RESEARCH
Original Research

Consuming High-Carotenoid Fruit and Vegetables Influences Skin Yellowness and Plasma Carotenoids in Young Women: A Single-Blind Randomized Crossover Trial

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ABSTRACT

Background Consumption of dietary carotenoids from fruits and vegetables (F/V) leads to accumulations in human skin, altering skin yellowness. The influence of the quantity of F/V consumed on skin yellowness and plasma carotenoid concentrations has not been examined previously.

Objective To compare the influence of consuming high-carotenoid-containing F/V (HCFV) (176,425 μg beta carotene/wk) vs low-carotenoid F/V (LCFV) (2,073 μg beta carotene/wk) on skin yellowness and plasma carotenoid concentrations, over 4 weeks.

Design and intervention A single-blind randomized controlled crossover trial from October 2013 to March 2014. Thirty women were randomized to receive 7 daily servings of HCFV or LCFV for 4 weeks. Following a 2-week washout period they followed the alternate intervention.

Main outcome measures Skin color (Commission Internationale de l'Eclairage L*a*b* color space, where L* represents skin lightness and positive values of a* and b* represent degrees of redness and yellowness, respectively) was assessed by reflectance spectroscopy in both sun-exposed and nonexposed skin areas. Fasting plasma carotenoids were determined by high-performance liquid chromatography, before and after each intervention period.

Statistical analyses performed Linear mixed models were used to determine the HCFV and LCFV response on skin color and plasma carotenoids, adjusting for intervention order, time, and interaction between baseline differences and time.

Results There were no significant differences in mean daily fruit (P=0.42) and vegetable (P=0.17) intakes between HCFV and LCFV groups. Dietary alpha carotene, beta carotene, lutein, and beta cryptoxanthin intakes were significantly different between the two groups (P<0.01). Following HCFV there was a significantly greater increase in skin yellowness (b*) in both sun-exposed (P<0.001) and unexposed areas, (P<0.001), with no change in skin lightness (L*) or redness (a*). Significantly higher plasma alpha carotene (P=0.004), beta carotene (P=0.001), and lutein (P=0.028) concentrations were found following the HCFV intervention. Skin yellowness correlated with alpha carotene and beta carotene.

Conclusions Skin yellowness (b*) and fasting plasma carotenoid concentrations were significantly higher following HCFV than LCFV over 4 weeks.
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CAROTENOIDS ARE A GROUP OF RED, YELLOW, AND orange fat-soluble pigments that are found primarily in fruits and vegetables (F/V).[1] The most common dietary carotenoids are alpha carotene, beta carotene, beta cryptoxanthin, lycopene, lutein, and zeaxanthin, which are predominantly sourced via F/V; however, they are also found in other food sources.

Beta carotene is among the most studied carotenoids[2] due to reported health effects and reduced risk of some diseases.[3] Beta carotene is highly abundant in brightly

colored F/V, including carrots, pumpkins, and sweet potatoes.[4]

The dietary carotenoids from the consumption of F/V are absorbed via the intestines then transported through the bloodstream to various target tissues including layers of the skin.[1,5] Circulating carotenoid levels can be measured by biochemical methods in blood samples, whereas noninvasive optical methods such as reflectance spectroscopy can be used to detect carotenoids present in human skin.[4] Reflectance spectroscopy measures skin color using Commission Internationale de l'Eclairage (CIE) L*a*b* color space (where L* represents skin lightness and positive values of a* and b* represent degrees of redness and yellowness, respectively).[1]

The accumulation of dietary carotenoids in the human skin contributes to skin color, particularly yellowness (b*).[1,5] This yellow coloration has been reported to be perceived as more healthy and attractive by young adults than coloration from tanning.[6,7] Several studies examining associations between F/V intake and skin color using spectrophotometry found individuals who reported higher F/V intake using a validated food frequency questionnaire had a skin tone that had a higher *b value (indicating increased skin yellowness).[8,9] Increased F/V intake over a 6-week period was also found to be associated with increased skin yellowness (b*) and redness (a*).[10]

Recently, a randomized controlled trial conducted by Tan and colleageus,[11] found significant increases of facial skin yellowness (b*) and redness (a*) in participants who consumed a daily F/V drink for 6 weeks.[11]

Although evidence suggests there is an association between F/V consumption and skin yellowness and redness, the influence of the quantity of F/V on skin color with intake consistent with the Australian dietary guidelines of two servings of fruit and five servings of vegetables has not been previously examined. Furthermore, the relationship between changes in skin coloration and plasma carotenoid concentrations has not been evaluated.

