Tomato Intake in Relation to Mortality and Morbidity among Sudanese Children[1]

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ABSTRACT The intake of foods that contain high levels of antioxidants may counteract the adverse effects of oxidative stress and lead to improved immune function and reduced risk of infectious disease. We prospectively examined the relationship between the consumption of tomatoes, a rich source of antioxidants, and mortality and diarrheal and respiratory morbidity rates among 28,753 children who were 6–60 mo old and enrolled in a longitudinal study in the Sudan. Children in each household were visited every 6 mo for a maximum of four visits. At each round, mothers recalled whether a child had consumed tomatoes in the previous 24 h. Events (death or morbidity) reported at each round were prospectively allocated according to the number of days of tomato intake. Intake of tomatoes for 2 or 3 d compared with none was associated, respectively, with 48% (relative risk, 0.53; 95% confidence interval, 0.30–0.91) and 83% (0.17; 0.04–0.72) reductions in morality rates (*P* for trend = 0.002). The association between tomato use and death remained statistically significant (*P* for trend = 0.004), even after further adjustment for total vitamin A intake. Tomato intake was also associated with a reduced risk of death associated with diarrhea in the week preceding death (*P* for trend = 0.009) or fever (*P* for trend = 0.04). Intake of tomatoes was also inversely and significantly associated with the risks of diarrheal and respiratory infections. Our data suggest that tomatoes may be beneficial for child health but also emphasize the general importance of food-based approaches to the prevention of micronutrient malnutrition and protection of the health of children in developing countries. J. Nutr. 130: 2537–2542, 2000.

KEY WORDS: • *vitamin A* • *tomato* • *children* • *diarrhea* • *respiratory infection* • *Sudan*

Many recent studies have implicated micronutrient malnutrition in the etiology of diarrhea, acute respiratory infection and other infectious diseases among children in developing countries (Underwood 1998). The role of vitamin A supplements has been extensively examined in several large controlled trials (Beaton et al. 1993; Fawzi et al. 1993). In addition to periodic supplementation of children with large doses of vitamin A, food-based approaches have been advocated as a more affordable and sustainable public health solution to the larger problem of multiple nutritional deficiencies (Coombs et al. 1996).

Although the role of dietary factors in chronic diseases has been extensively examined in the past few years, much less is known about their contribution to infectious diseases. In numerous studies, the consumption of fruits and vegetables was associated with a reduced occurrence of cancer and cardiovascular disease (Willett 1994). The consumption of tomatoes, tomato sauce and pizza was associated with a reduced risk of prostate cancer among men in the United States (Giovannucci et al. 1995). In a study from Italy, the consumption of raw tomatoes was inversely associated with the occurrence of digestive tract cancers (Franceschi et al. 1994). In a recent review of the literature, 72 studies examined the intake of tomatoes, tomato-based products and lycopene in relation to cancer at various anatomic sites, with a majority reporting protective associations (Giovannucci 1999).

The presumed protective effect of fruits and vegetables, including tomatoes, may be due to their high concentration of antioxidants. Antioxidants may counteract the adverse effects of oxidative stress and lead to improved immune function and reduced risk of infectious disease (Bendich 1988, Khaled 1994). Free radicals are products of the inflammatory response to infections, can damage healthy cells in the process of fighting pathogens and have been proposed as important in the pathogenesis of malaria among other infections (Levander and Ager 1995) and malnutrition (Golden and Ramdath 1987). Antioxidant nutrients, including lycopene and other carotenoids, neutralize the adverse effects of these molecules. Hence the balance between free radicals and antioxidants is important for maintaining healthy body systems, including the immune system.

Tomatoes are fruits that are rich in lycopene, an antioxidant with immunostimulatory properties, and contain moderate amounts of α- and β-carotene and vitamin C. In a recent study among healthy men, a 2-wk low carotenoid diet was associated with a significant decrease in immune function (Watzl et al. 1999). However, 2 wk of ingestion of tomato

[1] Carried under cooperative agreement no. DAN-0045-G-SS-6067 of the Office of Nutrition, U.S. Agency for International Development, Washington, D.C., and the Harvard Institute for International Development, Cambridge, MA.

