

## Circulating concentrations and relative percent composition of trans fatty acids in healthy Canadian young adults between 2004 and 2010: a cross-sectional study

Salma A. Abdelmagid PhD, Daiva E. Nielsen PhD, Alaa Badawi PhD, Ahmed El-Sohemy PhD, David M. Mutch PhD, David W.L. Ma PhD

### Abstract

**Background:** Trans fatty acids (TFAs) produced from industrial partial hydrogenation of vegetable oils have been the subject of much research regarding their negative effect on the development of chronic diseases, and recommendations to label foods with partially hydrogenated vegetable oils and limit their levels were introduced in Canada in 2003 and 2007, respectively. Our aim was to determine temporal changes in circulating plasma TFAs in a population of young healthy Canadian adults after the introduction of the guidelines.

**Methods:** In this study, circulating plasma concentrations and relative percent composition of individual TFAs over time (2004–2010) were determined in a cross-sectional cohort of young healthy Canadian adults as part of the Toronto Nutrigenomics study.

**Results:** A total of 1294 participants were included in the cohort. Relative to 2004, total TFA levels were significantly lower in 2005–2009 ( $p < 0.05$ ), but not in 2010. Although levels of 16:1t9 and 18:1t11 declined after 2004, levels of 18:1t9 and 18:1t10 were significantly lower in 2005–2009 ( $p < 0.05$ ), but not in 2010.

**Interpretation:** Trans fatty acids were lower in 2009 relative to 2004, but not different in 2010, suggesting that young Canadians may remain vulnerable to partially hydrogenated vegetable oil exposure and that there is a need for further monitoring of specific food categories and vulnerable populations.

A large body of research has linked partially hydrogenated vegetable oil trans fatty acids (TFAs) to negative health outcomes.<sup>1–3</sup> Intake of partially hydrogenated vegetable oil TFAs has been shown to be proinflammatory, increase low-density lipoprotein cholesterol, decrease high-density lipoprotein cholesterol and increase risk of coronary artery disease.<sup>4,5</sup> These findings have led to the establishment of initiatives around the world regulating TFAs in the food supply. In 2003, the Danish government limited the accepted amount of partially hydrogenated vegetable oil TFAs to 2% of total fat in foods.<sup>6</sup> The United States has considered TFAs as “generally regarded as safe” for decades; however, in 2013, the US Food and Drug Administration proposed banning partially hydrogenated vegetable oil<sup>7</sup> and in a final judgment removed the generally regarded as safe status of partially hydrogenated vegetable oil in 2015.<sup>8</sup> In 2003, the Canadian government required mandatory TFA food labelling to begin by 2005.<sup>9</sup> Subsequently, in 2007, the Canadian government adopted recom-

mendations from the 2006 Health Canada Trans Fat Task Force for the voluntary reduction of TFAs in vegetable oils and soft margarines to 2% of total fats and in all other foods to 5%.<sup>10</sup> Health Canada called for these limits to be achieved within 2 years and, according to Health Canada’s Trans Monitoring Program (from 2007 to 2009), partially hydrogenated vegetable oil TFAs were substantially reduced from most foods sold in Canada and continued to improve in follow-up label assessments for TFAs in 2010 and 2011.<sup>10–12</sup>

Trans fatty acids are found in industrially produced partially hydrogenated vegetable oil and by natural biohydrogenation

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**Correspondence to:** David Ma, davidma@uoguelph.ca

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of unsaturated fats by bacteria in ruminants.<sup>11</sup> Partially hydrogenated vegetable oils are used by the food industry to improve the texture and stability of food products and extend their shelf life.<sup>4,12,13</sup> Partially hydrogenated vegetable oil TFA isomers present in these products include C16:1t, C18:1t, C18:2t and other long-chain polyunsaturated TFAs.<sup>4,14,15</sup> The C18:1t isomers account for 80%–90% of total TFAs in foods, with C18:1t9 and t10 being the most common.<sup>4,14,15</sup> Trans fatty acids in ruminant meats and milk account for about 2%–6% of total fat content.<sup>12</sup> It is estimated that 10%–25% of total TFAs consumed are from ruminant sources.<sup>14,16,17</sup> The predominant TFAs found in ruminant products are C16:1t9, C18:1t11, and conjugated linoleic acid (CLA) isomers of C18:2c9t11 and C18:2t10c12.<sup>4</sup> There remains debate regarding the potential linkage between ruminant fat and cardiovascular disease; however, growing evidence suggests that the major isomers of ruminant TFAs are benign or potentially beneficial for health.<sup>3,18,19</sup>

