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Changing BMI scores among Canadian Indigenous and non-Indigenous children, youth and young adults: Untangling age, period, and cohort effects

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Abstract

The objective of this study was to examine age, period, and cohort effects on BMI among Indigenous and non-Indigenous populations, using repeated cross-sectional survey data from the CCHS (2001 to 2014). Cross-classified random-effects two level models were used to estimate fixed effects for age and its quadratic term (Level 1), and also estimate random effects for time periods and birth cohorts (Level 2), while controlling for the effects of Level 1 control variables: sex, model of interview, and response by proxy. Overall, the results support the hypothesis that age and period effects are primarily responsible for the current obesity epidemic.

Keywords: age-period-cohort analysis; BMI; CCHS; Canada; obesity.

Résumé

L'objectif de cette étude était d'examiner les effets de l'âge, de la période et de la cohorte sur l'IMC chez les populations autochtones et non autochtones, en utilisant des données d'enquêtes transversales répétées de l'ESCC (2001 à 2014). On a utilisé des modèles à deux niveaux à effets aléatoires croisés pour estimer les effets fixes pour l'âge et son terme quadratique (niveau 1), et également estimer les effets aléatoires pour les périodes et les cohortes de naissance (niveau 2), tout en contrôlant les effets du niveau 1 Variables de contrôle: sexe, modèle d'interview et réponse par procuration. Dans l'ensemble, les résultats confirment l'hypothèse selon laquelle les effets de l'âge et de la période sont les principaux responsables de l'épidémie actuelle d'obésité.

Mots-clés : analyse de l'âge, de la période et de la cohorte; l'IMC; l'ESCC; Canada; obésité.

Introduction

Overweight and obesity is a critical public health issue worldwide, and is associated with the prevalence of co-morbidities such as type 2 diabetes, cancer, and cardiovascular diseases (Guh et al. 2009). Between 1980 and 2013, the combined global rates of overweight and obesity among children rose 47.1 per cent, and 27.5 per cent for adults (Ng et al. 2014). In total, from 1980 to 2013, the number of individuals with overweight and obesity has risen from 857 million to 2.1 billion (Ng et al. 2014). Within Canada, approximately one-third of 5- to 17-year-olds are overweight or obese; 19.8 and 11.7 per cent, respectively (Roberts et al. 2012). Among Canadians 18 years and older, 33.6 per cent could be classified as overweight and 18.3 per cent as obese (Twells et al. 2014). It has been estimated that by 2019, approximately 55 per cent of Canadians will be overweight or obese (Twells et al. 2014). These trends are worrisome given that the prevalence and severity of obesity has been found to negatively impact population life expectancy in the United States (Olshansky et al. 2005). Olshanksy and colleagues highlight that the rise of obesity rates among children in particular may worsen this effect, with the result that life expectancy might

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decrease for recently born cohorts (Olshansky et al. 2005). If this pervasive and difficult public health problem is not addressed, further population health consequences and impacts on mortality are likely (Preston 2005).

In Canada, obesity rates among Indigenous populations are particularly concerning, as they tend to be significantly higher than those among non-Indigenous Canadians (Ng et al. 2012). Given that obesity-related comorbidities, such as type 2 diabetes, are also high in this population (Amed et al. 2010), it is important to reduce the rates of overweight and obesity to prevent further chronic disease.

Indigenous populations in Canada are young and growing; 28 per cent of the Indigenous population is aged 14 and under, compared to 16.5 per cent of the total Canadian population, and about 7 per cent of all children in Canada are Indigenous (Statcan 2013). An important but often neglected fact is that the majority of Indigenous people in Canada, nearly 60 per cent in 2006, live outside of discrete Indigenous communities such as First Nations reserves, Inuit communities, and Métis settlements (Statcan 2013). Moreover, much of the recent growth in Indigenous populations, and therefore in the number of Indigenous children and youth, has occurred in cities and other off-reserve areas. Understanding the trends and dynamics of the health of these off-reserve Indigenous populations should therefore be a priority for researchers (Young 2003).

Overweight and obesity are associated with a variety of physical, emotional, and social consequences. Among children, they are a strong risk factor for the early onset of type 2 diabetes (Amed et al. 2010) and significantly increases the risk of obesity in adulthood (Srinivasan et al. 1996), with attendant implications for dyslipidemia, hypertension, and certain types of cancers (Bhaskaran et al. 2014; Srinivasan et al. 1996). They are also associated with osteoarthritis as well as other adverse health outcomes (Dietz 1998a, 1998b; Janssen et al. 2005; Lawlor and Leon 2005; Maffeis and Tato 2001). Psycho-social effects are also important. Children who are overweight can develop negative self-image and low self-esteem, with implications for older ages (Strauss 2000).

Taking into account that childhood overweight and obesity may continue into adulthood (Telama et al. 2005) and can have short- and long-term health consequences, it is critical to understand better how weight status changes across the life course. As well, understanding these age-related trends means considering whether or not they have changed across time periods, and for different birth cohorts.

This requires separating the effects of age, period, and cohort on the problem, using what has been known as *age-period-cohort analysis* (APC). *Age effects*, in this case, refer to the developmental changes that occur (biologically or socially) throughout the life course (Reither et al. 2009; Yang and Land 2008). *Period effects* refer to variations between calendar years, which may impact all age groups and birth cohorts simultaneously. This includes the broad effects of social changes or historical effects (Yang and Land 2008). Lastly, birth cohorts are defined as groups of people who experience historical or social events at the same age (Reither et al. 2009; Yang and Land 2008). As described by Keyes et al. (2010), a *cohort effect* can be understood as a period effect that is differentially experienced through age-specific exposure to changing or new environmental causes.