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Manuscript received 22 March 2000. Initial review completed 28 April 2000. Revision accepted 27 June 2000.

juice resulted in a significant increase in lycopene levels, as well an increase in T-lymphocyte function, as measured by mitogen-stimulated lymphocyte proliferation and interleukin-2 production. In another study (Periquet et al. 1995), human immunodeficiency virus–positive children had significantly lower plasma lycopene levels compared with healthy controls; among positive children, lycopene levels were significantly correlated with CD4 cell counts (correlation coefficient = 0.57, $P < 0.001$). Plasma lycopene levels were also significantly low in malnourished children from Morocco (Houssaini et al. 1997) and Nigeria (Becker et al. 1994). Other antioxidants found in tomatoes have also been related to immune function in numerous human and animal studies (Bendich 1988).

In this report, we prospectively examined the relationship between the consumption of tomatoes and mortality and diarrheal and respiratory morbidity rates among children in the Sudan.

MATERIALS AND METHODS

In June 1988, 28,753 children were enrolled in a field trial to determine the effect of vitamin A supplementation on child mortality and morbidity rates. Additional details have been published elsewhere (Fawzi et al. 1994 and 1995, Herrera et al. 1992). Briefly, the study population consisted of children aged 6–72 mo who were free of eye signs and symptoms of vitamin A deficiency. All eligible children in alternate households were assigned to receive every 6 mo either a capsule of 60 mg (200,000 IU) of vitamin A palmitate and 40 mg (40 IU) of vitamin E or a capsule of 40 IU of vitamin E without vitamin A. Field personnel were divided into six teams, each consisting of two interviewers, two anthropometers and a supervisor.

After enrollment (round 1), each household was visited every 6 mo for a maximum of three visits (rounds 2–4). Follow-up rates were 92% at round 2, 87% at round 3 and 84% at round 4. All children available at the last round received 200,000 IU of vitamin A. Children who had evidence of xerophthalmia (night blindness assessed by questioning the mother, Bitot's spots, corneal ulcers or corneal scars) at any round were given vitamin A capsules (200,000 IU) and dropped from further follow-up.

Deaths were ascertained from the mother or relatives at a follow-up visit. Children who were not available at home at the time of a visit were not followed further, but their survival status was assessed at that round and at subsequent rounds by questioning relatives and neighbors; in this way, we were able to determine the survival status of 99.5% of all children. Information was obtained about any illness in the week preceding death; mothers were asked about which signs occurred in the period preceding death: diarrhea, breathlessness, fever, rash or convulsions.

We assessed morbidity status at each round by asking the mother whether, in the preceding 7 d, the child had diarrhea (three or more loose or watery motions in a 24-h period), cough (lasting $\geq$24 h), fever or measles. We grouped these signs as the following six mutually exclusive end points: diarrhea alone, diarrhea with fever, cough alone, cough with fever and/or diarrhea, fever alone and measles regardless of signs associated with it.

Information on potential risk factors for death was collected at baseline, including household wealth as assessed by the interviewers on a four-point scale, availability of water in the house, maternal literacy and region of residence. We found that each of the latter three variables was highly correlated with household wealth and therefore used the four variables as indicators of socioeconomic status. At each round, the anthropometers measured each child's height and weight. We assessed the nutritional status of a child at a particular round using the CASP anthropometric software developed by the U.S. Centers for Disease Control and Prevention (Hamill et al. 1977). We considered as abnormal all values below -2 Z scores of the reference value of weight-for-height or height-for-age.

