Am Diet Assoc. 1988;88:817-821.
4. Yuhas JA, Bolland JE, Bolland TW. The impact of training, food type, gender, and container size on the estimation of food portion sizes. J Am Diet Assoc. 1989;89:1473-1477.
5. Bolland JE, Ward JY, Bolland TW. Improved accuracy of estimating food quantities up to 4 weeks after training. J Am Diet Assoc. 1990;90:1402-1407.
6. Gittelsohn J, Shankar AV, Pokhrel RP, West KP. Accuracy of estimating food intake by observation. J Am Diet Assoc. 1994;94:1273-1277.
7. Weber JL, Tinsley AM, Houtkooper LB, Lohman TG. Multimethod training increases portion-size estimation accuracy. J Am Diet Assoc. 1997;97:176-179.
8. Slawson DL, Eck LH. Intense practice enhances accuracy of portion size estimation of amorphous foods. J Am Diet Assoc. 1997;97:295-297.
9. Weber JL, Cunningham-Sabo L, Skipper B, Lytle L, Stevens J, Gittelsohn J, Anliker J, Heller K, Pablo JL. Portion-size estimation training in second- and third-grade American Indian children. Am J Clin Nutr. 1999;69(suppl):S782-S787.

Dietary intakes and plasma concentrations of vitamin C are lowered in healthy people with chronic, nonprogressive physical disabilities

KATHLEEN M. CAHILL, MS; BETTY JANE BURRI, PhD; KATHRYN SUCHER, ScD

We hypothesized that people with severe physical disabilities would have increased risks for malnutrition and nutrient deficiencies, including vitamin C deficiency. Vitamin C is derived from a relatively small number of fruits and vegetables. These foods generally are perishable, require preparation, and are less likely to be eaten by people with low incomes (1,2) or who are institutionalized than by the general population. People with disabilities are much more likely to be living below the poverty level than the general population (3). In a study measuring nutrient quality of meals served to children with cerebral palsy, food served at home rarely included rich sources of vitamin C (4). The US Recommended Dietary Allowances (RDA) for vitamin C is relatively low—60 mg per day—based on its antiscorbutic ability (5,6); however, vitamin C is also the body's main water-soluble antioxidant (7). Several studies report inverse relationships between vitamin C intake and death from cardiovascular disease and mortality from all causes (8,9). The amount of vitamin C required for optimal human health is a perennial controversy, but 250 mg per day may be beneficial (10). The purpose of this study was to compare dietary intakes and plasma concentrations of vitamin C in people with severe, chronic, nonprogressive physical disabilities with vitamin C intakes and concentrations of people in age-matched population without physical disabilities.

K. M. Cahill is a lecturer and K. S. Sucher is a professor in the Department of Nutrition and Food Science, San Jose State University, San Jose, Calif. B. J. Burri is a research chemist in the Department of Pomology at the Western Human Nutrition Research Center, University of California, Davis.

Address correspondence to: Betty Jane Burri, PhD, Western Human Nutrition Research Center, ARS/PWA, Department of Pomology, 1035 Wickson Hall, University of California—Davis, Davis, CA 95616-8685.

METHODS

The Human Subjects—Institutional Review Boards of San Jose State, San Jose, Calif, and the University of California at Davis, and the US Department of Agriculture approved this observational study. Subjects were recruited from the greater San Francisco bay area via word-of-mouth, flyers, and advertisements in local newspapers, and were compensated for their time. Subjects with disabilities had paraplegia or hemiplegia of at least 5 years' duration resulting from cerebral palsy, spinal cord injury, or polio. All subjects were healthy adults with normal swallowing ability, as judged by a health history questionnaire, a physical examination, and blood chemistries (complete blood counts and Chemzyme Plus diagnostic test [SmithKline Beecham, San Francisco, Calif]). We attempted to recruit nonsmokers exclusively; however, this was a secondary criteria and in the geographical area in which the study was conducted, it seemed to be that approximately 40% of people with disabilities smoke. Six (26%) of the subjects with disabilities and 8 (16%) control subjects smoked. Groups were age-matched: both control subjects and subjects with disabilities were aged 38±10 years. The groups also had the same ratio of men to women (58% male) and similar marital status (25% married).

Subjects completed several questionnaires, including a standard food frequency questionnaire, the Health Habits and History Questionnaire (1995 Scantron version, analyzed by Block Dietary Data Systems, Berkeley, Calif) with the assistance and under the observation of the recruiting and dietary staff of the Western Human Nutrition Research Center, University of California at Davis. Frequency and portion size data from this questionnaire were converted into estimates of citrus fruit and fruit and vegetable intake, then into vitamin C intake.

Fasting blood was collected from the antecubital vein, then prepared for vitamin C analysis by standard procedures. Two mL plasma was mixed with 2.0 mL trichloroacetic acid (10%) and centrifuged for 15 minutes at 3,000 g. Stabilized plasma samples were analyzed with a Spectronic Genesys 5 spectrophotometer (Milton Roy Co, Rochester, NY) for vitamin C concentrations using 2,4-dinitrophenylhydrazine by the method of Roe and Kuether (11). Chemicals were purchased from Sigma Chemical Company (St Louis, Mo) and J. T. Baker Chemical Company (Phillipsburg, NJ).

We collected questionnaires and blood samples from 78 subjects—26 people with physical disabilities and 57 control subjects. Three subjects with disabilities and 7 control subjects were excluded from data analysis because they took a

Table
Vitamin C concentrations in subjects with and without severe physical disabilities

All		Men		Women	
With disabilities (n=23)	Without disabilities (n=50)	With disabilities (n=14)	Without disabilities (n=29)	With disabilities (n=9)	Without disabilities (n=21)
Plasma vitamin C/µmol/L (mean±SD)[a]					
62.1 (28.5)	77.9 (24.5)	56.9 (30.4)	67.2 (22.5)	71.5 (23.6)	88.0 (22.4)
P=.02		*P*=.28		*P*=.11	
Dietary intake of citrus fruits (servings per day)					
0.25 (0.30)	0.65 (0.66)	0.20 (0.27)	0.55 (0.43)	0.30 (0.36)	0.73 (0.79)
P=.008		*P*=.12		*P*=.13	
Dietary intake of servings of fruits and vegetables (except potatoes)					
1.02 (0.68)	2.29 (1.2)	0.97 (0.80)	1.51 (1.3)	1.08 (0.56)	2.06 (1.6)
P=.02		*P*=.34		*P*=.05	
Dietary vitamin C from foods					
89 (49)	118 (66)	87 (37)	114 (52)	88 (33)	112 (69)
P=.06		*P*=.09		*P*=.10	

[a]Standard deviation

large supplemental dose of vitamin C (more than 500 mg) within 24 hours of the blood draw. Data was evaluated by simple statistics and the Wilcoxin rank sums test for nonparametric measures (Statistical Analysis System, version 6.05, Cary NC). Box plots were drawn using SigmaPlot 4 (Jandel Scientific, San Rafael, Calif).

RESULTS AND DISCUSSION

Plasma vitamin C concentrations are shown in the Table and the Figure. The majority of both subjects with disabilities and control subjects had adequate vitamin C status. Yet people with disabilities tended to have lower plasma concentrations of vitamin C (*P*=0.02). The percentage of people with marginal vitamin C status (11 to 23 mmol/L) was much higher in the subjects with disabilities (17%, n=54) than in the control subjects (2%, n=51). One of the subjects with disabilities (4%) had a vitamin C concentration suggestive of deficiency. Significant differences remained when only the nonsmokers of the 2 groups were compared (*P*=0.02). Plasma vitamin C levels (mean±SD) for nonsmokers was 64.1±9.2 mmol/L for people with disabilities and 81.4±18.0 mmol/L for control subjects. Smokers in both groups had similarly low plasma vitamin C concentrations, at 51.3±4.2 mmol/L for people with disabilities (n56) and 52.2±22.2 mmol/L for control subjects (n58).

Dietary information was consistent with blood chemistry results. Intake of citrus fruit tended to be low, with median intakes of 0.2 servings per day for subjects with disabilities and 0.4 servings per day for control subjects (*P*=0.008, see Table). Dietary intake estimates of fruits and vegetables (excluding potatoes) were also lower in people with disabilities (*P*=0.02); however, total estimated vitamin C intakes from food (89±49 mg per day for people with disabilities, 118±56 mg per day for control subjects) was not quite significant (*P*=0.06).

To our knowledge, there has not been much nutrition research on adults with nonprogressive physical disabilities; however, a few studies have found a high incidence of malnutrition in this population (12,13). In a study by Levine et al (14) the nutritional composition of the diets of 33 subjects with spinal cord injury showed mean dietary intakes of several water-soluble and fat-soluble vitamins below the RDAs. In another study, the average daily intake of vitamin C by adolescents with cerebral palsy was 29 mg, half of the recommended dietary intake (15).

Most people with chronic, nonprogressive physical disabilities who participated in our study have normal vitamin C concentrations; however, the subjects with disabilities had 6 times as many people with marginal or deficient vitamin C plasma concentrations as the control group. Our data suggest that larger studies of people with chronic physical disabilities may result in defining a group at high risk for marginal vitamin C status with potentially physiologically significant consequences. These consequences could include a greater incidence of muscle weakness, mild mood disorders, and a greater risk of disease including coronary heart disease. In fact, people with spinal cord injury have a shorter life expectancy, with a risk for developing premature coronary heart disease that is double the risk of the general population (16).

To our knowledge, this is the first report of vitamin C intakes and status in healthy adults with severe, chronic physical disabilities. Our results suggest that this group is at higher risk for marginal deficiencies of vitamin C than a comparable group of age-matched controls. Differences in smoking rate appeared to account for some, but not all, of this increased risk, because smokers in both groups had equivalent plasma vitamin C concentrations that were lower than respective nonsmokers. The group with disabilities had a high percentage of people with marginal vitamin C status, including one person with deficient vitamin C status.

APPLICATIONS

We recommend that dietetics professionals should collect information on vitamin C and fruit and vegetable intakes of people with severe physical disabilities. If these intakes seem to be low, or are accompanied by symptoms of vitamin C deficiency (gingivitis, lethargy), then they should test plasma vitamin C concentrations. If plasma vitamin C concentrations are low, then vitamin C status can be corrected either with increased citrus fruit consumption or by vitamin C supplementation.

