Using Marginal Structural Modeling to Estimate the Cumulative Impact of an Unconditional Tax Credit on Self-Rated Health

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Using Marginal Structural Modeling to Estimate the Cumulative Impact of an Unconditional Tax Credit on Self-Rated Health

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In previous studies, researchers estimated short-term relationships between financial credits and health outcomes using conventional regression analyses, but they did not account for time-varying confounders affected by prior treatment (CAPTs) or the credits’ cumulative impacts over time. In this study, we examined the association between total number of years of receiving New Zealand’s Family Tax Credit (FTC) and self-rated health (SRH) in 6,900 working-age parents using 7 waves of New Zealand longitudinal data (2002–2009). We conducted conventional linear regression analyses, both unadjusted and adjusted for time-invariant and time-varying confounders measured at baseline, and fitted marginal structural models (MSMs) that more fully adjusted for confounders, including CAPTs. Of all participants, 5.1%–6.8% received the FTC for 1–3 years and 1.8%–3.6% for 4–7 years. In unadjusted and adjusted conventional regression analyses, each additional year of receiving the FTC was associated with 0.033 (95% confidence interval (CI): −0.047, −0.019) and 0.026 (95% CI: −0.041, −0.010) units worse SRH (on a 5-unit scale). In the MSMs, the average causal treatment effect also reflected a small decrease in SRH (unstabilized weights: $\beta = -0.039$ unit, 95% CI: $-0.058, -0.020$; stabilized weights: $\beta = -0.031$ unit, 95% CI: $-0.050, -0.007$). Cumulatively receiving the FTC marginally reduced SRH. Conventional regression analyses and MSMs produced similar estimates, suggesting little bias from CAPTs.

Abbreviations: ACTE, average causal treatment effect; CAPTs, confounders affected by prior treatment; CI, confidence interval; FTC, Family Tax Credit; IPTWs, inverse probability of treatment weights; MSMs, marginal structural models; SD, standard deviation; SoFIE, Survey of Family, Income and Employment; SRH, self-rated health.

An important question in both social policy and social epidemiology is whether the provision of financial credits improves health. Financial credits are hypothesized to influence health by impacting material circumstances, psychosocial factors, and/or employment through increasing income (1). Theoretically, they could beneficially affect, adversely affect, or not affect health outcomes (1). For example, recipients could spend the additional income from financial credits on goods and services that may improve health (e.g., nutrient-rich food), worsen health (e.g., tobacco), or neither improve nor worsen health.

Previous empirical studies have found little evidence for short-term associations between financial credits and health outcomes in high-income countries (2, 3), including New Zealand (4, 5). These studies generally used individual fixed-effects regression models (6), which are—by design—focused on detecting the short-term health changes resulting from income changes and are limited in their ability to estimate any health changes that might accumulate over time. (They also cannot estimate average causal treatment effects (ACTEs), because they only identify people who experienced temporal change in treatment or outcome.) Financial credits may affect health not through the short-term boost in living standards that they provide but through supplementing income sustainably over a longer period of years, thereby enabling recipients to build the economic basis for improving their health (4, 5, 7). Therefore, researchers have called for studies investigating the long-term health impacts of financial
Figure 1. Hypothesized relationship between the total number of years of receiving New Zealand’s Family Tax Credit (FTC) over 3 waves (wave, to wave, +2) of the Survey of Family, Income and Employment (2002–2009) and self-rated health at wave 7, detailing causal pathways operating through time-invariant confounders and time-varying determinants of receiving the FTC. Time-invariant confounders included age, sex, ethnicity, and education. Time-varying determinants of receiving the FTC were family income (minus FTC), number of dependent children, and family type. The letters A–D depict hypothesized relationships between 2 variables (e.g., A denotes the causal influence of the determinants of FTC receipt at wave on the total number of years of FTC receipt at wave +2). The diagram suggests that each of the determinants of receiving FTC could be a time-varying confounder (confounding through pathway A-B) that could be affected by prior treatment (mediation through pathway C-D).

pathway A-B in Figure 1) that could be affected by prior treatment (mediation through pathway C-D). For example, it is hypothesized that family income is a confounding variable, since it determines FTC receipt (pathway A-B in Figure 2), as well as potentially being a mediating variable, since (in theory (18)) receiving the FTC might lower subsequent non-FTC sources of family income by reducing the number of hours worked (pathway C-D).