Tomato consumption, either raw or as part of a cooked meal, was assessed at each round as part of a dietary questionnaire that was administered to mothers. This entailed recalling whether a child had consumed each of a list of vitamin A–containing foods in the previous 24 h. In this report, events (death or complications) reported at round 2 were allocated according to the tomato intake at round 1, whereas events reported at rounds 3 and 4 were allocated according to the number of days that tomato was eaten in the first two and the first three rounds, respectively. The occurrence of an event among children who ate tomatoes on 1, 2 or 3 d of assessment was compared with that among children who did not consume tomatoes on any of the 3 d. A test for trend in the relationship between intake and mortality or morbidity rates over an increasing number of days was computed by modeling intake as a continuous variable.

Children who were lost to follow-up or who were excluded from further follow-up because they developed xerophthalmia were considered censored for the remainder of the study because their dietary exposure status was not available for the rounds after their exclusion from the study. Thus, each child who did not have xerophthalmia at the beginn-ing of a round and who received a trial capsule contributed one child-period, a period of 6 mo. We considered each child to be a new observation conditional on having survived to the beginning of the next round and updated the exposure variables accordingly.

Incident rates for a given exposure were calculated by dividing the number of events by the cumulated child-periods of follow up. The relative risk of mortality was computed as the rate among children in a certain number of days of tomato intake relative to the lowest category (0 d). Multivariate logistic regression was used to estimate relative risks and 95% confidence intervals (CIs)[3]. We adjusted for age, sex, capsule and socioeconomic variables. In separate models, we also adjusted for nutritional and morbidity status in the previous round and used the calendar month of each visit to control for seasonality. A P-value of <0.05 was used to denote statistical significance. Data were analyzed using Statistical Analysis System (SAS) Version 6.12.

The study was approved by the Committee on the Use of Human Subjects in Research of the Harvard School of Public Health, the Director General of Primary Health Care of the Ministry of Health in the Sudan and both Directors of Health for Khartoum and Central Regions.

RESULTS

The relations between tomato intake and child mortality and morbidity risk actors are presented in **Table 1**. Children who ate tomatoes on all 3 d of dietary assessment tended to be significantly older and less nutritionally deprived and from households with relatively higher economic status as indicated by maternal literacy and availability of water in the house (Table 1). Tomato intake was also higher among children from region 5, Gezira, which is in the agricultural belt.

Tomato intake was inversely related to risk of death during the 18 mo of follow-up. Compared with children who did not eat tomatoes during any of the 3 d, those who did so on $\geq$1 d were at an increasingly reduced risk of death (P for trend < 0.0001) (**Table 2**). The age- and sex-adjusted relative risk of death among children who consumed tomatoes on 1 or 2 d compared with no days was 0.46 (95% CI, 0.34–0.63) and 0.39 (0.23–0.64), respectively. Children who ate tomatoes on all 3 d were at 0.13 times the risk of death compared with those who did not eat tomatoes at all (0.13; 0.03–0.53).

These results were attenuated when we adjusted for the four socioeconomic variables. Intake of tomatoes on 2 or 3 d compared with none was associated with 48% (0.52; 0.30–0.91) and 83% (0.17; 0.04–0.72) reductions in morality rate (P for trend = 0.002). On further adjustment for the occurrence of morbidity in the previous round, nutritional status and seasonality, the results were attenuated slightly, and the test for trend remained significant (P = 0.002) (Table 2).

[3] Abbreviation used: CI, confidence interval.

TABLE 1

Distribution of potential risk factors for child death and complications according to frequency of tomato consumption