Hierarchical age-period-cohort analysis (HAPC) is a promising methodology that has been used to examine the independent effects of age, time period, and birth cohort for the prevalence of various health outcomes while overcoming some of the constraints of traditional APC methods (Yang and Land 2006). A notable problem with APC analysis is with model identification occurring from the mathematical linear dependency between age, period, and cohort [calendar year = birth year + age] (Yang and Land 2008). To address this issue, Yang and Land (2006, 2013) have proposed a HAPC approach, which allows for separate estimates of age, period, and cohort effects. Unlike the traditional APC method, the HAPC framework considers period and cohort effects to be "contextual," while age is entered as an individual-level variable in a hierarchical model (Yang and Land 2013). Using a mixed-effect model is an appropriate alternative to the linear model as it does not assume fixed age, period, or cohort effects that are additive (Yang and Land 2013), thereby removing the identification problem.

Previous studies have employed a HAPC framework to explore trends in overweight and obesity (Fu and Land 2015; Reither et al. 2009; Yang and Land 2013). The results of these studies indicate that trends in age typically show a lower average body mass index (BMI) scores amongst younger people that steadily increases with age, followed by a decrease in older adult ages (Jiang et al. 2013). Secular changes in diet and levels of physical activity across time (period effects) are generally thought to be the root of the current obesity epidemics (An and Xiang 2016; Reither et al. 2009). However, analyses of data in the United States (Reither et al. 2009; Robinson et al. 2013), China (Fu and Land 2015; Jaacks et al. 2013), Japan (Yamakita et al. 2014), and Australia

(Allman-Farinelli et al. 2008) have found unique effects of birth cohort membership as well. Rapid social and environmental changes over recent decades have meant that succeeding birth cohorts have grown up in decidedly different social, technological, and physical environments. These changed environments affect not only their behaviours in terms of their diets and physical activity, but also their expectations and preferences with regard to lifestyles, social activity, and other factors that indirectly affect the risk of overweight and obesity (Reither et al. 2009).

It is not surprising that given the current obesogenic environment, more recent birth cohorts are more at risk for overweight and obesity compared to past cohorts (Reither et al. 2009). These effects might be even stronger among cohorts of Indigenous peoples, who are not only at higher risk of overweight and obesity, but also might have experienced even more rapid social change than the non-Indigenous Canadian population. Thus, understanding the reasons for changing trends in weight status requires careful attention to the three unique effects of age, period, and cohort.

To our knowledge, assessment of age, period, and cohort effects has not been carried out in a Canadian context since 2009 (Ng et al. 2012), and therefore needs to be updated to continue to monitor trends in weight status among Canadians, and among Indigenous populations in particular. Using data from the longitudinal National Population Health Survey (NPHS), Ng and colleagues examined BMI trajectories among Indigenous (n=311) and non-Indigenous Canadians (n=10,967) living off-reserve between 1994 and 2009 (Ng et al. 2012). Respondents were divided into five birth cohorts (1940s, 50s, 60s, 70s, and 80s) and linear growth curve models were estimated. That analysis found that Indigenous Canadians had experienced a greater average BMI increase between 1994 and 2009 than did non-Indigenous Canadians, and that Indigenous people born in the 1960s and 70s had even higher BMI scores, rising more quickly than those born before or after (Ng et al. 2012). The authors speculate that the faster BMI increase among those born in the 1960s and 70s may be a result of birth cohort membership, and that this generation of Indigenous people could have experienced substantial cultural and social shifts that negatively influenced their health status (Ng et al. 2012). On the other hand, the result could also be due to differences that are age-related and specific to the Indigenous Canadians.

As Ng, Corey et al.'s (2012) study used NPHS data, only off-reserve First Nations, Inuit, and Métis populations in the ten provinces were included. Additionally, as the data were longitudinal, the study was limited to cohorts born before the 1980s and a relatively high rate of attrition, observed at the latest periods of data collection (n=1,408 in 1994/95 to n=971 in 2008/09), limited the generalizability of the results. The present study hopes to address some of these limitations by using cross-sectional data from repeated waves of the Canadian Community Health Survey (CCHS), which provide a much larger sample of Indigenous respondents and are not affected by attrition. Additionally, although the CCHS also does not sample on-reserve populations, it does include populations from the three Canadian territories (which have majority Indigenous populations). Finally, using HAPC analysis may offer a different analytical framework to address research questions involving assessment of the independent effects of age, period, and cohort. Taking into account that most of the current Canadian survey data containing information on Indigenous peoples are cross-sections, there is a need to develop methodological techniques that will enable us to assess changing behaviours and patterns of health outcomes among various populations over time.

The objective of this study was therefore to conduct an analysis of age, period, and cohort effects on weight status among Indigenous and non-Indigenous children, youth, and young adults, using repeated cross-sectional survey data from the CCHS from 2001 to 2014.

Methods

Study populations

The CCHS is a repeated cross-sectional survey that began in 2000/01 and is primarily used for health surveillance and population health research (Statcan 2016).[2] The survey includes those 12 years and older living within the ten provinces and three territories of Canada. Seven cycles of the CCHS were used: 2001, 2003, 2005, 2007/08,

2. The data for this paper were provided by Statistics Canada through the Research Data Centres program. The analyses and interpretation are the authors' alone.

2009/10, 2011/12, and 2013/14.[3] For the purpose of this study, a sample of respondents between 12 and 40 years old was selected. Within this sample, we identified a group of 20,247 (6.93 per cent) respondents who self-identified as belonging to one of three Indigenous identity groups in Canada (approximately 58.7 per cent First Nations, 11.5 per cent Inuit, and 29.7 per cent Métis) and a group of non- Indigenous respondents (N = 291,883; 93.07 per cent). These two samples excluded respondents who indicated that they were pregnant at the time of the interview.