Efforts to reduce partially hydrogenated vegetable oil in foods and intake in the US are reflected in decreased total TFAs measured from archived plasma ( $n = 521$ ), which fell from 93.1  $\mu\text{mol/L}$  in 2000 to 39.0  $\mu\text{mol/L}$  in 2009 in the US National Health and Nutrition Examination Survey (NHANES).<sup>20</sup> Studies by Health Canada report a significant decrease in estimated average intake of TFAs in Canada, in children and adults, from 8.4 g/d (~3.7% of energy) in the 1990s to 3.4 g/d (~1.4% of energy) in 2008.<sup>12</sup> In tandem with changes in the regulatory environment, food supply, estimated intake and monitoring by Health Canada, 2 small Canadian studies have shown a decline in breast milk TFA of breastfeeding women from 1998 to 2004–2006 ( $n = 190$ )<sup>21</sup> and again in 2009–2011 ( $n = 639$ ).<sup>22</sup> However, these findings in human milk may not be generalizable to the Canadian population. Therefore, the aim of the present study was to determine temporal changes in circulating plasma TFA in consecutive years from 2004 to 2010 in a larger population of young, healthy, Canadian adults from the Toronto Nutrigenomics and Health Study.

## Methods

### Study population

Participants, aged 20–29 yr ( $n = 1294$ ; 396 men, 898 women), were part of the cross-sectional Toronto Nutrigenomics and Health Study,<sup>23</sup> and were recruited between September 2004 and November 2010 (2004,  $n = 95$ ; 2005,  $n = 234$ ; 2006,  $n = 227$ ; 2007,  $n = 137$ ; 2008,  $n = 203$ ; 2009,  $n = 201$ ; 2010,  $n = 197$ ). The study was a cross-sectional examination of independent-living, ethnoculturally diverse men and women. The targeted recruitment of young adults to assess TFA exposure was not the original intent of the present study; however, this cohort has helped to shed light on TFA exposure in an at-risk group, because it is estimated that Canadian men and women aged 19–51 years consume more partially hydrogenated vegetable oil TFAs than those aged more than 51 years.<sup>12</sup> Written informed consent was obtained from all participants. Anthropometric measure-

ments, health, lifestyle, food frequency questionnaires and levels of health biomarkers were obtained and described elsewhere.<sup>24</sup> Briefly, age, body mass index (BMI) and percent energy from dietary fat were determined from information, anthropometric measurements and food frequency questionnaire, respectively. Women who were pregnant or breastfeeding were not included in the study.

### Gas chromatography analysis

Participants were required to fast overnight for a minimum of 12 hours before blood collection, separation of plasma and subsequent freezing of samples at  $-80^{\circ}\text{C}$ . Sample preparation and fatty acid analysis were carried out as described previously.<sup>24,25</sup> Plasma samples were stored in a 96-well format and processed together for gas chromatography analysis. A total of 16 plates were processed. Fatty acid methyl esters were eluted using the approved SP-2560 column for the separation of TFAs indicated in the American Oil Chemists' Society official method Ce 1H-05. Accompanying American Oil Chemists' Society authentic partially hydrogenated vegetable oil standards (margarine) were purchased with individually identified trans fatty acid isomers. The internal standard C17:0 was used to calculate fatty acid concentrations ( $\mu\text{mol/L}$ ). The C17:0 standard was prepared as a single batch and aliquoted for use throughout the study. The limit of quantification of the flame ionization detector was checked through serial dilution measurement of a known C17 standard, which was 1.4  $\mu\text{mol/L}$ . Response factors of fatty acid methyl esters measured by flame ionization detector are about 1. Additional fatty acid methyl esters were identified by retention time in comparison with authentic gas liquid chromatographic standards (Nu-Chek Prep Inc.) with reported compositional values. When a peak was not detected, an integrated value of 0 was recorded. Interassay coefficient of variance for major fatty acids such as 16:0 and 18:0 were 3%–4%; minor fatty acids were higher — for example, 18:3n3 was 7%. The coefficient of variance for such analyses by gas chromatography is 5%–15%.<sup>26–28</sup>

