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A phytochemical-rich diet may explain the absence of age-related decline in visual acuity of Amazonian hunter-gatherers in Ecuador

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ABSTRACT

Myopia is absent in undisturbed hunter-gatherers but ubiquitous in modern populations. The link between dietary phytochemicals and eye health is well established, although transition away from a wild diet has reduced phytochemical variety. We hypothesized that when larger quantities and greater variety of wild, seasonal phytochemicals are consumed in a food system, there will be a reduced prevalence of degenerative-based eye disease as measured by visual acuity. We compared food systems and visual acuity across isolated Amazonian Kawymeno Waorani hunter-gatherers and neighboring Kichwa subsistence agrarians, using dietary surveys, dietary pattern observation, and Snellen Illiterate E visual acuity examinations. Hunter-gatherers consumed more food species (130 vs. 63) and more wild plants (80 vs. 4) including 76 wild fruits, thereby obtaining larger variety and quantity of phytochemicals than agrarians. Visual acuity was inversely related to age only in agrarians ($r = -.846$, $P < .001$). As hypothesized, when stratified by age (<40 and ≥ 40 years), Mann-Whitney *U* tests revealed that hunter-gatherers maintained high visual acuity throughout life, whereas agrarian visual acuity declined (*P* values < .001); visual acuity of younger participants was high across the board, however, did not differ between groups ($P > .05$). This unusual absence of juvenile-onset vision problems may be related to local, organic, whole food diets of subsistence food systems isolated from modern food production. Our results suggest that intake of a wider variety of plant foods supplying necessary phytochemicals for eye health may help maintain visual acuity and prevent degenerative eye conditions as humans age.

1. Introduction

Myopia, commonly referred to as "being nearsighted," is a condition where light entering the eye focuses in front of the retina rather than directly on the retina, putting distant objects out of focus and reducing visual acuity [1]. Visual distance impairment is emerging as a major global public health problem, with myopia as the most frequent cause; dramatic increases in myopia have been observed in urbanized developing countries [2]. Juvenile-onset myopia is largely perceived as benign because of the ease of visual correction; however, adult-onset myopia is associated with the risk of

Abbreviations: approxETDRS, approximate measurement using Early 50 Treatment Diabetic Retinopathy Study methodology; logMAR units, logarithm of the minimum angle of resolution.

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more serious degenerative visual disorders such as glaucoma, retinal detachment, macular degeneration, cataract, and blindness [3].

Normally, beginning in early childhood, axial length and eyeball size are modified by the developing human body to lock in and stabilize optimum refractive status [4]. Juvenile-onset myopia is mostly attributed to growth complications of a developing eyeball size and axial length [1]. In adult-onset myopia, recent evidence implicates accumulation of oxidative damage in the eye lens and retina that reduce lens clarity and visual acuity [5].

Large-scale studies investigating hunter-gatherers, also called *foragers*, over the last century that measured visual acuity using refraction examinations and Snellen charts found that myopia was virtually absent in isolated forager populations around the world prior to disruption of their native wild foraging lifestyle [6–10]. In an early study, Holm (1937) [7] refracted 3624 African foragers' eyes (20-65 years of age), finding only 14 eyes (0.4%) that were myopic, 9 of which were between only –0.50 to 1.00 D. Skeller (1954) [10] found a similar low myopia rate of 13 eyes (1.2%) in 1123 eyes of foraging arctic Angmagssalik Eskimo, 9 of which were –1.00 D or lower. However, myopia rapidly appears in foragers as they transition away from isolated full-time foraging to a modern diet and lifestyle [11–14]. Arctic forager diets are particularly high in phytochemical-rich wild berries [15].

Evidence is lacking in identifying the underlying reasons for differences in myopia prevalence between foragers and modern populations. Although a genetic basis for myopia has been suggested [16], epidemiological and experimental research indicates that myopia prevalence also depends on exposure to environmental stressors [1]. Populations from the same genetic background living in different global regions have major differences in prevalence of myopia [17]. Almost 23% of Latino immigrants born in the United States reported having myopia compared to 14% born elsewhere [18]. Changes in diet and lifestyle in the same community affect myopia prevalence; second-generation immigrants of Indians in Singapore had higher prevalence of myopia than the first-generation immigrants [2].

Since humans foraged for wild food for more than 99% of their history, a substantial modification of the evolutionary diet may provoke chronic disease related to modern dietary change [19]. In Westernized nations, diet-related chronic disease represents the single largest cause of morbidity and mortality, afflicting 50% to 65% of the adult population; yet these conditions are rare or nonexistent in modern foragers who attain the same advanced ages [20,21].

Dietary intake of phytochemicals is increasingly recognized as beneficial for modern human eye health [22] and may help explain the eye health differences between foragers and modern agriculturalists. Few primary studies comparing food systems have examined the health impact of the recent reduction of phytochemical content in our modern global food system. Phytochemicals are defense biochemicals that all plants produce to survive and are 10% of the dry weight of many food plants [23]. Well-known major classes of dietary phytochemicals include carotenoids, flavonoids, and polyphenols. Far from being inert, it is well established that dietary phytochemicals actively interact in a multitude of ways with human physiological processes. In fact, beyond plants, wild game flesh also reflects the phytochemical content of the wild plant foods animals consume, as does grain-based domesticated animal flesh, because phytochemicals are absorbed and stored in body organs such as liver, brain, and eyes [24,25]. The Women's Health Study with 35 551 participants found that higher overall intake of varied phytochemicals resulted in the largest reduction in risk of developing cataracts [26]. In the 7-year Carotenoids in Age-Related Eye Disease Study examining age-related eye disease in 93 676 women, the protective effects of phytochemicals corresponded directly to the number of years of stable phytochemical intake [27], suggesting that long-term higher phytochemical intake is the norm in foraging diets and may reduce degenerative myopia disease over the life course.

In 1979, the National Institutes of Health sponsored a medical study of isolated Amazonian Waorani foragers who had recently come into peaceful contact with the outside world, and found that only a few percent suffered from any chronic diseases associated with the aging process including absence of adult-onset myopia [28,29]. These early findings made the Waorani a promising group to investigate the underlying reasons for better eye health in foragers. Beginning in 2010, our aim was to investigate the food system and health characteristics, including visual acuity, in an isolated Kawymeno Waorani forager subgroup in Amazonian Ecuador and compare them with a remote neighboring Kichwa indigenous subsistence agriculture community. We hypothesized that the foragers would have greater visual acuity and better eye health than the farmers, attributable to basic differences in their food systems and diet.

2. Methods and materials

This study was approved by the Institutional Review Board at Arizona State University and performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

2.1. *Participants*

The Kawymeno Waorani forager subgroup in 2010 was a band of 121 individuals that had a functioning full-time foraging food system located near the Yasuni River in the protected center of the 15 920-km^2 Yasuni National Park in the Ecuadoran Amazonian rainforest, widely regarded as one of the most biodiverse and pristine ecosystems in the world [30]. Kawymeno is isolated from the other more extensively studied Westernizing Waorani communities removed to nearby oil-drilling regions and increasingly dependent on outsiders for survival [31,32]. Kawymeno is not mentioned in the peer-reviewed literature other than by Kron et al (2000) [33] who commented on the marked difference in diet and lifestyle between Kawymeno and other Waorani groups. The Waorani are believed to descend from a pre–stone age culture that has not experienced agriculture, and their language shares no words with other languages [34,35]. The Yasuni region is not an area where Waorani were forced to move as