Measurement instruments

As direct measures of body fatness were not available in the CCHS, BMI was used to assess weight status. BMI was calculated using self-reported height and weight values from the CCHS [BMI = weight(kg)/height^2(m)]. Although weight tends to be underreported and height to be overreported (Connor Gorber et al. 2007), it is assumed that this bias is consistent across time periods, birth cohorts, and age groups. In order to make our results more comparable to those of Ng and colleagues (2012), we decided to use BMI as the outcome variable, as opposed to overweight and obesity rates, which were used in other HAPC studies (Allman-Farinelli et al. 2008; Reither et al. 2009). The initial screening of BMI scores suggested that a small number of respondents had extremely high scores. To prevent these values from disproportionately affecting the result of the analysis, we removed any respondents with BMI scores greater than 80.

Age and a quadratic function of age were included in the models as individual-level focal variables. The quadratic term was added, as the BMI trajectory between age 12 and 40 is expected to follow a non-linear trend (Jaacks et al. 2013). Age was centered at the group mean, and divided by 10 to increase interpretability. Respondent-level control variables included in the analysis were sex, mode of interview, and an indicator whether survey responses had been given by a proxy. Interaction effects between sex and age variables were included as it is expected that BMI changes across the life course would differ between males and females (Allman-Farinelli et al. 2008). Mode of interview (e.g., in person or by telephone) was included as a control, as differences in the proportion of respondents interviewed by each mode across survey cycles might affect the distribution of reporting bias for the outcome variable (St-Pierre and Béland 2004). Interviews conducted by proxy may also be subject to bias.

Based on the year when data for each of the seven cycles of the CCHS were collected, we identified seven time periods: 2001, 2003, 2005, 2007/08, 2009/10, 2011/12, and 2013/14. To examine the effects of birth cohort on weight status, we constructed ten three-year synthetic birth cohorts: 1966–68, 1969–71, 1972–74, 1975–77, 1978–80, 1981–83, 1984–86, 1987–89, 1990–92, and 1993–95. Membership in each cohort was identified based on respondents' age at the time of survey and the year of the CCHS data collection. For instance, the 1981–83 cohort consists of respondents who were 18–20 years old in the 2001 cycle of the CCHS, 22–24 years old in the 2005 cycle of the CCHS, 26–29 years old in the 2009/10 cycle of the CCHS, and 30–33 years old in the 2013/14 cycle of the CCHS. These ten birth cohorts allowed us to examine time trends in BMI scores from 2001 to 2014, and to explore differences in these trends between the cohorts at ages 12 to 40.

Statistical analyses

Means for the BMI scores were derived in order to describe the time trends in weight status by age, time period, and birth cohort. Cross-classified random-effect two-level models were used to estimate fixed effects for age and its quadratic term (Level 1), and also to estimate random effects for time periods and birth cohorts (Level 2), while controlling for the effects of Level 1 control variables: sex, model of interview, and response by proxy. Separate statistics were computed for Indigenous and non-Indigenous respondents. In the CCHS, each respondent was assigned a cross-sectional sampling weight that represented his or her contribution to the total population. This weight took into account the CCHS multi-stage sampling design, and was adjusted to be calibrated with population projections of age and sex strata within each province; these sampling weights were also adjusted for survey non-response (Statcan 2016). Sampling weights were normalized to reflect the actual num-

3. Before 2007, the CCHS data were collected every two years, over a one-year period. In 2007 and later cycles, data were collected annually, with adjacent years combined by Statistics Canada to provide comparable sample sizes to the 2005 and earlier cycles.

bers of respondents participating in each cycle of the CCHS. Bootstrap weights were not used in this study, as they are not available for models with random effects. SAS 9.4 was used for all analyses (SAS Institute Inc. 2013).

Results

Descriptive statistics

Table 1 presents the means and proportions for the variables used in the analysis. The mean values for BMI across all age groups, time periods, and birth cohorts were 25.55 for Indigenous and 24.27 for non-Indigenous populations. Within the Indigenous population, 47.73 per cent were classified as overweight and 20.09 per cent as obese, compared to 37.28 and 11.90 per cent, respectively, among the non-Indigenous population. The average age was 25.18 for Indigenous people and 25.77 for non-Indigenous people.

Table 1. Means and proportions for non-Indigenous and Indigenous populations

	non-Indigenous	Indigenous
Weight status		
BMI (kg/m^2)	24.27	25.55
Overweight	37.28	47.73
Obese	11.90	20.09
Age (yrs.)	25.77	25.18
Sex: male	51.51	49.64
Interview mode: in person	39.63	44.79
Interview by proxy	2.75	2.92

The mean values for BMI scores for all ten birth cohorts across the seven time periods are depicted in Table 2, separately for Indigenous and non-Indigenous respondents. The trends shown in Table 2 appear to

Table 2. Mean BMI for non-Indigenous and Indigenous populations by birth cohort and time period (kg/m^2)

	Time periods							
Birth cohort	2001	2003	2005	2007/08	2009/10	2011/12	2013/14	Average
Non-Indigenous								
1966–68	25.36	25.46	25.62	25.98	27.03			25.60
1969–71	25.12	25.52	25.60	25.89	25.95	26.68		25.65
1972–74	24.91	25.31	25.64	25.75	25.91	26.65	26.88	25.70
1975–77	24.07	24.74	25.08	25.63	25.78	26.74	26.88	25.39
1978–80	23.34	24.28	24.62	25.19	25.33	25.79	26.57	24.82
1981–83	22.70	23.49	23.81	24.59	25.09	25.55	26.42	24.29
1984–86	21.48	22.32	23.24	23.91	24.52	25.09	25.67	23.51
1987–89	20.16	21.11	22.11	23.25	23.71	24.55	24.83	22.70
1990–92		19.83	20.60	21.85	22.87	23.70	24.49	22.29
1993–95			19.31	20.21	21.36	22.52	23.16	21.66
Average	23.51	23.82	23.99	24.30	24.56	25.06	25.49	24.27
Indigenous								
1966–68	27.30	28.29	28.64	26.93	27.71			27.88
1969–71	26.96	26.84	27.48	27.12	27.97	26.37		27.19
1972–74	26.72	27.68	26.67	27.79	27.96	28.49	29.42	27.72
1975–77	26.21	26.78	27.92	26.68	28.98	27.41	29.54	27.64
1978–80	24.39	27.02	25.94	26.02	26.42	27.74	27.45	26.48
1981–83	23.51	25.07	24.84	25.46	26.70	26.57	27.19	25.70
1984–86	22.12	23.61	24.93	24.80	25.84	26.64	26.93	25.02
1987–89	20.60	21.79	22.78	23.02	24.91	25.12	26.82	23.68
1990–92		20.94	22.00	22.79	23.31	24.52	25.01	23.33
1993–95			20.47	20.82	22.30	23.27	24.96	22.63
Average	24.77	25.39	25.36	24.78	25.70	26.15	26.84	25.55

be very linear for the non-Indigenous group; at each time period, BMI increases for each successive cohort. Among the Indigenous group, there are some deviations from the expected linear trends. For example, within the Indigenous cohort born in 1975–77, BMI is higher during the 2005 time period but decreases in 2007/08, followed by another increase in 2009/10. For both groups, more recently born cohorts have lower BMI than earlier-born cohorts.

HAPC Analysis – BMI changes between ages 12 and 40

Table 3 presents the results from the HAPC analysis, separately for Indigenous and non-Indigenous Canadians. In both populations, age ($p < 0.0001$) and sex ($p < 0.0001$) were found to have statistically significant effects. Interaction effects between sex and a quadratic function of age were also statistically significant in the two populations ($p < 0.0012$ and $p < 0.0001$), although the interaction effect involving the linear age variable was significant only in the non-Indigenous population ($p < 0.0001$).

Figure 1 presents the BMI changes between ages 12 and 40 for Indigenous and non-Indigenous respondents, and by sex. On average, the BMI scores were higher for Indigenous than for non-Indigenous Canadians, although 12-year-old Indigenous girls and boys had very similar BMI compared to non-Indigenous girls and boys of the same age. Between the ages of 12 and 40, Indigenous males' BMI increased at a faster rate compared to Indigenous females; however, overall increases in average BMI for Indigenous males (7.73) and females (7.50) were comparable and higher than for non-Indigenous males and females. Non-Indigenous females (4.98), in particular, experienced a noticeably smaller increase in average BMI than any other group, including non-Indigenous males (5.96). These findings suggest that Indigenous and non-Indigenous females and males experience different patterns of change in BMI as they age.

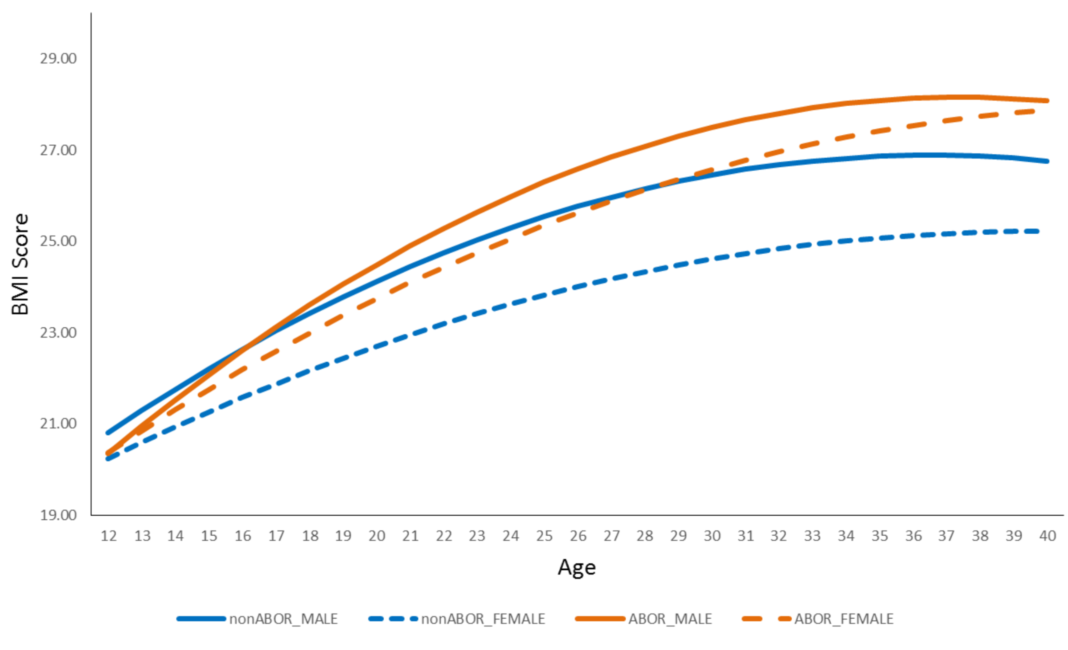

***Figure 1.* BMI changes between ages 12 and 40 for Indigenous and non-Indigenous males and females.**

HAPC analysis period and cohort effects on BMI from 2001 to 2014

Level 2 variances for period and cohort effects were both found to be statistically significant only for the non-Indigenous group. The results indicate that after controlling for age and other covariates, across-cohort variance in the non-Indigenous population was 0.021 ($p < 0.05$), and across-period variance was 0.096 ($p < 0.05$). However, most of the variance in BMI scores was still due to individual-level differences (21.312; $p < 0.0001$).