	Tomato consumption, *d*			
Characteristic	0	1	2	3
Child periods	34,335	27,960	12,774	5010
Age, *mo*[1]	44.3 ± 20.2	45.0 ± 19.4	49.1 ± 18.8	51.9 ± 18.2
Males, %	50.3	50.6	51.0	50.9
Received vitamin A capsule, %	48.1	50.9	52.0	58.0
Nutritional status, %[2]				
Wasted	5.3	4.3	4.5	3.9
Stunted	39.0	33.6	30.6	29.3
Wasted and stunted	5.8	4.0	3.2	2.0
Normal	39.8	50.7	55.0	57.2
Unknown	10.1	7.3	6.7	7.7
Wealth, %[3]				
1 (well off)	5.6	11.9	13.6	13.4
2	38.3	55.8	61.0	67.2
3	39.4	27.6	23.0	17.7
4 (very poor)	16.8	4.8	2.5	1.7
Mother literate, %	18.2	33.2	40.3	44.4
Water in house, %	27.7	51.3	61.3	65.5
Region, %[4]				
1	25.1	7.3	3.0	0.4
2	34.3	13.8	4.8	1.4
3	10.6	15.8	18.4	15.3
4	15.8	16.2	17.6	15.0
5	14.2	47.0	56.2	68.0

[1] Values are means ± SD.
[2] Wasted, below −2 *Z* score of weight for height; stunted, below −2 *Z* score of height for age; unknown, children whose height, weight, or age was not available. NCHS standard was used in calculation of *Z* scores.
[3] Wealth is a four-point scale: 1, well off; 2, average; 3, poor; 4, very poor.
[4] Region of residence: 1, Abu Dileig; 2, Rifi Genoub; 3, El Jaeli; 4, Rifi Shamal; 5, Gezira.

To examine the relationship between child mortality rates and tomato consumption independent of its vitamin A content, we added total dietary vitamin A intake to the multivariate model that also included age, sex and socioeconomic variables. The association between tomato use and death remained significant (P for trend = 0.004), although the measures of association were attenuated: compared with children who did not consume tomatoes on any of the 3 d, those who consumed tomatoes for 1 d had a relative risk of 0.64 for death (95% CI, 0.44–0.92), those who consumed tomatoes for 2 d had a relative risk of 0.61 (95% CI, 0.34–1.08), and children who consumed tomatoes for all 3 d had a multivariate relative risk of 0.21 (95% CI, 0.05–0.89).

We also calculated a partial score of caloric intake from the

TABLE 2

Relative risk of death according to frequency of tomato consumption by Sudanese children

	Consumption of tomato, *d*				
	0	1	2	3	*P* for trend[2]
Cases	158	55	17	2	
Child periods	34,335	27,960	12,774	5010	
Age- and sex-adjusted RR (95% CI)[3]	1.00	0.46 (0.34–0.63)	0.39 (0.23–0.64)	0.13 (0.03–0.53)	<0.0001
Multivariate RR 1 (95% CI)[3]	1.00	0.57 (0.40–0.81)	0.52 (0.30–0.91)	0.17 (0.04–0.72)	0.0002
Multivariate RR 2 (95% CI)[3]	1.00	0.62 (0.43–0.89)	0.60 (0.34–1.05)	0.20 (0.05–0.84)	0.0002

[1] Child periods between rounds 1 and 2 were allocated to groups according to consumption of tomatoes assessed at round 1 (0 or 1 time); those between rounds 2 and 3 were allocated according to consumption of tomatoes assessed at rounds 1 and 2, respectively (0, 1, or 2 times); and those between rounds 3 and 4 were allocated according to consumption of tomatoes assessed at rounds 1, 2, and 3, respectively (0, 1, 2, or 3 times).
[2] Test for trend was obtained with frequency of tomato consumption as a continuous variable.
[3] Relative risk (RR) and confidence interval (CI) are derived from logistic models. The model for multivariate RR 1 included age (six-level ordinal), sex, and (in multivariate model 1) capsule (vitamin A or placebo), wealth (four-level ordinal variable), maternal literacy (yes/no), water in house (yes/no), and region (four dummy variables). In addition to these variables, multivariate model 2 included morbidity in the previous round (four dummy variables: diarrhea with or without fever, cough, cough with fever, measles with "no signs" as reference), nutritional status (four dummy variables: wasted, stunted, wasted and stunted, not known with "normal" as reference), and seasonality (five dummy variables for six 2-mo periods).

