceral fat [25–28]. The distances between the posterior edge of the abdominal muscles and the lumbar spine or psoas muscles were measured. For all images, the transducer was placed on a straight line drawn between the left and right midpoint of the lower rib and iliac crest. A mark was made in the middle, 10 cm from the left and right side. Distances were measured from 3 different angles: medial, left, and right for intra-abdominal fat mass and medial for subcutaneous fat mass. The medial measurement was performed twice during the same ultrasound measurement. Measurements were made at the end of quiet expiration, applying minimal pressure without displacement of intra-abdominal contents as observed by ultrasound image. The amount of abdominal visceral abdominal fat was expressed in centimetres.

2.3. Muscle strength

Muscle strength was defined as isometric grip strength and leg extension power.

Isometric grip strength was measured in Newton using an adjustable hand dynamometer. Participants were in standing position with the arm in a 90° flexion and neutral wrist. They were instructed to squeeze the grip with the non-dominant hand three times, using maximal strength. The mean isometric grip strength was calculated from the outcomes of the three measurements and used for the analysis. Handgrip strength has previously been described as method for assessing general muscle strength and function [29].

Leg extension power of both legs in Newton was measured using a hand-held dynamometer. The maximum strength of the participant was measured three times. The best result of each leg was used for the analysis.

2.4. Physical activity

Physical activity was evaluated by self-report using the modified Baecke questionnaire which assesses physical activity over the past year including household activities, sports activities and leisure time activities [30]. The questionnaire was validated previously in independent-living elderly persons in The Netherlands [31–33]. The questions on household activities have four to five possible answers, classifying the activity from inactive to very active. Questions about sport and leisure time activities include the type, frequency, and the number of months per year that the activity is performed. All items result in a separate score that reflects the activity duration, frequency, and intensity. Summing the household score, sport score, and leisure time activity score results in a continuous overall activity score (range 1.1–41.95). A low score indicates low physical activity levels.

2.5. Metabolic risk factors

Blood pressure was measured twice in the right brachial artery with a semi-automated device (Dinamap, GE HealthCare, Tampa, FL). The average of the two measurements was used for analysis. A venapuncture was performed, and fasting blood samples were obtained. Fasting blood glucose was measured by using a reagent-strip glucose oxidase method, GlucoTouch reflectometer (LifeScan, Inc., Benelux). Venous whole blood was immediately applied to the test strip. Platelet free serum was obtained by centrifugation and was immediately stored in −20 °C. An automatic enzymatic procedure was used to determine HDL cholesterol and triglycerides (Synchron LX Systems; Beckman Coulter, Mijdrecht, The Netherlands).

2.6. Covariates

Information on smoking status (never, current past), education level (low, middle, high/university) and prevalence of chronic diseases (including cardiovascular and coronary heart diseases, diabetes, angina pectoris, malignancy, pulmonary diseases and peripheral arterial diseases) was obtained by questionnaires. Alcohol consumption (units/week) and the average daily energy intake (kcal/day) were assessed by a validated Food Frequency Questionnaire (FFQ) designed to estimate regular intake of 178 food items in the year prior to enrolment [34].

2.7. Data-analysis

We studied the association of visceral fat with the MetS and its separate components; the associations of both physical activity as well as muscle strength with the MetS and its separate components independent of visceral fat; and we studied these associations within participants with low and high amounts of visceral fat.

MetS and its separate components were defined according to the National Cholesterol Education Program (NCEP) as having 3 or more of the following 5 metabolic risk factors above a critical value: waist circumference > 102 cm (abdominal obesity); plasma triglycerides > 1.7 mmol/l (150 mg/dl) (hypertriglyceridemia), plasma high-density lipoprotein (HDL) cholesterol < 1.0 mmol/l (40 mg/dl), high blood pressure (≧ 130/85 mm Hg or anti-hypertensive medication) (hypertension), fasting plasma glucose levels ≧ 6.1 mmol/l (110 mg/dl) (hyperglycaemia) [5,6].

Logistic regression models were used to study the individual associations of visceral fat (cm), physical activity (total physical activity score of the modified Baecke questionnaire) muscle strength (first defined as grip strength (Newton) and additionally defined as leg extension power (Newton)) with MetS (yes/no) and its separate components (metabolic risk factor above critical value yes/no).

Four subgroups were made to study the association of physical activity with the MetS (and its separate components) within participants with low and high levels of visceral fat: