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Original Research

Diet quality improves for parents and children when almonds are incorporated into their daily diet: a randomized, crossover study☆

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ABSTRACT

The health benefits of nuts may, in part, be due to the fiber that provides substrate for the maintenance of a healthy and diverse microbiota. We hypothesized that consuming almonds would benefit immune status through improving diet quality and modulation of microbiota composition in parents and their children, while improving gastrointestinal function. In a crossover trial, 29 parents (35 ± 0.6 years) and their children (n = 29; 4 ± 0.2 years; pairs) consumed 1.5 and 0.5 oz, respectively, of almonds and/or almond butter or control (no almonds) for 3 weeks followed by 4-week washouts. Parents completed daily questionnaires of stool frequency and compliance with nut intake. The Gastrointestinal Symptom Response Scale was administered weekly. Participants provided stools for microbiota analysis and saliva for secretory immunoglobulin A. Serum antioxidant/proinflammatory balance was determined in parents. From weekly dietary recalls (Automated Self-Administered 24-Hour Dietary Recall), nutrient and energy intake were assessed and Healthy Eating Index-2010 scores were calculated. Consuming almonds increased total Healthy Eating Index score from 53.7 ± 1.8 to 61.4 ± 1.4 (parents) and 53.7 ± 2.6 to 61.4 ± 2.2 (children; $P < .001$). Minimal changes in gastrointestinal symptoms and no change in stool frequency were noted with the almond intervention. Microbiota was stable at the phylum and family level, but genus-level changes occurred with nut intake, especially in children. No differences were observed for immune markers. Although higher intakes of almonds or longer interventions may be needed to

Abbreviations: ASA24, Automated Self-Administered 24-Hour Dietary Recall; GSRS, Gastrointestinal Symptom Response Scale; HEI, Healthy Eating Index; IgA, immunoglobin A; IL, interleukin; LAB, lactic acid bacteria; LPS, lipopolysaccharide; OTUs, operational taxonomic units; qPCR, quantitative polymerase chain reaction; TNF-α, tumor necrosis factor α.

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demonstrate effects on immune status, a moderate intake of almonds improves diet quality in adults and their young children and modulates microbiota composition.

1. Introduction

Almonds contain a variety of nutrients known to modulate immune and inflammatory processes including monounsaturated and polyunsaturated fats, vitamin E primarily as α-tocopherol, flavonoids (catechin, epicatechin, kaempferol, isorhamnetin), and plant sterols/stanols [1–3]. In addition, the incompletely digested nut residue, primarily the dietary fiber component, provides substrate for the colonic bacteria. Thus, almonds offer the potential for modulation of microbiota composition and its activities that in turn may affect immunity, inflammation, and general health. The provision of 2 oz/d of almonds or 10 g/d of almond skins has been shown to increase the viable counts of *Bifidobacterium* and *Lactobacillus* spp over a 6-week period in healthy young adults [4]. In contrast, providing 3 oz/d for 18 days had no impact on total fecal *Bifidobacterium* spp or lactic acid bacteria (LAB) genome equivalents, but did increase butyrate-producing organisms and the proportion of organisms belonging to the phylum Firmicutes [5]. The health effects of almond-induced microbiota changes have not been investigated.

Although few human studies have examined the effect of consuming almonds on immune and gastrointestinal health, the health effects of whole grains, which also provide antioxidant nutrients and fiber, have been studied. Providing middle-school children with whole or refined grains for 8 weeks increased LAB, whereas *Bifidobacterium* spp increased only for the whole-grain intervention [6]. Both diet intervention groups showed increased antioxidant levels and decreased production of inflammatory cytokines. These changes may have been due to improved quality of diet and decreased intake of unhealthy fats.

The nutritional benefits of nuts in general are reflected in the Dietary Guidelines for Americans. Specifically, it is recommended that individuals consume "a variety of protein foods, which include seafood, lean meat and poultry, eggs, beans and peas, soy products, and unsalted nuts and seeds"[7]. However, over the past 20 years, per-capita consumption of nuts and seeds has decreased by 80 kJ/d (19 kcal/d) in children aged 2 to 6 years, whereas intake from savory snacks has increased by 213 kJ/d (51 kcal/d) [8]. Early childhood (birth to year 8) is recognized as a time when the foundation for lifelong health, learning, and well-being is being laid [9]. Encouraging intake of nuts during early childhood and throughout life may have numerous benefits.

Including almonds in the diet may benefit immune and gastrointestinal health and improve diet quality. We hypothesized that consuming almonds would benefit immune status through improving diet quality and modulation of microbiota in parents and their children, while improving gastrointestinal function. The specific aims were to determine the effects of incorporating almonds vs usual diet of parents and their young children on fecal microbial profiles, stool frequency, gastrointestinal symptoms, serum antioxidant status, and dietary intake and quality. An additional outcome was to assess the feasibility of incorporating almonds and/or almond-containing foods into the diets of preschool children aged 3 to 6 years, an age when children are developing food preferences.

2. Methods and materials

2.1. Participants

Parents (18-40 years) with at least 1 child (3-6 years) living in North Central Florida were recruited from October 2013 to January 2014 by flyers, social media, and word of mouth. Parent-child pairs (pairs) were screened and excluded if they were allergic to any type of nut, taking any immune-enhancing dietary supplements or medications for constipation, diarrhea, or inflammation on a regular basis, currently being treated for any physician-diagnosed immune modulating or gastrointestinal disease or disorder, or received antibiotic therapy or a colonoscopy in the past 2 months. Of the 80 pairs screened, 29 were eligible and provided written informed consent/assent (Fig. 1). This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all study procedures were approved by the University of Florida Institutional Review Board and registered at Clinicaltrial.gov #NCT01973595.

2.2. Study design

A 14-week, randomized crossover study was conducted from January 2014 to May 2014. Pairs completed a 1-week prebaseline, followed by a 3-week intervention and a 6-week washout which included a 1-week postintervention and the 1-week prebaseline for the crossover. Pairs then received the alternate intervention for 3 weeks followed by a 1-week postintervention. During the prebaseline week, pairs completed daily questionnaires and provided one stool sample. Self-reported demographic data were obtained, height (portable stadiometer; Seca; Hanover, MD, USA), and weight (digital scale; Seca; Hanvover, MD, USA) were measured, and body mass index was calculated. At the randomization appointment (baseline), parents provided a blood sample and both parents and children provided a saliva sample. Pairs were then randomized to receive the almond or no-almond (control) interventions and asked to complete daily and weekly questionnaires as well as 3 nonconsecutive, unannounced 24-hour dietary recalls throughout the 3-week intervention. A second stool sample was collected from each participant before each final intervention appointment, and blood (parents only) and saliva samples, as well as anthropometrics were obtained. Pairs then completed 1 week of postintervention daily and weekly questionnaires. After 4 weeks with no study related procedures (washout), the participants completed the prebaseline through postintervention weeks as previously described but with the opposite intervention.

In the absence of studies examining immune health in adults or children consuming almonds, a sample size of