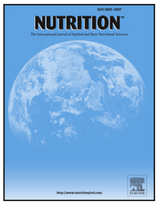
Nutrition 49 (2018) 96–101

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com



Applied nutritional investigation

Encouraging effects of a short-term, adapted Nordic diet intervention on skin microvascular function and skin oxygen tension in younger and older adults

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ARTICLE INFO

Article history:
Received 28 March 2017
Received in revised form
26 June 2017
Accepted 1 November 2017

Keywords:
Nordic diet
Laser Doppler flowmetry
Oxygen tension
microcirculation
sedentary adults

ABSTRACT

Objectives: The microvascular benefits of regional diets appear in the literature; however, little is known about Nordic-type diets. We investigated the effects of a short-term, adapted, Nordic diet on microvascular function in younger and older individuals at rest and during activity.
Methods: Thirteen young (mean age: 28 y; standard deviation: 5 y) and 15 older (mean age: 68 y; standard deviation: 6 y) participants consumed a modified Nordic diet for 4 wk. Laser Doppler flowmetry and transcutaneous oxygen monitoring were used to assess cutaneous microvascular function and oxygen tension pre- and postintervention; blood pressure, body mass, body fat percentage, ratings of perceived exertion, and peak heart rate during activity were examined concurrently.
Results: Axon-mediated vasodilation improved in older participants (1.17 [0.30] to 1.30 [0.30]; $P < 0.05$). Improvements in endothelium-dependent vasodilation were noted in both young (1.67 [0.50] to 2.03 [0.62]; $P < 0.05$) and older participants (1.49 [0.37] to 1.63 [0.39]; $P < 0.05$). Reduced peak heart rate during activity was noted in older participants only (36.5 [8.9] to 35.3 [8.5]; $P < 0.05$) and reduced body fat percentage in young participants only (young = 27.2 [8.3] to 25.2 [8.8]; $P < 0.05$). No other variables reached statistical significance; however, trends were observed.
Conclusions: We observed statistically significant improvements in microvascular function, peak heart rate, and body composition. An adapted Nordic diet might improve microvascular health.

Introduction

Cardiovascular disease (CVD) is the number one cause of death worldwide with 17.5 million deaths reported in 2012 [1]. Risk factors for developing CVD include inflammatory diseases such as type II diabetes and hypertension, aging, sex, and lifestyle factors such as smoking and poor nutrition [1]. Endothelial dysfunction, a pathologic condition characterized by impaired vasodilation and systemic inflammation [2], is a precursor of acute coronary syndromes, atherosclerosis, and CVD [3]. However, endothelial dysfunction appears to be reversible, and endothelial health can be improved by modifying cardiovascular risk factors [2]. Therefore, emerging literature has sought to investigate the effects of lifestyle modifications as possible treatment strategies [4], and dietary intervention is one lifestyle modification that appears promising [5].

However, dietary interventions are difficult to sustain, and factors such as taste preferences, culinary habits, and social acceptability might contribute to poor long-term adherence [6]. Bere and Brug [7] recommend that strategies that are tailored to regional eating preferences might lead to better long-term success and, interestingly, data are beginning to suggest that regional diets might offer health benefits. Indeed, evidence now suggests that the Mediterranean diet can reduce the risk of CVD [5], alleviate metabolic syndrome [8], reduce blood pressure, and enhance weight loss [9].

The Nordic diet is a regional diet that encourages the consumption of Nordic vegetables and fruits as well as whole grains, fish, rapeseed oil, and low-fat dairy products. Early data suggest

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Sources of support: This study was funded by the University of Sheffield and Sheffield Hallam University. The consumables supplied to the participants were provided by the Iceland Foods Charitable Foundation. No funding body or organization contributed to or influenced the design of the study or the collection, analysis, and interpretation of data or the writing of the manuscript.

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https://doi.org/10.1016/j.nut.2017.11.001
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that this diet might lead to reduced inflammation [10], improved insulin metabolism [11], and weight loss [6]. The cardiovascular health benefits of the diet are also beginning to appear in the literature: Adamsson et al. [12] demonstrated that a 10-wk intervention led to lower cholesterol, reduced blood pressure, and decreased serum insulin in patients with hypercholesterolemia.

However, to date, the microvascular health effects of Nordic diets have yet to be explored. The integrity of the microcirculation to sustain blood flood, tissue oxygenation, and nutrient delivery affects susceptibility to disease and appears to decline with age [13]. Therefore, the identification of strategies that maintain or improve microvascular function are important for sustaining long-term health.

The aim of this study was to investigate the effects of a short-term, adapted Nordic diet (AND), modified for British taste preferences, on the microvasculature by assessing tissue oxygenation and endothelial function. The circulatory system functions differently at rest and during activity [14], and age-related endothelial dysfunction, characterized by diminished arterial vasodilation and reduced nitric oxide supply, has been observed in older adults [15]. Therefore, we compared the effects of the diet in younger (18–35 y old) and older, sedentary participants (55–75 y old) at rest and during submaximal exercise. We hypothesized that the intervention would improve microvascular health and endothelial function in both groups, with older participants experiencing greater improvements.

Material and methods

Ethical approval

Ethical approval for this research was granted by Sheffield Hallam University's Health and Wellbeing Research Ethics Committee. This research was conducted in accordance with the Declaration of Helsinki.

Participants

A total of 16 young participants ages 18 to 35 y (mean 28 y [standard deviation (SD), 5 y]) and 16 older participants ages 55 to 75 y (mean 64 y [6 y]) provided informed consent. Recruitment took place via posters, word of mouth, and through the emailing systems of Sheffield Hallam University and the University of Sheffield. Participants' eligibility was assessed preintervention using physical activity and nutrition questionnaires.

