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Low skin carotenoid concentration measured by resonance Raman spectroscopy is associated with metabolic syndrome in adults

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ARTICLE INFO

Article history:
Received 9 May 2014
Revised 21 August 2014
Accepted 29 August 2014

Keywords:
Skin carotenoids
Resonance Raman spectroscopy
Antioxidant
Obesity
Metabolic syndrome

ABSTRACT

Oxidative stress is increased in patients with metabolic syndrome (MS). Antioxidants, including carotenoids, are decreased in MS. We hypothesized that a low skin carotenoid score (SCS), calculated using resonance Raman spectroscopy, would correlate with the presence of MS. We retrospectively reviewed consecutive patients referred for dietary assessment between 2010 and 2012. For each patient, a nutrition history, medical history, and SCS were recorded. χ^2 and Student t test were used to determine factors associated with MS. Multivariate logistic regression was used to identify factors associated with MS. One hundred fifty-five patients were included. The mean age was 54.1 ± 13.1 years, and the mean body mass index was 28.3 ± 6.1 kg/m^2. Metabolic syndrome was present in 43.9% of patients. The mean SCS was 28 084 ± 14 006 Raman counts (RC), including 23 058 ± 9812 RC for patients with MS and 32 011 ± 15 514 RC for patients without MS (P = .0001). In a multivariate analysis, SCS less than 25 000 RC (odds ratio, 3.71; 95% confidence interval, 1.36-10.7; P = .01) was independently associated with MS. A higher number of MS components was associated with a progressively lower SCS (P = .004). In a consecutive sample of patients referred for dietary assessment, a noninvasively measured SCS was lower among patients with MS.

1. Introduction

Metabolic syndrome (MS), defined by obesity, glucose intolerance, dyslipidemia, and hypertension, has been linked to cardiovascular disease, cerebrovascular disease, and liver disease [1–6]. A recent report from the US Centers for Disease Control estimates that 34% of Americans have MS [7]. Oxidative stress, including hyperhomocysteinemia, contributes to vascular injury and other complications of MS [8]. Antioxidants reduce oxidative stress in MS by scavenging reactive oxygen species and preventing tissue injury [9–15]. Carotenoids, found in a wide variety of fruits and vegetables, are an important dietary source of antioxidants. Published data suggest that carotenoids may reduce the risk of

Abbreviations: BMI, body mass index; HDL-C, high-density lipoprotein cholesterol; MS, metabolic syndrome; RC, Raman counts; RRS, resonance Raman spectroscopy; SCS, skin carotenoid score.

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http://dx.doi.org/10.1016/j.nutres.2014.08.017
0271-5317/

cardiovascular disease, cancer, and ocular disease [16,17]. Patients with MS have lower serum levels of antioxidants, including carotenoids. Likewise, a diet enriched with carotenoids is associated with a lower prevalence of MS [18].

Serum carotenoid levels have been used as a biomarker for oxidative stress [19]. However, their measurement requires phlebotomy and is therefore associated with discomfort and expense. Resonance Raman spectroscopy (RRS) allows for noninvasive, accurate, and reproducible measurement of carotenoids in human skin based on a recognizable pattern of scattered monochromatic light produced when carotenoids interacting with laser light [20–22]. Skin carotenoid levels measured by RRS have been shown to correlate with serum carotenoid levels [23–25]. In addition, measurement of skin carotenoids using RRS has been shown to correlate with fruit and vegetable intake [26,27].

Few studies have examined the association between MS and skin carotenoid levels. We hypothesized that a skin carotenoid score (SCS), calculated noninvasively using RRS, would correlate with the presence or absence of MS. We aimed to test the correlation between SCS and MS in patients with a broad spectrum of metabolic risk factors.

2. Methods and materials

2.1. Patient enrollment

The study was approved by our center's institutional review board; consent was waived due to the study's retrospective design. We reviewed the records of consecutive adult patients who were referred to our center for dietary assessment between December 2010 and June 2012. Our center is a local and tertiary referral center for patients in San Francisco and across Northern California. Patients in the study were referred to a private practice dietitian by their primary physician; data were collected for clinical purposes only. Laboratory, clinical, and spectroscopic data were retrospectively collected for each patient through medical record review.

2.2. Resonance Raman spectroscopy

Each patient underwent a single measurement of skin carotenoids from the palm of the hand using the Biophotonic Scanner (Pharmanex; Nu Skin Enterprises, Provo, UT, USA). Patients were instructed to place their palm in front of the scanner's laser for up to 3 minutes while the local carotenoid concentration was measured. Blue laser light from the scanner produces excitation of the major carotenoids found in human skin, which scatter within a narrow range of wavelengths between 440 and 450 nm [28]. Resonance Raman spectroscopy calculation of skin carotenoid concentration is based on the peak absorbance signal generated by excitation of skin carotenoids. The SCS, reported in the nonstandardized unit Raman counts (RC), correlates directly with the concentration of carotenoid molecules in the skin. All measurements were taken by a single experienced operator (N.B.).

2.3. Metabolic syndrome

A diagnosis of MS was made based on the National Cholesterol Education Program Adult Treatment Panel III [29]. Body mass index (BMI) was used in place of waist circumference, as has been previously reported [30]. Metabolic syndrome was defined as 3 or more of the following at the time of SCS measurement: (1) BMI ≥30 kg/m^2, (2) triglycerides ≥150 mg/dL or on medication for hypertriglylceridemia, (3) high-density lipoprotein cholesterol (HDL-C) <40 mg/dL in men or <50 mg/dL in women or on medication for low HDL-C, (4) systolic blood pressure ≥130 mm Hg, diastolic blood pressure ≥85 mm Hg or on antihypertensive medication, (5) fasting glucose ≥100 mg/dL, or on diabetic medications. Criteria for diagnosis were established through medical record review.

2.4. Nutrition history

A standard nutrition history was obtained during each clinical visit. Body mass index was calculated from measured weight and self-reported height. Patients were asked to quantify their fruit and vegetable intake and report "juicing" (extraction of juice from fruits or vegetables) or the use of nutritional supplements. Alcohol intake, activity level, and the use of tobacco and dietary supplements were self-reported using a standardized questionnaire. The cutoff for fruit and vegetable intake was set at 5 servings/d or greater, based on previously published data [31]. The cutoff for exercise was set at 3 h/wk or greater, the amount above which weight loss is likely to occur [32]. Laboratory values were included if they were obtained within 12 months of SCS measurement.

2.5. Statistical analyses

χ^2 and Student t test were used to determine factors associated with MS. Multivariate logistic regression was used to identify independent predictors of MS [33]. Variables entered into the multivariate analysis included age, sex, SCS, fruit and vegetable intake, and weekly exercise. Body mass index was not included as a predictor variable because it is part of the outcome variable, MS. Skin carotenoid score was tested both as a dichotomous and a continuous variable. When tested as a dichotomous variable, the median value for all patients was used as a cutoff: 25 000 RC. Additional analysis was performed to examine the relationship between SCS and the number of MS components. Differences were considered statistically significant if $P < .05$.

3. Results

One hundred sixty-two consecutive patients underwent nutritional evaluation. Six subjects were excluded for insufficient data, and 1 was excluded because of age less than 18 years. One hundred fifty-five patients met the inclusion criteria and were included in the analysis.

In the study cohort of 155 patients, 44% were male, 78% were white, 9% were African American, 10% were Asian, 3% were Hispanic, and less than 1% were Native American. The