Significant effects for specific time periods were found for both Indigenous and non-Indigenous groups, despite the lack of statistically significant effects in the overall level 2 variances in the Indigenous group. In this

Table 3. Estimates from HAPC models for non-Indigenous and Indigenous populations, 2001–14

	non-Indigenous				Indigenous			
Effect	Estimate	Std error	*t*-value	*p* value	Estimate	Std error	*t*-value	*p* value
Fixed effects								
Intercept	23.852	0.128	186.75	**<0.0001**	25.560	0.168	152.42	**<0.0001**
Age	1.885	0.047	39.71	**<0.0001**	2.715	0.112	24.35	**<0.0001**
Age^2	−0.654	0.025	−26.11	**<0.0001**	−0.763	0.106	−7.21	**<0.0001**
Sex								
Male	1.730	0.026	66.46	**<0.0001**	0.954	0.112	8.52	**<0.0001**
Female	Reference							
Age × Sex	0.408	0.023	17.45	**<0.0001**	0.101	0.102	0.99	0.3237
Age^2 × Sex	−0.358	0.032	−11.29	**<0.0001**	−0.444	0.137	−3.25	**0.0012**
Interview mode								
In person	0.081	0.019	4.37	**<0.0001**	0.153	0.079	1.95	0.0507
By phone	Reference							
Response by proxy								
Yes	−0.128	0.066	−1.93	0.0535	0.156	0.291	0.54	0.5924
No	Reference							
Random effects								
Period								
2001	−0.333	0.123	−2.71	**0.007**	−0.186	0.162	−1.14	0.253
2003	−0.216	0.121	−1.79	0.073	0.303	0.152	2.00	**0.046**
2005	−0.201	0.120	−1.68	0.093	0.063	0.146	0.43	0.664
2007/08	−0.081	0.119	−0.68	0.499	−0.495	0.142	−3.49	**0.001**
2009/10	−0.018	0.120	−0.15	0.882	0.046	0.145	0.32	0.751
2011/12	0.333	0.122	2.74	**0.006**	−0.070	0.151	−0.47	0.641
2013/14	0.515	0.124	4.17	**<0.0001**	0.338	0.157	2.16	**0.031**
Birth cohorts								
1966−68	−0.168	0.080	−2.10	**0.035**	0.009	0.179	0.05	0.960
1969−71	−0.076	0.070	−1.09	0.278	−0.359	0.158	−2.27	**0.023**
1972−74	0.073	0.062	1.18	0.238	0.139	0.145	0.96	0.338
1975−77	0.083	0.056	1.49	0.137	0.397	0.136	2.92	**0.004**
1978−80	0.040	0.053	0.75	0.452	−0.085	0.130	−0.66	0.512
1981−83	0.131	0.053	2.49	**0.013**	−0.173	0.130	−1.33	0.184
1984−86	0.119	0.056	2.13	**0.033**	0.117	0.131	0.89	0.372
1987−89	0.072	0.062	1.17	0.243	−0.155	0.138	−1.13	0.260
1990−92	0.008	0.070	0.11	0.914	0.020	0.150	0.13	0.896
1993−95	−0.281	0.081	−3.47	**0.001**	0.091	0.169	0.54	0.590
Variances								
Period	0.096	0.057	1.70	**0.044**	0.093	0.059	1.57	0.058
Cohort	0.021	0.011	1.93	**0.027**	0.061	0.038	1.60	0.054
Residual	21.318	0.059	362.36	**<0.0001**	29.073	0.299	97.26	**<0.0001**
Fit statistics								
-2 Res Log Likelihood		1673215			130280			
AIC		1673221			130286			
AICC		1673221			130286			
BIC		1673221			130286			

group, significant period effects were found for years 2003, 2007/08, and 2013/14, with all p-values <0.05, suggesting that average BMI for these periods differs from overall average BMI across all periods (reference value). For the non-Indigenous population, statistically significant effects were found for years 2001, 2011/12, and 2013/14, with all p-values <0.01. Statistically significant birth cohort effects were also found for both populations. For Indigenous people born in 1969–71 and 1975–77, cohort effects were statistically significant ($p<0.05$), whereas non-Indigenous 1966–68, 1981–83, 1984–86, and 1993–95 cohorts had higher BMI scores than the overall average BMI across all cohorts.

To examine the effects of time period on weight status, we displayed the estimates from the HAPC models (with confidence intervals) at seven different time periods: 2001, 2003, 2005, 2007/08, 2009/10, 2011/12, and 2013/14. Figure 2A presents the results for Indigenous and Figure 2B for non-Indigenous populations. These results indicate that the period-specific BMI scores for non-Indigenous group followed a steady linear trend, increasing from 2001 to 2009/10 then increasing at an accelerated rate from 2009/10 to 2013/14. For non-Indigenous people, only the specific effects for 2003, 2007/08, and 2013/14 demonstrated statistically significant differences in BMI scores from the average BMI score. However, as is clearly visible in Figure 2A, the pattern of period-specific effects is not the same for the Indigenous population; no clear trend for the overall period effects can be identified, and the results are more difficult to interpret.