Regarding the direction of confounding, assuming monotonicity, family income at wave, has a negative association with number of years of FTC receipt at wave, (pathway A) and a positive association with SRH at wave 7 (pathway B), suggesting that confounding results in underestimation of treatment effects (see VanderWeele et al. (19) for rules; Figure 2).

In terms of mediation, number of years of receiving the FTC at wave, is hypothesized to have a negative dose-response association with family income at wave, (pathway C in Figure 2), while family income at wave, is hypothesized to have a positive monotonic association with SRH at wave 7 (pathway D). Given that confounding and mediation biases operate in different directions, if the strengths of these biases are similar they may cancel each other out and produce a spuriously null finding in a conventional regression analysis (regardless of whether or not the results are adjusted for these variables). Therefore, family income could theoretically be a CAPT, and this could result in bias in conventional regression analyses. Equivalently, the other 2 determinants of FTC receipt (i.e., number of dependent children and family type) could be CAPTs. Previous studies have raised concerns about bias from CAPTs in studies examining tax credit–health relationships (4, 5).

In this study, we estimated the cumulative causal association of FTC receipt with SRH among adults in New Zealand using marginal structural modeling to ensure stronger adjustment for measured CAPTs. Methodologically, the study compared findings from conventional regression analytical models and MSMs to determine the presence and magnitude of bias from CAPTs. More specifically, it answered 2 research questions: 1) What is the ACTE between each additional year of receiving the FTC (over a 7-year study period) and SRH at wave 7 among adults in New Zealand? 2) Do estimates from conventional regression analyses (no control for CAPTs) differ from those from MSMs (stronger control for CAPTs), indicating risk of bias from CAPTs?

**METHODS**

**Study design**

The University of Otago (Wellington, New Zealand) Human Ethics Committee granted ethics approval for this study. Seven waves of data (2002–2009) were extracted from the Survey of Family, Income and Employment (SoFIE) (http://www.stats.govt.nz/survey-participants/a-z-of-our-surveys/survey-of-family-income-and-employment.aspx, data version V.2), a representative longitudinal study conducted by Statistics New Zealand between October 2002 and September 2010 (20). The SoFIE investigators collected data from a representative sample of the New Zealand population residing in non-institutionalized households, interviewing 29,790 persons (>22,000 adults) in 11,500 households at wave 1 baseline (20). These original sample members were followed up annually over the 7-year study period (see Carter et al. (20) for full cohort profile). We restricted the survey sample to 6,900 working-age (19–65 years) parents in 1- or 2-parent families who responded during all 7 waves of the study (Figure 3).
Our exposure was the total number of years a participant received the FTC over the 7-year study period, a continuous variable ranging from 0 to 7. We preferred this exposure over the total dollar amount of FTC received, because receipt itself may be as important for improving social outcomes as the specific amount received (1, 21, 22). Previous MSM studies have also used cumulative measures (i.e., numbers of time units over which participants received the treatment of interest) as the exposures (23, 24). We determined, for each wave, whether a participant self-reported receiving the FTC. Information on receipt of the FTC over the previous year was collected from the participants at each wave in the SoFIE income module, using the following question (pertaining to the past year only): “Looking at this calendar, can you tell me when you received the Family Tax Credit?” From these data, we calculated for each participant the total number of years of receiving the FTC over the 7-year study period.