TABLE 3

Relative risk of diarrheal and respiratory infection according to frequency of tomato consumption by Sudanese children

	Consumption of tomato, *d*				
	0	1	2	3	*P* for trend[2]
Child periods	34,335	27,960	12,774	5010	
Diarrhea alone					
Cases	1821	1688	549	227	
Multivariate RR (95% CI)[3]	1.00	0.95 (0.88–1.03)	0.75 (0.67–0.84)	0.83 (0.71–0.97)	<0.0001
Diarrhea and fever					
Cases	335	304	77	27	
Multivariate RR (95% CI)[3]	1.00	0.86 (0.72–1.03)	0.55 (0.42–0.72)	0.50 (0.33–0.86)	<0.0001
Cough alone					
Cases	4695	4478	2394	761	
Multivariate RR (95% CI)[3]	1.00	1.28 (1.21–1.34)	1.62 (1.53–1.73)	1.26 (1.15–1.38)	<0.0001
Cough and fever					
Cases	1341	835	302	89	
Multivariate RR (95% CI)[3]	1.00	0.72 (0.65–0.79)	0.62 (0.54–0.72)	0.49 (0.39–0.61)	<0.0001

RR, relative risk, CI, confidence interval.

same list of foods in this study. As expected, tomato intake was significantly associated with energy intake. However, on further adjustment for this caloric score, the association between tomatoes and death was only slightly attenuated. Energy intake per se was not associated with death ($P = 0.69$).

Of 232 deaths, there were 101 (43.5%) associated with diarrhea in the week preceding death, 63 (27.2%) associated with fever and 23 (9.9%) associated with difficulty in breathing; the remainder were due to other causes, including body rashes, convulsions and accidents. We examined the relationship between the number of days of tomato intake (modeled as a continuous variable) and cause-specific death. With each additional day that a child consumed tomatoes, diarrhea-related mortality rates were reduced by ~45%, with adjustment for age, sex and socioeconomic variables (0.55; 0.35–0.86; $P = 0.009$). Tomato intake was also associated with a reduced risk of death associated with fever (multivariate relative risk = 0.65; 0.44–0.97; $P = 0.04$) but was not related to death associated with difficulty in breathing.

The intake of tomatoes was also inversely associated with the occurrence of diarrhea, and an even stronger relationship with the risk of diarrhea with fever was noted (multivariate *P* for trend for both <0.0001) (**Table 3**). Compared with children who did not consume tomatoes at all, those who ate tomatoes on all 3 d were at a 17% reduced risk of diarrhea alone (multivariate relative risk = 0.83; 95% CI, 0.71–0.97) and a 50% reduction in the risk of diarrhea with fever (0.50; 0.33–0.86).

Children who had a relatively higher intake of tomatoes were more likely to have cough alone but were at a significantly reduced risk of having cough with fever (multivariate *P* for trend for both <0.0001) (Table 3). The multivariate relative risk of cough among children who ate tomatoes on all 3 d compared with those who had none during the period of follow-up was 1.26 (1.15–1.38). The corresponding result for the occurrence of cough with fever was 0.49 (0.39–0.61). A higher frequency of tomato intake was also associated with a significant and inverse relationship with the risk of measles (multivariate $P = 0.0005$) (Table 3) but was not related to the occurrence of fever alone (data not shown).

When we added total vitamin A intake to each of the above multivariate models, the intake of tomatoes was still significantly associated with the risks of diarrhea alone ($P < 0.0001$), diarrhea with fever ($P < 0.0001$), cough with fever ($P < 0.0001$) and measles ($P = 0.05$) but also with increased occurrence of cough ($P < 0.0001$). The relative risks were slightly attenuated compared with the results that were not adjusted for vitamin A intake. For example, compared with children who did not consume tomatoes on any of the 3 d of assessment, those who consumed tomatoes on all 3 d were 0.52 times as likely to have diarrhea with fever (95% CI, 0.34–0.79) and 0.54 times as likely to have cough with fever (95% CI, 0.43–0.68).

