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Original article

Adherence to the Mediterranean diet is inversely associated with visceral abdominal tissue in Caucasian subjects

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SUMMARY

Background: & aim: Adherence to the Mediterranean dietary pattern (MDP) is inversely related with abdominal adiposity as detected by waist circumference but the specific association to subcutaneous and visceral abdominal tissue has not been investigated. To this purpose we evaluated the association between MDP, visceral (VAT) and subcutaneous (SAT) abdominal tissue in a large sample of Italian adults.
Methods: A cross-sectional study was carried out on 4388 consecutive adults (73.2% women) followed as outpatients at Nutritional Research Centre in Milan, ICANS. VAT and SAT were measured by ultrasonography. MDP was evaluated using a Mediterranean dietary score (MEDscore) obtained from a validated 14-item questionnaire.
Results: At multiple linear regression adjusted for sex, age, smoking and physical activity, a 1-unit increase in MEDscore was associated with a −0.118 kg/m^2 decrease in BMI ($p < 0.01$), a −0.292 cm decrease in waist circumference ($p < 0.01$), a −0.002 cm:cm decrease in waist to height ratio ($p < 0.001$), a −1.125 mm decrease in the sum of 4 skinfolds ($p < 0.001$), and with a −0.045 cm decrease in VAT ($p < 0.05$). MEDscore was, however, not associated with SAT. Finally, the adherence to the MDP was a protective factor for obesity (OR = 0.717, 95%CI: 0.555−0.922) and VAT excess (OR = 0.717, 95%CI: 0.530 −0.971).
Conclusion: Our study confirms the inverse association between MDP, BMI and waist circumference and adds that the association with abdominal obesity as detected by waist circumference is due to an association with VAT and not with SAT.

1. Introduction

Abdominal obesity is associated with metabolic syndrome and cardiometabolic diseases [1]. However, abdominal fat is composed of visceral abdominal fat tissue (VAT) and subcutaneous abdominal fat tissue (SAT) [2]. VAT plays a central role in the pathogenesis of metabolic syndrome [1,3] and is an independent predictor of cardiometabolic diseases [4]. Whether and to what degree subcutaneous abdominal fat tissue (SAT) contributes to cardiometabolic diseases is however the matter of substantial debate [3]. Computed tomography (CT) and magnetic resonance imaging (MRI) are the reference methods for the assessment of VAT and SAT. However, because of their high costs and exposure to ionizing radiation, they

Abbreviation: CT, Computed tomography; MDP, Mediterranean dietary pattern; MRI, Magnetic resonance imaging; SAT, Subcutaneous abdominal tissue; SF4, Sum of four skinfolds; VAT, Visceral abdominal tissue; WC, Waist circumference; WHtR, Waist-to-height ratio.

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cannot be used in routine clinical practice and epidemiological research. Ultrasonography offers a validated, cheap and non-invasive alternative to reference methods [5–7] and it has already been used in previous epidemiological researches [8,9].

Diet and lifestyle play a major role in the development of general and abdominal obesity [10]. In particular, the Mediterranean dietary pattern (MDP), moderate alcohol consumption, daily physical activity and nonsmoking, are associated with lower prevalence of general and abdominal obesity [10]. MDP, characterized by high consumption of olive oil, fruits and vegetables, nuts, fish and legumes, low consumption of saturated fats and sugars, and moderate consumption of wine, has been reported to be inversely associated with BMI, waist circumference (WC) and waist-to-height ratio (WHtR) in many cross-sectional studies and some cohort studies [10–18]. These results suggest that MDP may be related to abdominal fat distribution. However, such studies employed WC as surrogate measure of abdominal fat but WC does not allow to separate VAT from SAT [19] so that the association between MDP, VAT and SAT is presently unknown.

The aim of this study was to evaluate the association between MDP and VAT and SAT measured by ultrasonography in a large sample of adults.

2. Subjects and methods

2.1. Study design

4388 men and women were consecutively enrolled into the study at ICANS between June 2009 and September 2013. All came to ICANS to obtain a thorough nutritional assessment and/or to enter a structured weight loss program. Subjects aged $\geq$18 years and $\leq$80 years were studied. Exclusion criteria were: abdominal scars from previous surgery in the area of the ultrasound measurements, neurological, gastrointestinal, cardiac, renal and pulmonary failure, cancer, acute illness and use of medications known to cause lipodystrophy including steroids and antiretroviral agents. A very high activity level (participation in sports or training for greater than 12 h/week) was reason of exclusion as well. All measurements were performed on fasting subjects during the morning. A physician collected a clinical history and performed ultrasonographic assessment of VAT and SAT. A dietician performed anthropometric measurements and collected a structured interview on dietary and lifestyle habits (physical activity level and smoke attitude) [20]. Lastly, the patients were administered a validated questionnaire to assess MDP [21,22]. The study was carried out according to the Declaration of Helsinki and all subjects gave written informed consent. The institutional review board approved the study procedures.