### Statistical analysis of data

Results are expressed as mean and standard deviation (SD). All data were analyzed using JMP genomics software version 5 (SAS Institute). Data were not transformed and closely approximated normality, which was assessed by Shapiro-Wilk  $W$  test. The statistical significance of differences across years was assessed by analysis of variance and Tukey posthoc test. A  $p$  value of less than 0.05 was considered significant.

### Ethics approval

Research Ethics Boards at the University of Toronto and University of Guelph approved the study protocol.

## Results

### Study population characteristics

Participant characteristics of the total study population are shown in Table 1. Stratified by year, characteristics of total

study population, men and women, are shown in Appendix 1 (available at [www.cmajopen.ca/content/5/1/E130/suppl/DC1](http://www.cmajopen.ca/content/5/1/E130/suppl/DC1)).

**Relative percent and concentrations of TFAs over time**

Relative percent composition and concentrations of circulating TFAs are shown in Table 2 and Table 3. Circulating TFAs found predominantly in ruminant fat include 18:1t11, 18:2c9t11-CLA and 18:2t10c12-CLA (Table 2, Table 3, Figure 1). 18:1t11 consistently declined each year from 2004–2010 (Table 2, Table 3, Figure 1). The 18:2c9t11-CLA isomer declined from 2004 to 2009, but concentrations were not significantly different between 2004 and 2010 (Table 2, Table 3, Figure 1). There was no trend observed for 18:2t10c12-CLA (Table 2, Table 3).

Trans fatty acids found predominantly in partially hydrogenated vegetable oil include 18:1t9, 18:1t10 and 18:2t9t12. Examination of the annual mean for partially hydrogenated vegetable oil showed that 18:1t9 and 18:1t10 trended lower each year from 2004 to 2009, but were higher in 2010 (Table 2, Table 3, Figure 1). There was no clear trend in polyunsaturated *cis/trans* TFAs; however, levels of the di-trans isomers 18:2t9t12 and 18:2tt increased significantly by 2010 ( $p < 0.05$ ) (Table 2, Table 3, Figure 1). 16:1t9, which may be obtained from partially hydrogenated vegetable oil, ruminant or endogenous synthesis,<sup>29</sup> declined significantly by 2010 compared with 2004 ( $p < 0.05$ ; Table 2, Table 3, Figure 1).

Direction of change (decline v. increase) of the aforementioned fatty acid levels (concentrations and percent composition) in total population were similar to changes determined in men and women separately (Appendix 1).

**Table 1: General characteristics of study population**

Characteristic	Total population, mean ± SD n = 1294
Age, yr	22.7 ± 2.5
BMI, kg/m <sup>2</sup>	22.9 ± 3.5
HOMA-IR	1.5 ± 1.4
Glucose, mmol/L	4.8 ± 0.4
Insulin, pmol/L	47.7 ± 40.4
Total cholesterol, mmol/L	4.3 ± 0.8
HDL cholesterol, mmol/L	1.5 ± 0.4
LDL cholesterol, mmol/L	2.3 ± 0.6
Triglycerides, mmol/L	1.0 ± 2.9
Free fatty acids, µmol/L	477.6 ± 248.4
% Energy from dietary fat	27.1 ± 6.0

Note: BMI = body mass index, HDL = high-density lipoprotein, HOMA-IR = homeostatis model assistance and insulin resistance, LDL = low-density lipoprotein, SD = standard deviation.