DISCUSSION

In the present study, we found that the dietary intake of tomatoes was inversely associated with total and diarrhea- and fever-related deaths and with reduced risks of diarrheal and respiratory infection. Chance is an unlikely explanation for our results given the large numbers of cases (other than cases of measles) and narrow CIs. We considered whether misclassification of exposure or outcome variables might be an explanation for these results. Tomato intake was assessed during a previous 24-h period. This method is associated with substantial within-person day-to-day variability and is also likely to be affected by seasonality of production. This limitation would lead to random misclassification of intake exposure status, which would underestimate the associations, rather than create associations that do not exist. Random misclassification of children by morbidity variables is also unlikely to create associations that did not truly exist. We presented our results with control for a number of potentially confounding variables, including nutritional status, socioeconomic status, seasonality and morbidity status in the previous round. As in other prospective studies, residual confounding may exist given the imperfect measurement of the confounding variables, especially the indicators of socioeconomic status.

In the same study population, we previously reported that total dietary vitamin intake was associated with large and significant reductions in child mortality rates (Fawzi et al. 1994) and diarrheal and respiratory infections (Fawzi et al. 1994). We also examined the relationships between these end points and the consumption of six foods (other than tomatoes) that were selected because they contributed 97% of the between-person variability in total vitamin A intake. Protective relationships were noted with the following four plant sources of vitamin A: Jew's mallow, garden rocket (both green leafy vegetables), mango and pumpkin. The two foods of animal origin (eggs and fresh milk) were not related to any of the outcomes. The relationships with Jew's mallow and garden rocket were particularly significant: the multivariate relative risk per day of use of Jew's mallow was 0.32 (1.14–0.72), whereas for garden rocket, it was 0.58 (0.35–0.96) (Fawzi et al. 1994). However, when we adjusted the relationships between tomato intake and child mortality rates for these two foods simultaneously, the associations were only slightly attenuated and remained significant, suggesting that the findings for tomato are independent of the intake of the other foods. These results also did not differ with further adjustment for caloric score. As reported earlier, energy intake itself was not associated with death. This is not unexpected because the study population was not severely undernourished and energy intake probably was not a limiting nutrient. Finally, as in all observational dietary studies, tomato intake may be a proxy for vegetable intake overall; hence, the protective relationships observed in this study may be an indicator of a healthy food pattern (that includes relatively high amounts of vegetables and fruits) and not necessarily be due to tomato intake per se.

Tomato intake was associated with a reduction in the risk of severe diarrhea as shown by the reduced occurrence of diarrhea-related deaths and diarrheal morbidity among children in the higher categories of intake. The vitamin A content of tomatoes may explain, at least in part, the protective associations with tomato intake. Tomatoes contain moderate amounts of provitamin A carotenoids, mainly α- and β-carotene (Beecher 1998). In several large trials, vitamin A supplementation resulted in significant reductions in mortality rates associated with fatal and (presumably severe) diarrhea (Beaton et al. 1993; Fawzi et al. 1993). Vitamin A supplementation was also associated with a reduction in the duration (or severity) of diarrheal episodes among hospitalized patients with measles (Beaton et al. 1993). Vitamin A deficiency may contribute to gastrointestinal infection in a number of ways. It adversely affects the epithelial lining of the gastrointestinal tract (Wolbach and Howe 1925), leading to decreased mucus secretion and weakened local barriers to infection. In comparison with normal mice, vitamin A–deficient mice had more severe mucosal changes when infected with rotavirus (Ahmed et al. 1990), which is an important cause of diarrhea in children. Vitamin A deficiency also adversely affects humoral and cellular immune functions (Nauss 1986).