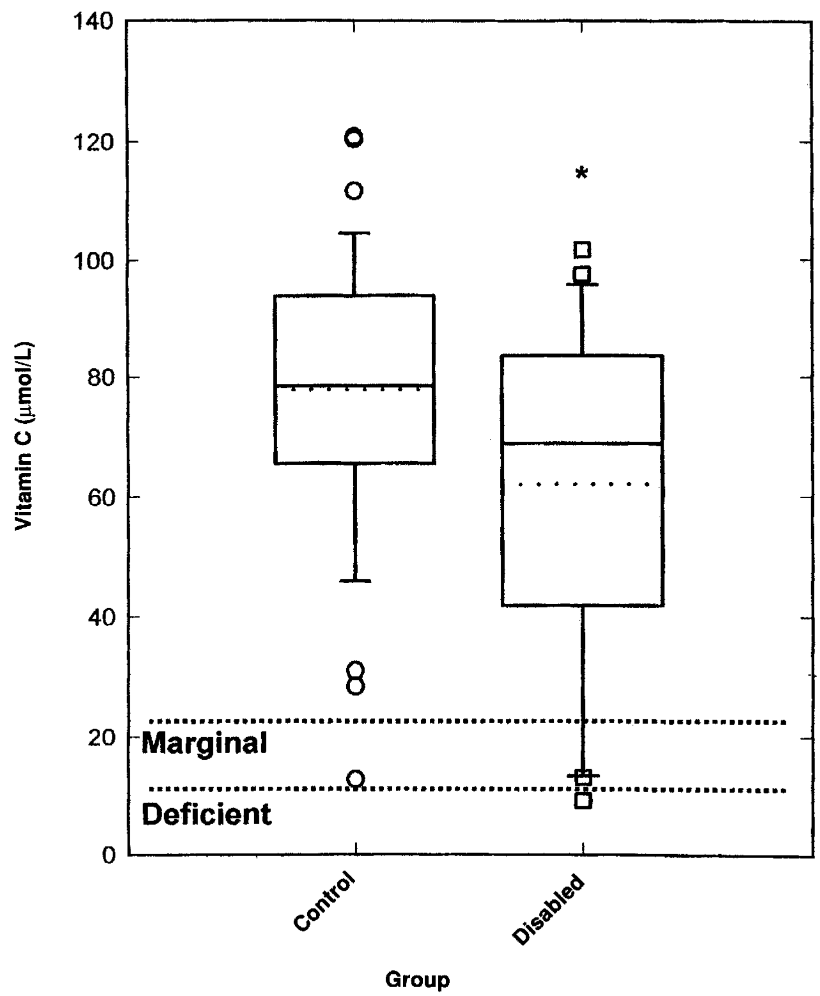

FIG. Vitamin C plasma concentrations of people with severe physical disabilities (n=23) and age-matched control subjects (n=50). Box plots show the range, 90% confidence limits, median (—), mean (. . .) concentrations for each group. Standard cut-off points—where plasma concentrations are deemed to connote marginal or deficient statuses—are shown by solid lines.

References

1. Kendall A, Olson CM, Frongillo EA. Relationship of hunger and food insecurity to food availability and consumption. *J Am Diet Assoc.* 1996;96:1019-1024.
2. Rogers MAM, Simon DG, Zucker LB, Mackessy JS, Newman-Palmer NB. Indicators of poor dietary habits in a high risk population. *J Am Coll Nutr.* 1995;14:159-164.
3. Shea M. Dynamics of Economic Well-Being: Poverty, 1991-1993, Washington, D.C.: US Bureau of the Census; 1995;5-6,P70-45.
4. Hammond MI, Lewis MN, Johnson EW. A nutritional study of cerebral palsied children. *J Am Diet Assoc.* 1996;49:196-201.
5. Burri BJ, Jacob RA. Human metabolism and the requirement for vitamin C. In: Packer L, Fuchs J, eds. *Vitamin C in Health and Disease.* New York, NY: Marcel Dekker; 1997:341-366.
6. National Research Council, Food and Nutrition Board, Subcommittee on the 10th edition of the RDA. *Recommended Dietary Allowances.* 10th Ed. National Academy Press, Washington, DC;1989.
7. Rock CL, Jacob RA, Bowen PE. Update on the biological characteristics of the antioxidant micronutrients: vitamin C, vitamin E, and the carotenoids. *J Am Diet Assoc.* 1996;96:693-702.
8. Enstrom JE, Kanim LE, Klein MA. Vitamin C intake and mortality among a sample of the United States population. *Epidemiology.* 1992;3:194-202.
9. Salonen JT, Nyyssonen K, Parviainen MT. Vitamin C, lipid peroxidation, and the risk of myocardial infarction: epidemiological evidence from Eastern Finland. In: Packer L, Fuchs J, eds. *Vitamin C in Health and Disease.* New York, NY: Marcel Dekker; 1997:341-366.
10. Levine M, Conry-Cantilena C, Wang Y, Welch RW, Washko PW, Dhariwal KR, Park JB, Lazarev A, Grammlich JF, King J, Cantilena LR. Vitamin C pharmacokinetics in healthy volunteers: evidence for a recommended dietary allowance. *Proc Natl Acad Sci USA* 1996;93:3704-3709.
11. Roe JH, Kuether CA. The determination of ascorbic acid in whole blood and urine through the 2,4-dinitrophenylhydrazine derivative of dehydroascorbic acid. *J Biol Chem.* 1943;147:399-407.
12. Lee BY, Agarwal N, Corcoran L, Thoden WR, Del Guercio LRM. Assessment of nutritional and metabolic status of paraplegics. *J Rehabil Res Dev.* 1985;22:11-17.
13. Peiffer SC, Blust P, Leyson JFJ. Nutritional assessment of the spinal cord injured patient. *J Am Diet Assoc.* 1981;78:501-505.
14. Levine AM, Nash MS, Green BA, Shea JD, Aronica MJ. An examination of dietary intake and nutritional status of chronic healthy spinal cord injured individuals. *Paraplegia.* 1992;30:880-889.
15. Eddy TP, Nicholson AL, Wheeler EF. Energy expenditures and dietary intakes in cerebral palsy. *Dev Med Child Neurol.* 1965;7:377-386.
16. Yeo JD, Walsh J, Rutkowski S, Soden R, Craven M, Middleton J. Mortality following spinal cord injury. *Spinal Cord.* 1998;36:329-336.

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