**Table 2: Trans fatty acids levels (% composition) by year**

Fatty acid	2004 n = 95 (M = 25, F = 70)	2005 n = 234 (M = 80, F = 154)	2006 n = 227 (M = 69, F = 158)	2007 n = 137 (M = 34, F = 103)	2008 n = 203 (M = 52, F = 151)	2009 n = 201 (M = 136, F = 65)	2010 n = 197 (M = 71, F = 126)
16:1t9	0.33 ± 0.09*	0.30 ± 0.08*	0.19 ± 0.15‡	0.19 ± 0.13‡	0.21 ± 0.07‡	0.24 ± 0.09‡	0.21 ± 0.08‡,‡
18:1t4	0.05 ± 0.05†,‡	0.03 ± 0.04‡	0.08 ± 0.09*,†	0.10 ± 0.12*	0.09 ± 0.09*	0.08 ± 0.10*,†	0.09 ± 0.12*
18:1t5	0.03 ± 0.04†	0.02 ± 0.03†,‡	0.01 ± 0.02‡	0.01 ± 0.02‡	0.01 ± 0.01‡	0.03 ± 0.07†	0.09 ± 0.09*
18:1t6–8	0.21 ± 0.11*	0.15 ± 0.07†	0.08 ± 0.04‡	0.08 ± 0.04‡	0.08 ± 0.08‡	0.08 ± 0.08‡	0.15 ± 0.12†
18:1t9	0.42 ± 0.18*	0.25 ± 0.11†	0.21 ± 0.09‡	0.21 ± 0.07‡,§	0.16 ± 0.13¶	0.17 ± 0.10§,¶	0.38 ± 0.15*
18:1t10	0.44 ± 0.17*	0.31 ± 0.13‡	0.19 ± 0.09§	0.19 ± 0.10§	0.13 ± 0.13¶	0.23 ± 0.13§	0.37 ± 0.15†
18:1t11	0.31 ± 0.15*	0.29 ± 0.14*	0.24 ± 0.10†	0.23 ± 0.08†	0.16 ± 0.11‡	0.17 ± 0.09‡	0.12 ± 0.07§
18:1t12	0.24 ± 0.10*	0.19 ± 0.09†	0.13 ± 0.07‡	0.15 ± 0.07‡	0.09 ± 0.07§	0.14 ± 0.17‡	0.14 ± 0.10‡
18:1t13 or c6	0.18 ± 0.08*,†,‡	0.06 ± 0.16‡	0.16 ± 0.09†,‡	0.20 ± 0.08†,‡	0.22 ± 1.36†,‡	0.45 ± 1.17*	0.36 ± 0.48†
18:2c9t12	0.26 ± 0.06*,†	0.17 ± 0.04§	0.30 ± 0.34*	0.24 ± 0.09†,‡	0.19 ± 0.38†,§	0.23 ± 0.10†,‡	0.26 ± 0.10*,†
18:2c9t13	0.21 ± 0.6*	0.17 ± 0.6*,†	0.19 ± 0.09*,†	0.16 ± 0.07†	0.04 ± 0.13§	0.07 ± 0.14§	0.11 ± 0.14‡
18:2t9c12	0.16 ± 0.04*,†	0.11 ± 0.05‡	0.16 ± 0.05†	0.16 ± 0.06†	0.12 ± 0.03‡	0.16 ± 0.08†	0.18 ± 0.07*
18:2t9t12	0.02 ± 0.01†,‡,§	0.01 ± 0.01§	0.03 ± 0.04†	0.03 ± 0.04†,‡	0.02 ± 0.02‡,§	0.04 ± 0.06†	0.10 ± 0.10*
18:2tt	0.02 ± 0.01§	0.03 ± 0.02§	0.04 ± 0.06‡,§	0.07 ± 0.20†	0.06 ± 0.03†,‡	0.05 ± 0.05†,‡,§	0.13 ± 0.13*
18:2c9t11 CLA	0.29 ± 0.07*	0.26 ± 0.07†	0.24 ± 0.06‡	0.20 ± 0.07‡,§	0.17 ± 0.06 e	0.17 ± 0.06 e	0.21 ± 0.11§
18:2c10t12 CLA	0.08 ± 0.02*	0.07 ± 0.02†,‡	0.06 ± 0.02‡,§	0.08 ± 0.04*,†	0.04 ± 0.02 e	0.06 ± 0.04§	0.07 ± 0.05*,†
Total trans	2.88 ± 0.88*	2.07 ± 0.70†	2.00 ± 0.69†	2.00 ± 0.63†	1.58 ± 1.50‡	2.12 ± 1.73†	2.69 ± 1.23*