We also found that children who consumed more tomatoes were more likely to present with cough. The occurrence of cough may indicate a more competent respiratory epithelium. Tomato consumption was inversely related to the risk of "cough with fever." In several placebo-controlled trials, however, large doses of vitamin A were not associated with a reduction in the severity of respiratory infection (Fawzi et al. 1998; Kjolhede et al. 1995), suggesting that the observed protective relationship with tomato intake may be attributed to nutrients in tomatoes other than vitamin A. Tomato intake was also associated with a reduced risk of measles, similar to findings for total dietary vitamin A with this end point (Fawzi et al. 1995). Because all study children are likely to have acquired the measles virus at some point in time, the reduced incidence of measles we report here probably represents reduced severity of the disease. These findings are in accord with a reduction in the risk of measles-related mortality rates associated with periodic vitamin A supplementation in community trials carried out among healthy children who were hospitalized with measles (Beaton et al. 1993; Fawzi et al. 1993). Although our results were not controlled for the possible confounding by measles immunization, we adjusted for socioeconomic variables and other factors that are known to be important predictors of immunization. Hence, it is unlikely that residual confounding by this variable would entirely explain the observed strong protective association.

When we adjusted the relationship between tomato intake and morbidity or mortality rates for total vitamin A intake, children in the higher categories of tomato consumption were still at significantly reduced risks for these adverse outcomes. This finding suggests that the observed protective relationships may be explained by nutrients in tomatoes other than vitamin A. Tomatoes are a rich source of antioxidants, including lycopene, α- and β-carotene and vitamin C. Lycopene, a non–provitamin A carotenoid, has an exceptionally high capacity for scavenging free radicals (DiMascio et al. 1989). It is responsible for the red color of tomatoes and is available in tomatoes in concentrations that are 30–40 times those of β-carotene (Beecher 1998). The inverse relationships between tomato consumption and the risks of cancer and cardiovascular disease (Franceschi et al. 1994, Giovannucci 1999, Giovannucci et al. 1995) have been attributed to its high content of antioxidant substances including carotenoids, mainly lycopene. Oxidative stress may also contribute to the occurrence of diarrheal disease and malnutrition among children (Khaled 1994), and antioxidants, including lycopene, may be beneficial in reducing the risk of these adverse conditions. Lycopene may be associated with enhanced immunity and reduced risks of infectious disease. In a study among healthy men, 2 wk of ingestion of tomato juice resulted in a significant increase in lycopene levels, as well an increase in T-lymphocyte function (Watzl et al. 1999). Plasma lycopene levels were also significantly low in malnourished children from Morocco (Houssaini et al. 1997) and Nigeria (Becker et al. 1994) and among human immunodeficiency virus–infected children (Periquet et al. 1995). In animal studies, intraperitoneal or intravenous injection of lycopene prolonged the survival of bacterially infected mice (Lingen et al. 1959). In two inflammatory conditions associated with oxidative stress, cystic fibrosis and septic shock, patients were reported to have low levels of antioxidants compared with controls (Goode et al. 1995, McGrath et al. 1999). Other antioxidants in tomatoes, including α- and β-carotene and vitamin C, are associated with protective effects on the immune system and have been associated with a reduced risk of infection (Gaby and Singh 1991, Garland and Fawzi 1999, Hemila 1997).

Tomatoes are widely consumed in many parts of the world. In sub-Saharan Africa, where child mortality, morbidity and malnutrition rates are particularly high, tomatoes are consumed as raw fruit but also as processed paste or sauce that is added to food during cooking, which incidentally improves the bioavailability of lycopene and other carotenoids (Tonucci et al. 1995). To our knowledge, this is the first study that examined the relationship of tomato intake and infectious disease and mortality rates in childhood. Additional data on this subject are needed. Nonetheless, our data emphasize the importance of considering food-based approaches to the prevention of micronutrient malnutrition and reduction in child morbidity and mortality rates in developing countries.

JN THE JOURNAL OF NUTRITION

ACKNOWLEDGMENTS

We would like to thank the field teams and the mothers and children who made the study possible and Edward Giovannuccu and David Thurnham, who reviewed an earlier version of the report.

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