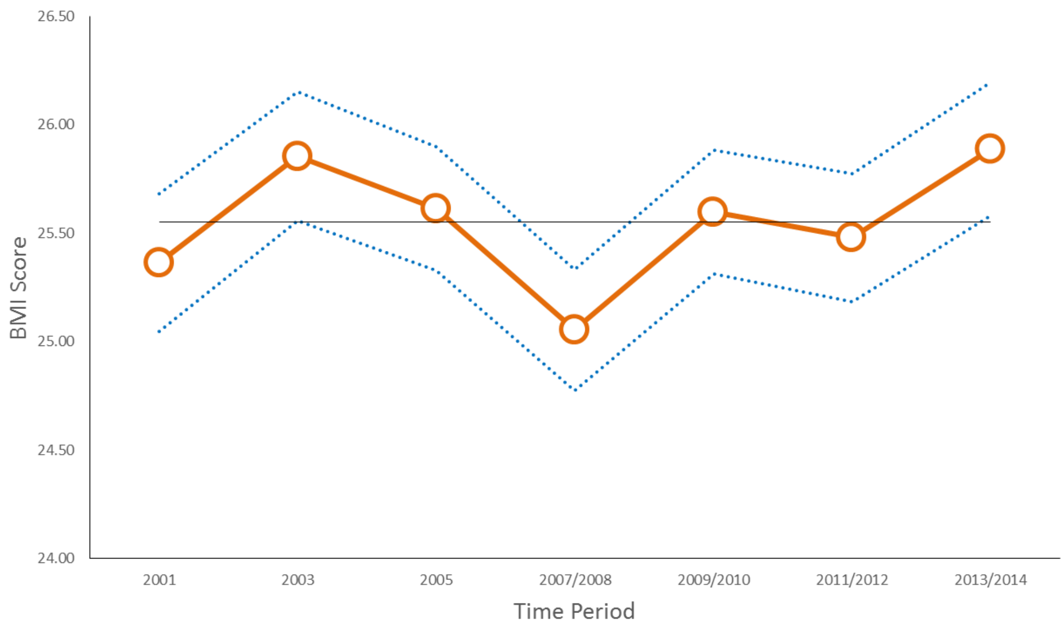

***Figure 2A.** The effects of time period on weight status for the Indigenous population.*

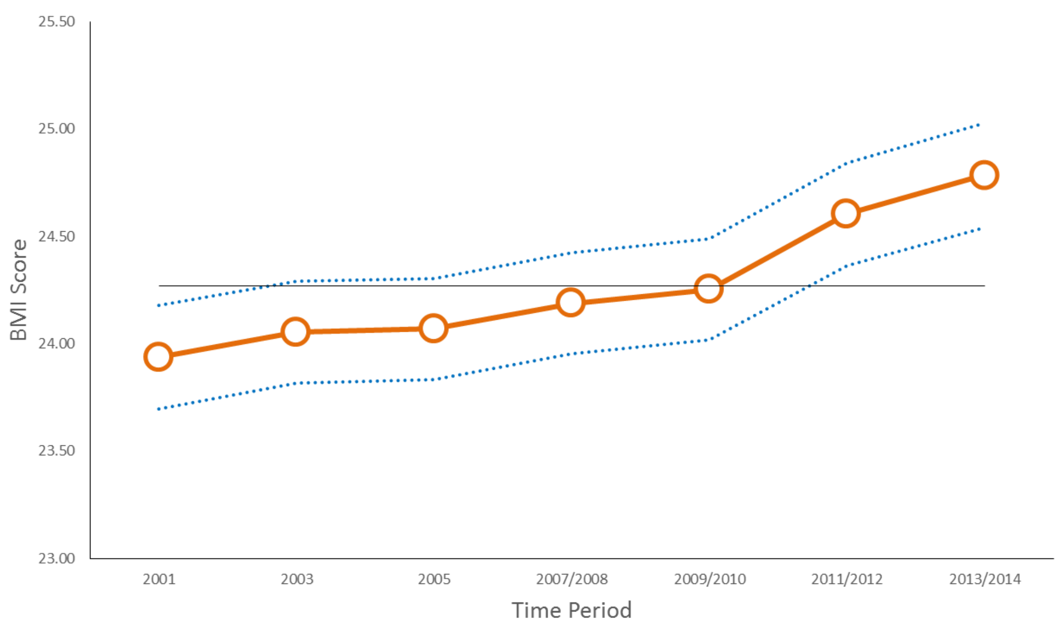

***Figure 2B.** The effects of time period on weight status for the non-Indigenous population.*

To illustrate the estimated effects of birth cohort on weight status, we displayed the results from the HAPC analysis in Figures 3A and 3B for the birth cohorts 1966–68, 1969–71, 1972–74, 1975–77, 1978–80, 1981–83, 1984–86, 1987–89, 1990–92, and 1993–95. Figure 3A presents the results for Indigenous and Figure 3B for non-Indigenous populations. There is no clear pattern for specific birth cohort effects for the Indigenous population. Two of these cohorts (1969–71 and 1975–77) had average BMI scores that were statistically different from the overall BMI score. For the non-Indigenous population, the specific cohort effects for the oldest cohort (1966–68), two middle cohorts (1981–83 and 1984–86), and the youngest cohort (1993–95) were statistically significant. Figure 3B demonstrates an inverted U-shaped trend, with those in the earliest cohorts having lower BMI compared to the middle cohorts, who had higher BMI. The youngest cohorts, those born between 1993 and 1995, also were estimated to have lower BMI than the middle cohorts, controlling for age and period.

