The following is an excerpt by Ahmed El-Sohemy, PhD, a lead researcher in the newly published Canadian study examining ascorbic acid deficiency and its link to chronic disease markers. The study appears in the American Journal of Epidemiology. To view the full study online, visit: http://aje.oxfordjournals.org/cgi/content/full/kwp156

The objective of this study was to determine the prevalence of ascorbic acid (vitamin C) deficiency and its association with markers of chronic disease in a population of young Canadian adults. The study participants – 692 women and 287 men aged 20-29 years – were recruited from the University of Toronto campus as part of a cross-sectional study called the Toronto Nutrigenomics and Health Study. Using a comprehensive 196-item food frequency questionnaire, participants were asked to assess their food intake over the previous month. Based on their responses, a total daily vitamin C intake for each person was computed. Subjects provided an overnight fasting blood sample that was used to measure blood levels of ascorbic acid as well as various biomarkers of chronic disease such as insulin, glucose, lipids, and CRP, which is a marker of inflammation. Subjects also had their blood pressure, height, weight, waist circumference and body mass index (BMI) assessed. Internationally recognized cut-points of serum ascorbic acid concentrations were used to determine which subjects had deficient (<11 µmol/L), suboptimal (11-28 µmol/L) or adequate (>28 µmol/L) levels of vitamin C.

New study finds 1 in 7 young Canadian adults vitamin C deficient
The results show that vitamin C deficiency is common among young Canadian adults, with only 53% of participants having adequate levels of circulating vitamin C. One in 7 (14%) were deficient and a further one-third had suboptimal levels. Despite their young age, the waist circumference, BMI, inflammation and blood pressure measurements were already significantly higher among those with vitamin C deficiency than in those with adequate blood concentrations. One in 4 participants did not consume the Recommended Dietary Allowance (RDA) for vitamin C, and these individuals were three times more likely to have a blood concentration deficiency than those who met the RDA.

There are 3 important take-home messages from the study:

(a) Vitamin C deficiency is prevalent among young Canadian adults.
(b) The deficiency in blood concentrations of vitamin C is associated with elevated markers of chronic disease in young adults, which may have long-term adverse health effects.
(c) Vitamin C deficiency and its health consequences can largely be prevented by meeting the RDA for vitamin C (75 mg/day for women and 90 mg/day for men).

The study was supported by the Advanced Foods and Materials Network, a national Network of Centres of Excellence and was conducted by University of Toronto researchers Ahmed El-Sohemy (Canada Research Chair in Nutrigenomics) and Leah Cahill (PhD student and Registered Dietitian) from the Department of Nutritional Sciences, and Paul N. Corey (Professor) from the Dalla Lana School of Public Health. Called Vitamin C Deficiency in a Population of Young Canadian Adults, the study was published in the American Journal of Epidemiology in July of 2009.
In the following section, Dr. El-Sohemy answers questions about the study and its findings as well as the health effects of vitamin C deficiency.

**Q:** What prompted you to study vitamin C deficiency?

The original aim of our research was to try and understand why some individuals have markedly different levels of serum ascorbic acid from others when they consume the same amount of vitamin C and have similar diets and lifestyles. We wanted to explore the possibility that certain genetic differences affecting vitamin C metabolism or utilization might be responsible. So, we began recruiting healthy young adults to start testing our hypotheses. One of my PhD students, Leah Cahill, who is also a Registered Dietitian, made the unexpected observation that a significant proportion had very low blood levels of ascorbic acid. We then related these values to markers of health and decided that this was an important observation worth pursuing. We have recently made some interesting observations on the genetic determinants of serum ascorbic acid response to vitamin C, which is being published in the American Journal of Clinical Nutrition.

**Q:** Were the results what you and your research team expected?

Even though we were expecting vitamin C deficiency to be present in some of our subjects, we were still surprised to see the prevalence of 1 in 7 subjects with deficiency and a further 1 in 3 with suboptimal levels. This means that only 53% of subjects had adequate serum levels of vitamin C.