Note: F = female, M = male. Values are expressed as mean ± standard deviation. Differences in years were analyzed by analysis of variance (ANOVA), and the Tukey posthoc test was used to determine differences between means. Total trans excludes conjugated linoleic acid isomers. Values within a row with different symbols are significantly different ( $p < 0.05$ ).

**Table 3: Trans fatty acids concentrations (µmol/L) by year**

Fatty acid	2004 <i>n</i> = 95 (M = 25, F = 70)	2005 <i>n</i> = 234 (M = 80, F = 154)	2006 <i>n</i> = 227 (M = 69, F = 158)	2007 <i>n</i> = 137 (M = 34, F = 103)	2008 <i>n</i> = 203 (M = 52, F = 151)	2009 <i>n</i> = 201 (M = 136, F = 65)	2010 <i>n</i> = 197 (M = 71, F = 126)
16:1t9	28.57 ± 10.10*	21.61 ± 8.23†	14.67 ± 12.64§	15.16 ± 11.43§	16.82 ± 7.05‡,§	19.43 ± 8.42†,‡	20.56 ± 10.05†
18:1t4	4.28 ± 4.27†	1.89 ± 2.23‡	5.06 ± 5.44*,†	6.77 ± 8.62*	6.56 ± 5.69*	6.06 ± 6.59*,†	5.79 ± 4.41*,†
18:1t5	2.34 ± 2.69†	1.10 ± 1.93‡	0.57 ± 1.24‡	0.56 ± 1.13‡	0.44 ± 0.83‡	1.87 ± 3.99†	6.43 ± 4.22*
18:1t6–8	16.85 ± 8.91*	9.71 ± 5.33‡	5.53 ± 3.10§	5.75 ± 3.01§	5.30 ± 4.39§	5.91 ± 5.56§	11.39 ± 8.18†
18:1t9	32.81 ± 15.96*	16.25 ± 8.32†	14.28 ± 6.83†,‡	14.39 ± 6.43†,‡	11.56 ± 7.54‡	13.13 ± 9.43†,‡	32.54 ± 22.07*
18:1t10	34.46 ± 14.95*	20.19 ± 9.53†	13.22 ± 7.26†,§	13.09 ± 6.36†,§	9.84 ± 6.50§	16.35 ± 9.84‡	31.80 ± 27.02*
18:1t11	24.34 ± 11.33*	19.01 ± 10.14†	16.25 ± 7.91‡	15.53 ± 5.79‡	11.95 ± 7.34§	12.53 ± 9.10§	9.41 ± 6.14¶
18:1t12	18.40 ± 8.12*	11.90 ± 5.92†	8.95 ± 4.66‡	10.00 ± 5.15†,‡	6.71 ± 4.33§	10.12 ± 8.06†,‡	11.04 ± 8.67†
18:1t13 or c6	13.63 ± 6.03†,‡	3.73 ± 7.10‡	10.89 ± 6.32‡	13.62 ± 6.72†,‡	15.00 ± 86.76†,‡	30.98 ± 58.95*	27.45 ± 34.33*,†
18:2c9t12	20.57 ± 6.33*,†	11.10 ± 4.14§	20.00 ± 24.53*,†	17.10 ± 7.62†,‡	14.17 ± 4.79‡,§	17.13 ± 7.65†,‡	22.01 ± 10.94*
18:2c9t13	16.33 ± 5.79*	11.19 ± 5.47†	12.90 ± 6.62†	11.29 ± 5.89†	2.91 ± 10.08§	4.93 ± 9.42§	7.83 ± 4.96‡
18:2t9c12	12.82 ± 3.81†	7.11 ± 3.49 e	10.48 ± 3.93‡	10.87 ± 4.73‡	8.90 ± 3.07§	11.64 ± 6.25†,‡	15.06 ± 7.44*
18:2t9t12	1.67 ± 0.79†,‡	0.34 ± 0.66§	2.22 ± 3.06†	2.00 ± 2.87†,‡	1.26 ± 1.34‡	2.57 ± 3.76†	7.33 ± 5.11*
18:2tt	1.93 ± 1.27‡,§	1.69 ± 1.25§	2.39 ± 3.50‡,§	4.30 ± 10.12†	4.18 ± 2.39†	3.43 ± 3.56†	10.26 ± 8.01*
18:2c9t11 CLA	23.62 ± 8.94*	17.26 ± 7.22†	16.32 ± 6.34†	16.28 ± 6.91†	12.62 ± 5.79‡	12.95 ± 7.41‡	17.49 ± 9.89†
18:2c10t12 CLA	6.25 ± 1.86*	4.28 ± 1.62‡	3.85 ± 1.31†	5.09 ± 2.37§	3.02 ± 1.41‡	3.93 ± 3.13‡	6.29 ± 4.30*
Total trans	228.99 ± 81.6*	136.83 ± 56.1†,‡	137.41 ± 58.4†,‡	140.42 ± 54.5†,‡	115.60 ± 96.9‡	156.08 ± 97.8†	218.89 ± 112.6*