2.2. Anthropometry

Anthropometric measurements were performed following international guidelines [23]. Body weight was measured to the nearest 100 g using a Seca 700 scale and height was measured to the nearest 0.1 cm using a Seca 217 vertical stadiometer (Seca Corporation, Hanover, MD, USA). BMI was calculated as weight (kg)/height (m^2) and classified according to the World Health Organization. Waist circumference was measured midway between the lower rib margin and the superior anterior iliac spine. WHtR was calculated as WC (cm) divided by height (cm). Skinfolds (triceps, biceps, subscapular and suprailiac) were measured using a Tanner-Whitehouse calliper (Holtain Ltd, Crymych, UK). The skinfolds were then summed to obtain the sum of four skinfolds (SF4). In our Centre, the intra-observer coefficient of variation for repeated measurements of these skinfolds is $\leq$ 2.9%.

2.3. Abdominal ultrasonography

Abdominal US was performed on fasting patients by the same operator using a Logiq 3 Pro equipped with a 3.5 MHz convex-array probe and with a 7.5 MHz linear probe (GE Healthcare, Milwaukee, WI, USA). VAT and SAT were measured 1 cm above the umbilicus. The examination was performed at end-expiration and same pressure of the ultrasonographic probe was applied for all participants. SAT was measured with the 7.5 MHz linear probe as the distance between the epidermis and the external face of the *rectus abdominis* muscle, VAT was measured with the 3.5 MHz convex-array probe as the distance between the anterior wall of the aorta and the posterior surface of the *rectus abdominis* muscle [5]. Each measurement was performed three times and a mean was calculated. The within-dayintra-operator coefficient of variation for repeated measures of VAT and SAT in our laboratory is 0.8%.

2.4. Mediterranean dietary pattern

MDP was evaluated using a validated 14-item questionnaire [21,22], which is the extension of an original 9-item questionnaire [24]. A Mediterranean score (MEDscore) was obtained from this questionnaire following Estruch et al. [21]. Briefly, one point was attributed for each of the following: 1) olive oil as main cooking fat,

Table 1
Measurements of the study subjects.

	Women (n = 3214)	Men (n = 1174)	Total (n = 4388)
Age (years)	45 (37–55)	47 (39–57)	46 (37–56)
Weight (kg)	70.8 (63.5–79.4)	89.6 (81.4–98.1)	75.2 (66.0–86.7)
Height (m)	1.62 (1.57–1.66)	1.75 (1.70–1.79)	1.64 (1.59–1.71)
BMI (kg/m^2)	27.2 (24.4–30.4)	29.3 (27.0–32.0)	27.9 (25.0–31.0)
BSF (mm)	15 (11–20)	10 (7–13)	13 (9–18)
TSF (mm)	28 (23–32)	17 (13–22)	25 (19–31)
SSF (mm)	28 (20–36)	30 (24–36)	29 (21–36)
SISF (mm)	37 (31–42)	40 (34–44)	38 (32–42)
SF4 (mm)	109 (88–128)	98 (81–113)	105 (86–124)
WC (cm)	89.6 (81.7–97.4)	103.5 (96.0–111.0)	93.2 (84.2–102.5)
WHtR (cm/cm)	0.55 (0.50–0.61)	0.59 (0.55–0.64)	0.57 (0.52–0.62)
VAT (mm)	3.97 (2.92–5.50)	6.87 (5.13–8.77)	4.61 (3.20–6.54)
SAT (mm)	2.69 (1.97–3.48)	2.48 (1.75–3.31)	2.63 (1.90–3.44)
MEDscore (units)	7.0 (5.0–8.0)	7.0 (6.0–8.0)	7.0 (5.0–8.0)

Values are reported as median and interquartile range (between parentheses).
Abbreviations: BMI = body mass index; BSF = biceps skinfold; TSF = triceps skinfold; SSF = subscapular skinfold; SISF = suprailiac skinfold; SF4 = sum of four skinfolds; WC = waist circumference; WHtR = waist to height ratio; VAT = visceral adipose tissue; SAT = subcutaneous adipose tissue.