**Q:** How do your findings compare to mass population health surveys conducted in Canada and U.S.?

We report 13% of females and 16% of males aged 20-29 years have serum ascorbic acid deficiency (defined as <11 µmol/L). Our findings are comparable to data from the third National Health and Nutrition Examination Survey (NHANES III 1988-1994) in the United States, which revealed deficiency rates of 11% for females and 13% for males aged 18-24 years, and 12% and 17% for females and males aged 25-44 years. Deficiency rates have been reported to be much higher in a low-income population from the U.K. Serum ascorbic acid deficiency data from the latest NHANES (2003-2004) has just been published, and it appears that deficiency rates have declined. Of the adult subjects aged 20-39 years, 8% of females and 11% of males were deficient. The cause of this decrease could be the rise in use of vitamin C supplements and multivitamins that was also reported in the same publication. To our knowledge, our study is the first to report the prevalence of deficient serum ascorbic acid concentrations among young Canadian adults.
Q: Why does ascorbic acid continue to generate interest among researchers?

Vitamin C has always interested researchers because it is essential to human survival and has a wide range of functions. Vitamin C is a powerful antioxidant, which has been implicated in the development of chronic diseases such as diabetes, heart disease and cancer. Many studies have shown that people with adequate vitamin C concentrations in their blood have a lower risk of various diseases. This inverse relationship with serum ascorbic acid concentrations has been observed not only with the diagnosis of diseases such as cardiovascular disease and diabetes, but also with several markers of these chronic diseases including glucose homeostasis, blood pressure, oxidative stress, inflammation, and indicators of obesity such as BMI and waist-to-hip ratio. These studies have been conducted using older adults as subjects. We now show that the association between inadequate blood concentrations of vitamin C and markers of chronic disease is present even when individuals are still in their 20’s.

Q: What is the correlation between vitamin C deficiency to unhealthy BMI, body mass distribution, high blood pressure and other chronic disease markers?

Until now, the health consequences of having inadequate vitamin C levels at a young age were not known. Our study shows that this deficiency could already be adversely affecting these young adults since the participants with vitamin C deficiency had higher measures of obesity, blood pressure and other markers for risk of chronic disease compared to those with adequate levels. There are several biological mechanisms that could explain this inverse association between serum vitamin C and risk of chronic disease. For example, with insufficient vitamin C the body is unable to produce the carnitine it needs for fatty acid oxidation which could result in higher BMI and waist circumference than if adequate vitamin C was available. Furthermore, the antioxidant functions of vitamin C have been shown to protect against lipid peroxidation and inflammation associated with increased blood pressure. In addition, vitamin C intake may be a marker for other dietary and lifestyle factors that contribute to increased risk of obesity, high blood pressure and other chronic disease.

Q: Results showed 47% of Canada’s young adult population were vitamin C deficient or had suboptimal vitamin C serum levels. What is the likelihood these deficiencies extend beyond this age cohort (eg. children/teens; older adults)?

Based on studies conducted in the U.S., we think it is very likely that vitamin C deficiencies extend beyond our cohort’s age range of 20-29 years. The prevalence of deficiency that we observed is similar to what has previously been reported in the NHANES study, which reported similar rates of deficiency among older adults. A greater proportion of teens aged 12-17 years had adequate concentrations of ascorbic acid, but about 20-25% did not. We do not know the prevalence of deficiency among children.
Q: If suboptimal vitamin C levels are prevalent, is there also evidence of deficiencies in folate and potassium, which are commonly found in citrus fruits?

We did not assess folate or potassium deficiency in our population, so we cannot say for certain. Vitamin C is found almost exclusively in fruits, vegetables and supplements, while potassium and folate can be obtained from other sources. For example, potassium is also found in dairy products and meats and alternatives. However, data from the National Health and Nutrition Examination Survey (NHANES) 1999-2002 indicated that mean and median potassium intakes did not meet the age-appropriate Adequate Intakes (AI) for all age groups of American subjects. Since adequate potassium intake is associated with decreased risk of chronic disease, consumption of a variety of potassium-rich foods, including fruits, vegetables and dairy products, should continue to be encouraged. Folate deficiency used to be a major public health concern in Canada and so now it is fortified in breads and cereals, which has decreased substantially the prevalence of low serum folate concentrations in Canada. Citrus fruits and their juices contain many other important nutrients such as water, fibre, vitamins and minerals and are very healthy food choices.

Q: What type of fruit and fruit juices were observed in the participants’ dietary survey data?

Although we did not publish data on which foods specifically contributed to the vitamin C intake of the subjects, we did an analysis and found that orange, grapefruit and tomato juices were main vitamin C contributors along with vitamin C supplements, multivitamins, oranges, peppers, strawberries, broccoli, potatoes, kale and several other fruits and vegetables.