Note: F = female, M = male. Values are expressed as mean ± standard deviation. Differences in years were analyzed by analysis of variance (ANOVA), and the Tukey posthoc test was used to determine differences between means. Total trans excludes conjugated linoleic acid isomers. Values within a row with different symbols are significantly different ( $p < 0.05$ ).

## Interpretation

Mean plasma TFA levels were significantly lower after 2004 until 2009, but some levels increased in 2010 in a cohort of young Canadian adults.

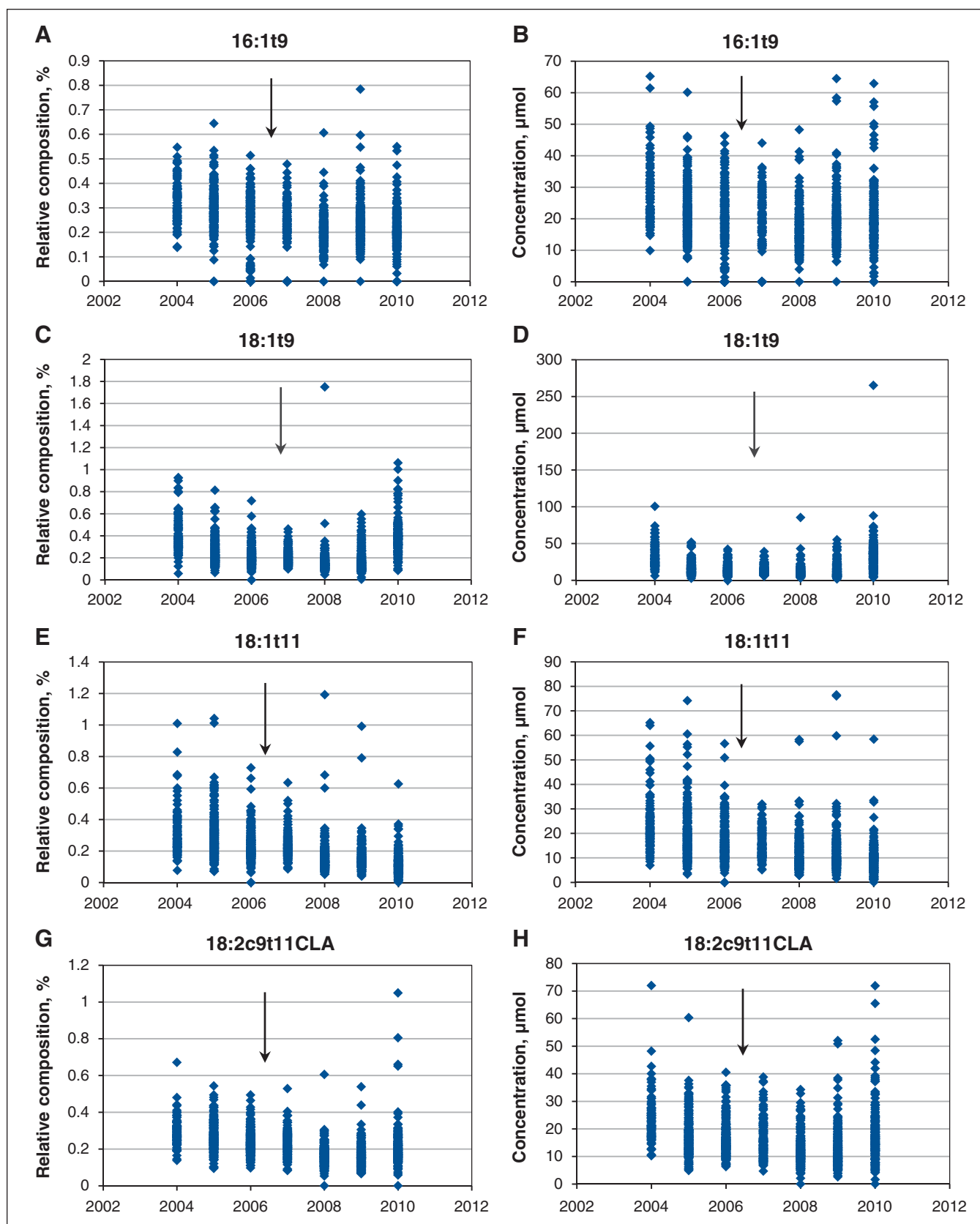
Circulating plasma TFAs are biomarkers of dietary intake and appear to complement changes seen in the Canadian food supply.<sup>10,12,30</sup> Partially hydrogenated vegetable oil TFAs in Canada continue to be of concern, and efforts to encourage positive changes in the food supply, through labelling and voluntary product reformulations, have been reflected in reduced TFA intake (measured in 2008) and in the food supply (measured in 2009).<sup>10,12</sup> Many products meet the less than 5% TFA target, or less than 2% for margarines, and estimated partially hydrogenated vegetable oil intake among Canadians has declined.<sup>12</sup> Data from Canadian breastfeeding women show consistent declines, suggesting that health-conscious populations have reduced TFA intake, but these findings are not necessarily generalizable to all Canadians.<sup>21,22</sup>