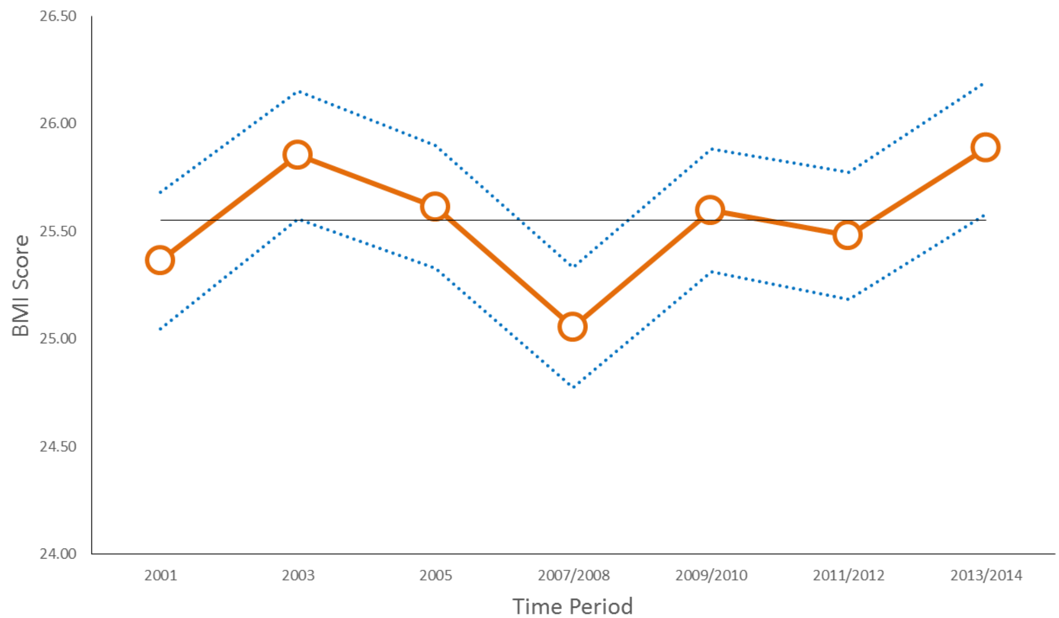

***Figure 3A.* The effects of birth cohort on weight status for the Indigenous population.**

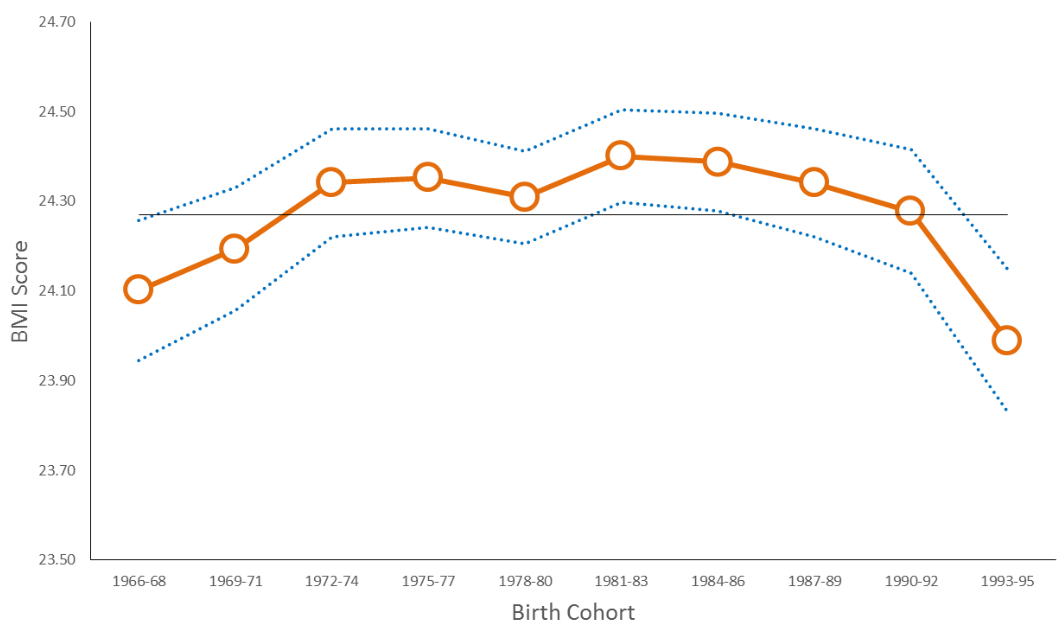

***Figure 3B.* The effects of birth cohort on weight status for the non-Indigenous population.**

Discussion

Overweight and obesity continues to be an important public health issue among the Canadian population. Results from the current study indicate clearly that this remains particularly true for Indigenous peoples living off-reserve. Our analysis of the data from seven cycles of the CCHS suggests that close to 48 per cent of Indigenous people between ages 12 and 40, living off-reserve, were either overweight or obese; about 10 per cent more than non-Indigenous Canadians of the same age.

Results of the HAPC analysis suggest that the increase in BMI in the non-Indigenous Canadian population between 2000 and 2014 can be accounted for by age-related and secular (period) trends, as well as by cohort effects. Among Indigenous people, however, there was no clear evidence of period or birth cohort effects, which is likely due to the smaller sample size and differences in non-response patterns across time.

In terms of the age effect, we found that BMI increased with age among both Indigenous and non-Indigenous people. Previous studies have also found that BMI tends to increase with age, often followed by a decline in later life (Allman-Farinelli et al. 2008; Jaacks et al. 2013; Reither et al. 2009). However, as our sample only included those up to the age of 40, we were not able to observe a downward trend in BMI in later years. The effects of age were more pronounced among Indigenous people, with BMI increasing at a faster rate than in the non-Indigenous population. Within the Indigenous population, BMI increased at earlier ages among Indigenous males compared to Indigenous females; however, the average BMI scores for the two groups were almost identical at age 40. Compared to other groups, non-Indigenous females experienced the lowest increase in BMI. Previous studies have also indicated that overweight and obesity tend to be more prevalent among men (Statcan 2012), especially among Indigenous men (Katzmarzyk 2008; Tremblay et al. 2005), and the odds of overweight and obesity increase with age for both sexes (Statcan 2012; Tremblay et al. 2005).

Several studies investigating overweight and obesity trends using the HAPC approach have found statistically significant period effects (An and Xiang 2016; Jiang et al. 2013; Ng et al. 2012; Reither et al. 2009), suggesting that obesity epidemics may be due to nationwide changes over time that affect people of all ages (An and Xiang 2016). Reither and colleagues suggest the current obesity epidemic should be seen as principally due to period effects (Reither et al. 2009). In the current study, we found some evidence that period effects may play an independent role in explaining increasing rates of overweight among non-Indigenous Canadians. Specifically, the results of this study confirm that during the time period when the CCHS data were collected (2001–14), there was an upward trend in BMI scores that was independent of age and cohort.