The primary aim of this randomized controlled crossover trial was to determine whether, over a 4-week period, consumption of F/V high in beta carotene (HCFV) (176,425 μg beta carotene/wk) compared with low-beta-carotene carotene F/V (LCFV) (2,073 μg beta carotene/wk) can lead to a difference in skin yellowness as measured by reflectance spectroscopy (CIE L*a*b*) and plasma carotenoid concentration levels. A secondary aim was to examine the relationship between the change in skin coloration and the change in plasma carotenoids following the intervention. We hypothesize that consumption of the HCFV diet will increase skin yellowness (b*) and plasma carotenoid levels, in particular beta carotene. We also hypothesize that changes in plasma concentrations will be associated with changes in skin yellowness.

MATERIALS AND METHODS

Study Design

This study was a randomized controlled 2×2 crossover trial with a 2-week washout period, with participants blinded to group allocation. Participants were randomly assigned to either a HCFV (176,425 μg beta carotene/wk) or LCFV (2,073 μg beta carotene/wk) intervention during the first 4 weeks (Weeks 1 to 4). The following 2-week period (Weeks 5 and 6) was a washout period based on the estimated half-life of beta carotene of 14 days.[12,13] During the second 4-week period (Weeks 7 to 10) participants followed the alternate intervention. This study was conducted at the University of Newcastle. The study protocol was approved by the University of Newcastle Human Research Ethics committee (H-2012-0338). The trial is registered at www.isrctn.com (ISRCTN8629745).

Participants

Study participants were recruited between October 2013 and March 2014 (spring, summer, and autumn) via flyers posted on the University of Newcastle's noticeboards and through the University's School of Nursing Research Awareness Program, where students were advised they would receive course credit points for research participation. Eligible participants were nonsmoking women aged 18 to 30 years, with a body mass index >18.5 who had low fruit and vegetable consumption (consumed vegetables with evening meal <3 to 4 times per week and <5 to 6 pieces of fruit per week). Young women were chosen because they have among the lowest adult intakes[14] and as a group they are potentially more motivated by appearance.[15,16] Exclusion criteria included current eating disorder; pregnancy; lactation; diagnosis of liver, renal, gastrointestinal tract, or cardiovascular disease; type 2 diabetes; hypertension; hypotension or with any special dietary requirements (eg celiac disease, FODMAPS [fermentable oligosaccharides disaccharides monosaccharides and polyols], or low-fiber diet). Participants were required to abstain from using tanning/lotion/sprays and sunbathing for the 11-week study period due to the influence on skin pigmentation and the likelihood of affecting skin lightness (L*) and yellowness (b*).[17] They also had to be available to attend the university laboratory on four occasions for measurements. To improve compliance to each of the intervention regimens, boxes of F/V were provided for the duration of both intervention periods. Participants were asked to collect their weekly F/V boxes containing all servings of F/V for the week on eight occasions.

Of the 154 participants who completed the online eligibility screen, 50.6% (n=78) were eligible. Thirty-one consented to participate and were enrolled, with written informed consent obtained. Participants received monetary compensation ($25 gift voucher) for their time and travel associated with data collection. Post randomization, one participant (randomly allocated to commence with the low carotenoid box) withdrew because she became pregnant. Per protocol, data analysis was conducted using data from the 30 participants who completed both arms of the study.

Randomization

Participants who were eligible were provided with a written consent form. Upon written consent participants were randomly assigned to one of the two groups (HCFV or LCFV). The allocation sequence was generated by a computer-based random number producing algorithm in block lengths of five. The randomization sequence was generated by an investigator not involved in the allocation of participants. Another investigator involved in enrollment assigned the F/V boxes, organized the F/V, and conducted the data collection.