The long International Physical Activity Questionnaire (IPAQ) was used to assess physical activity; scores >3000 metabolic equivalent of task min/wk would necessitate participants' exclusion due to non-sedentariness. A validated Nordic Diet Score (NDS) questionnaire [16] was used similarly, and participants who scored >5 points also were excluded. Additional exclusion criteria included smoking, pregnancy, and chronic conditions that might affect safe participation.

Dietary intervention

Participants were advised to adhere to Public Health England's portion size guidelines [17] but to follow the AND without restricting energy. During initial assessments, participants were briefed about AND-compliant foods (Table 1), obtained individualized diet plans, and were provided with materials (e.g., recipes) and food items (e.g., root vegetables, cruciferous vegetables, fish, rye bread, and apples; enough for 2 wk) to improve adherence and foster behavior change [18]. Participants were also instructed to complete a 3-d diet diary pre- and postintervention (two assessments); data were entered into software (Nutritics, Dublin, Ireland), which incorporated the McCance and Widdowson's UK Composition of Food Database [19] within its databank (Nutritics Ltd, Version 1.7, Dublin, Ireland) for dietary analysis.

Kcals, total and saturated fat, protein, carbohydrates, fiber, and omega 3 (total *n*-3) were calculated to measure dietary changes that might affect microvascular function [20]. Follow-up consultations were conducted via telephone and email at weeks 1 and 3 to foster support, and a private social media group similarly was created to engender social support [18]. Participants were advised to maintain activity as indicated by their preintervention International Physical Activity Questionnaire scores; no physical activity intervention was provided.

Table 1
Nordic foods

Vegetables	Fruit	Fish/Meat	Grains	Other
Cabbages	Blueberries	Game	Wholegrain breads	Dill
Cauliflower	Blackcurrants	Poultry	Rye	Parsley
Broccoli	Redcurrants	Cod	Oats	Chive
Kale	Gooseberries	Salmon	Barley	Legumes
Onions	Apples	Herring		Rapeseed oil
Swede	Pears	Haddock		
Carrots	Plums	Mackerel		
Beetroot		Halibut		
Turnip				
Potatoes				
Parsnips				
Mushrooms				

Protocol

We used laser Doppler flowmetry (LDF) and transcutaneous oxygen monitoring (TcPO2) to assess microvascular function pre- and postintervention per the procedures described by Wasilewski et al. [21]. LDF was used to determine cutaneous microvascular responsiveness to local heating [22] and TcPO2 was used to assess tissue oxygen supply [23]. To measure LDF and TcPO2 pre- and postintervention, we required participants to attend the laboratory on two occasions, separated by a 4-wk intervention period, and instructed them to abstain from caffeine before attending to eliminate acute vasoconstriction [24]. Stature (cm) body mass (kg), body fat percentage, and body mass index (BMI; kg/m^2) were measured concurrently using a segmental body-composition analyzer (InBody 720, Derwent Healthcare) and compared at both time points.

LDF procedure

Microvascular blood flow was measured as cutaneous red blood cell flux using an LDF (Periflux system 5000, Perimed 122 AB, Järfälla; Sweden) and a seven-point LDF probe (Probe 413, 123 Perimed AB) using the procedures outlined by Tew et al. [13]. Participants were acclimated to a temperature-controlled room (ambient temperature set to 22°C–24°C) before collection of data. Participants' forearms were cleansed before attaching the LDF probe to the skin on the underside of the right arm, avoiding veins and hair, to circumvent abnormal readings. Local thermal hyperemia was induced with a heating disk (Model 455, Perimed AB) connected to a heating unit (Model 5020, Perimed AB), and LDF signals were recorded using PeriSoft software (PSW 9.0).

Baseline blood-flow data were recorded for 5 min with the local heating disk set to 30°C. The temperature then was increased to 42°C (1°C/10 s^{-1}) to induce rapid local heating, which was maintained for 30 min. Next, the probe temperature was increased to 44°C for 10 min to achieve maximal vasodilation. Resting blood pressure (mmHg) and heart rate (beats/min) were recorded at baseline and every 5 min during data collection using a patient monitoring device (Dinamap Dash 2500, GE Healthcare). Thermal hyperemic data were recorded during the test and expressed as cutaneous vascular conductance (CVC) at four regions (baseline, initial peak, plateau, and maximum regions) and presented as raw CVC and CVC normalized to maximum (%CVCmax: [(CVC / maximum CVC) × 100]).

Transcutaneous oxygen measurement

The submaximal exercise test (Table 2) was performed after the LDF procedure using a cycle ergometer (824 E, Monark AB). Heart rate (Sports Tester, Polar) and ratings of perceived exertion (RPE; CR10 scale) [25] were recorded at each minute, and blood pressure (mmHg) was recorded 1 min into every 2-min rest period using participants' contralateral arm and the patient monitoring device (Dinamap Dash 2500, GE Healthcare). Oxygen tension was measured using a calibrated TINA TCM400 tcp02 device (Radiometer) during the test. A temperature probe that was set to 44.5°C to achieve maximal skin vasodilation was attached to the skin of the participants' subscapular area using a fixation ring, which was attached to participants' back approximately 10 mm below the left scapula, avoiding the bone and using contact solution.

The solution was allowed to heat, causing skin to dilate. Dilation of the skin-blood capillaries increases blood flow, causing a diffusion of oxygen through the skin into the senor, which then measures TcPO2. Subsequently, TcPO2 measurements were temperature corrected to 37°C with the TINA device. For the purposes