Recently, a follow-up study examining TFA levels in the Canadian food supply in 2010–2011, using databases from Health Canada (2005–2009), the University of Toronto Food Label Information Program (2010–2011) and the Restaurant Database (2010), found that 97% of products met recommended TFA limits.<sup>30</sup> However, the study also found that several food categories and products exceeded the recommended limit, such as coffee whiteners, some types of doughnuts and

cookies, frosting and dairy-free cheese, and contained levels that may leave some subgroups, specifically young adults, at risk for higher intake of TFAs.<sup>12,30</sup> These findings may help explain the apparent upward trend in TFAs we saw in 2010 (Table 2). Unfortunately, accurate data on participants' trans fats intake are not available to further corroborate the circulating TFA data. This is challenging to quantify given substantial changes to the food supply during this period, and accurate food composition tables in all years containing partially hydrogenated vegetable oil are lacking.

The NHANES report is the only other comparable study ( $n = 229$ ) to examine temporal changes in TFAs in North America from plasma. Levels of total TFAs in the present study were about 100 µmol/L higher ( $n = 1294$ ), but comprised 16 TFAs, in contrast to 4 in the NHANES study. Comparing the total value of the same 4 TFAs, 16:1t9, 18:1t9, 18:1t11 and 18:2t9t12,<sup>20</sup> showed similar declines between 2004 and 2009. Concentrations declined from 87 to 47 µmol/L in the present study, compared with 93 to 39 µmol/L in the NHANES study.