Period effects were also found by Jiang and colleagues, who conducted a study using APC analysis on BMI trends in Ireland (Jiang et al. 2013), and both period and cohort effects were found in a recent longitudinal study conducted in China (Jaacks et al. 2013). Jiang and colleagues suggest that the period effects could be a result of dietary changes (e.g., increased consumption and availability of fast foods and takeaways) and a reduction in physical activities (Jiang et al. 2013). Similarly, Fu and Land (2015) examined the relationship between urban transformation and rising rates of overweight in China, and found that the period of increase in overweight coincided with China's urbanization (Fu and Land 2015). In comparison, Indigenous people in Canada have experienced even more rapid social change than the non-Indigenous population. However, in the current study, due to the relatively small sample size of Indigenous respondents and differences in non-response patterns across time, the results for the period effects were statistically insignificant and difficult to interpret.

In the United States, Reither et al. found that independent of age and period effects, birth cohort membership significantly increases the odds of becoming overweight (Reither et al. 2009). Birth cohort membership in our study was also related to weight status, controlling for age and period effects, for the non-Indigenous group. Prior research indicates that more recently born cohorts have a greater chance of becoming overweight than older cohorts (Allman-Farinelli et al. 2008; Jaacks et al. 2013; Reither et al. 2009). For example, Jaacks and colleagues found that younger Chinese cohorts have higher age-specific mean BMI than older cohorts (Jaacks et al. 2013). Unlike these studies, our results demonstrated that cohort trends among the non-Indigenous population followed an inverted U-shape pattern; while controlling for age and period, older and more recent cohorts have lower BMI compared to cohorts born between 1971 and 1989.

While this contradicts previous findings from other studies using HAPC analysis, it may suggest that BMI trends in Canada among younger cohorts are reversing or stabilizing; this has also recently been found among children and youth (3–19 years) using the CCHS from 2004/05 and the Canadian Health Measures Survey (CHMS) from 2009/13 (Rodd and Sharma 2016). According to Rodd and Sharma (2016) this may be a result of progress being made through public health initiatives and weight management programs. However, other researchers suggest that while preventive measures and treatment may be taking root, significant decreases in overweight and obesity are not yet occurring among this population (Jayaraman et al. 2016). In fact, Bancej et al. (2015) found that objectively measured BMI stabilized in children and adolescents but rose slightly in adults using data from the 2007–09, 2009–11, and 2012–13 cycles of the CHMS.

An and Xiang failed to find any consistent cohort effect in the US population; they suggest that given the strong period effect (along with the lack of cohort effect), the obesity epidemic may be primarily driven by nationwide changes over time that affect the entire population (An and Xiang 2016). Given the inconsistencies in the effects of birth cohort membership on BMI and the unexpected nature of these effects for the younger cohorts, further investigation is necessary.

Similar to the findings for period effects, birth cohort effects showed mixed results for Indigenous groups in this study. Our findings did not indicate a clear pattern for specific birth cohort effects, and the overall cohort effect was statistically non-significant. Comparably, research by Ng and colleagues was unclear whether cohort or age effects accounted for the divergent BMI trends among Indigenous Canadians (Ng et al. 2012). As this population has experienced profound social and cultural changes, investigating cohort effects using a larger sample of the population is warranted to better understand trends in overweight and obesity.

While this study provides important insight into the trends of weight status among the Canadian population, it is not without limitations. First, the height and weight data used to calculate BMI were self-reported, which tends to be subject to measurement error or social desirability bias (Connor Gorber et al. 2007; Shields et al. 2008). Moreover, it is unlikely that this bias is consistent across time, cohorts, and age groups. Given the tendency to underreport weight and overreport height, the study results would be a conservative account of the current weight status among these populations (Connor Gorber et al. 2007). Second, sampling in the CCHS does not include Indigenous populations living on reserve, and therefore the findings may not be generalizable to all Indigenous Canadians. As well, the Indigenous identity questions in the early waves of the CCHS make it impossible to separately identify First Nations, Inuit, and Métis groups, which may have different dynamics. Furthermore, due to a relatively small sample size and across-time differences in non-response patterns, the results for the Indigenous population are more difficult to interpret. Lastly, as the CCHS is a repeated cross-sectional study, no causal inferences can be made. Regardless, the use of a large, nationally representative sample is a strength of this study.

Conclusions

Overall, the results of this study give further support to the hypothesis that age and period effects are responsible for the current obesity epidemic. For the non-Indigenous population, all three effects were significant; however, cohort effects should be further investigated given the inconsistent results within the literature. Moreover, the non-significant effects for the Indigenous population highlight the need for better data among this group, in order to be able to explore trends in health.

It is evident that Indigenous Canadians experience higher rates of BMI compared to non-Indigenous Canadians, and therefore they may be at a greater risk for obesity-related co-morbidities. Furthermore, in line with the findings of Ng and colleagues, BMI tends to increase at a faster rate and be sustained longer among Indigenous peoples, which may have greater health implications (Ng et al. 2012). To curb the rates of overweight and obesity, especially among the Indigenous population in Canada, it may be necessary to develop nationwide initiatives that attend to changes in weight gain such as promoting healthy diet and physical activity. Specifically, targeting younger Indigenous people, particularly males, may help to lessen the rate at which BMI increases, thereby decreasing the severity and duration of overweight throughout the lifespan. Moreover, it would be valuable for future research to explore changing patterns in more proximal determinants of health (e.g., health behaviours such as diet and physical activity), socioeconomic disadvantage, geographic variability (Public Health Agency of Canada 2011), and the influence of public health initiatives, as this would provide greater understanding of trends in overweight and obesity.

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