The assessment of TFA risk from epidemiologic studies has focused on food intake of partially hydrogenated vegetable oil whereby a 2% (energy) increase in partially hydrogenated vegetable oil was associated with a 25% increased relative risk for ischemic heart disease.<sup>31</sup> Trans fatty acids measured in plasma, red blood cells and adipose tissue have been shown to correlate with dietary intake.<sup>32,33</sup> However, the interpretation



**Figure 1:** Changes in circulating concentrations and percent composition levels of select trans fatty acids from 2004 to 2010. (Total  $N = 1294$ ; 2004,  $n = 95$ ; 2005,  $n = 234$ ; 2006,  $n = 227$ ; 2007,  $n = 137$ ; 2008,  $n = 203$ ; 2009,  $n = 201$ ; 2010,  $n = 197$ ). Arrow indicates 2007, the point at which Health Canada adopted recommendations for voluntary reduction of trans fatty acids.



of TFAs in tissues and blood is limited because of the lack of clinical reference values that outline normal versus undesirable circulating TFA levels.

Chemically, partially hydrogenated vegetable oil and natural ruminant TFAs are identical in structure; however, the relative composition of these isomers differs markedly.<sup>34,35</sup> Given that it is not possible to discriminate the source of TFAs in blood or tissues and that ruminant fat contributes a small fraction of total TFA intake (10%–25%),<sup>14,16,17</sup> it has been reasonable in the past to use total TFA as a reflection of partially hydrogenated vegetable oil. However, it is important to examine trends in specific TFAs given greater recognition of their biological effects.

Upward of 70% of total ruminant TFAs are 18:1t11.<sup>35</sup> Data from the Canadian Dairy Information Centre show that consumption of total dairy products per capita in Ontario decreased from 2004 to 2010.<sup>36</sup> This may explain why the ruminant fatty acids, 18:1t11 and 18:2c9t11, declined in all years (Table 2, Table 3, Figure 1).

The major partially hydrogenated vegetable oil TFAs are 18:1t9 and 18:1t10, and each comprises about 20% of total monounsaturated partially hydrogenated vegetable oil.<sup>35</sup> These same TFAs are also found in ruminant fat, but at very low levels.<sup>35</sup> Changes in both 18:1t9 and 18:1t10 were similar in relative percent composition and concentration and tracked similarly over time. On a percent basis, these TFA isomers appear to have plateaued by 2008 and 2009, and trended upward in 2010. It is estimated that 98% of trans fats are in the monounsaturated form.<sup>37</sup> However, polyunsaturated TFAs, such as trans-18:2, have been associated with higher risk for coronary artery disease than the predominant monounsaturated TFAs.<sup>38</sup> Direct experimental evidence for the adverse effects of these polyunsaturated TFAs has not yet been examined.<sup>37</sup>

### Limitations

A limitation of this study is the cross-sectional design, which limits prospective insight. However, this limitation was addressed by measuring random samples in multiple years. This limitation was also recognized by the NHANES study, in which their conclusions were based on 2 random samples from 2000 and 2009.<sup>20</sup> Other limitations include the small number of participants per year, as well as the sample demographic, which are all from a single urban centre, which may potentially limit the generalizability of the results.

### Conclusion

This study uniquely assessed plasma TFAs over 7 consecutive years, showing consistent declines in total TFAs from 2004 to 2009, which paralleled changes in food labelling, voluntary reformulation to reduce partially hydrogenated vegetable oil and lower estimated food intake of TFAs by Canadians. Although levels of 16:1t9 and 18:1t11 declined from 2004 to 2010, levels of 18:1t9 and 18:1t10 were only lower from 2005 to 2009. Consequently, total TFAs were lower in 2009 relative to 2004, but not different in 2010, suggesting that young Canadians may remain vulnerable to partially hydrogenated

vegetable oil exposure and that there is a need for further monitoring of specific food categories and vulnerable populations. Therefore, future direction in this area of study requires prospective monitoring of dietary intake and assessment of plasma TFAs in young adults. In addition, continuous monitoring of TFAs in the food supply is warranted.

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**Affiliations:** Department of Human Health and Nutritional Sciences (Abdelmagid, Mutch, Ma), University of Guelph, Guelph, Ont.; Department of Nutritional Sciences (Nielsen, El-Soheemy), University of Toronto, Toronto, Ont.; Office for Biotechnology (Badawi), Genomics and Population Health, Public Health Agency of Canada, Toronto, Ont.;

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