Our previous fixed-effects regression analysis defined the exposure differently; namely, we estimated eligibility for the FTC and the amount of FTC that a family was eligible for, because we sought to estimate the intention-to-treat effect rather than an ACTE (4). Eligibility for the FTC and receipt of the FTC are not perfectly correlated, because of imperfect administration of the tax credit and potentially also due to measurement error in 1 variable or both variables. Regarding imperfect administration, while an official report (25) from the organization administering the FTC estimated that 3%–5% of eligible persons did not take up the FTC, an independent study (26) suggested a more plausible, much larger (23%) nonuptake of the FTC. Moreover, a nontrivial percentage of ineligible persons erroneously received the FTC. In 2005–2006 and 2006–2007, for example, 4.8% and 3.2% of families were overpaid tax credits designated for families (including the FTC), and they were not required to repay part or all of the overpaid credit (27). The presence of these “counterfactual” participants indicated that a natural experiment on the FTC had occurred, and therefore the influence of the FTC among these participants was of particular interest.

Outcome

Our outcome was SRH at wave 7, treated as a continuous variable ranging from 1 to 5. Information on SRH was collected using the following question: “In general would you say your health is . . .,” with the following response categories (codes shown in parentheses): poor (1), fair (2), good (3), very good (4), and excellent (5). Previous studies of tax credit–health (4, 5) and income-health (28) relationships (using SoFIE data) found comparable associations regardless of whether SRH was treated as continuous or ordinal.

Time-invariant confounders and time-varying CAPTs

Potential time-invariant confounding variables included age (years; continuous), sex (2 categories: female, male), ethnicity (5 categories: indigenous Māori, Pacific, Asian, other, New Zealand European), and education (4 categories: no qualification, secondary school, postsecondary school, college degree), on which data were collected at wave 1 baseline using standard questions (20). We considered potential CAPTs to include the 3 determinants of FTC receipt: equivalized total gross annual family income (minus FTC) (New Zealand dollars; continuous), number of dependent children (continuous), and family type (2 categories: 1-parent family, 2-parent family), derived at each wave. (Detailed information on the derivation of these variables is available from the authors.)

Pooled regression analyses demonstrated that each of these 3 variables was predicted (P < 0.001) by the total number of years of receiving the FTC at the previous wave and predicted (P < 0.001) SRH at wave 7 (results available from the authors). This provided empirical support for the causal relationship hypothesized in Figure 1 and suggested that the 3 variables could indeed be CAPTs. These potential CAPTs define eligibility for the FTC (13), and most persons eligible for the FTC also received it (25, 26). Therefore, these CAPTs should largely capture time-varying confounding in the model (see Figure 1), and the exchangeability assumption of MSMs (9, 10) of no unmeasured (time-varying) confounding may hold. The MSMs also adjusted for SRH at all previous waves to control for health selection and adjusted for FTC receipt at all previous waves to control for treatment history.

Figure 3. Selection of the current study sample from participants in the Survey of Family, Income and Employment (SoFIE), 2002–2009.

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Statistical analysis

We first conducted conventional linear regression analyses. We then conducted an MSM analysis, which enabled us to quantify the net influence of stronger adjustment for CAPTs, health selection, and treatment history.

Unadjusted and adjusted linear regression models. We plotted the number of years of receiving the FTC by SRH score at wave 7 and fitted a smoothing curve (available from the authors), finding a linear exposure-outcome relationship. Model 1 was an unadjusted linear regression model estimating the association between receiving the FTC for an additional year (over the 7-year study period) and SRH at wave 7. Model 2a added the time-invariant confounders and the time-varying confounders measured at baseline. While this model adjusted for time-varying confounders at baseline, it was unable to control for CAPTs and also did not account for health selection and treatment history. Both models adjusted for household-level clustering. Model 1 used the 6,897 (99.96%) participants without any missing data on any variable included in the model, and model 2a used the 5,823 (84.4%) such participants.

MSM using unstabilized and stabilized inverse probability of treatment weights. Model 3 was an MSM estimating the ACTE between each additional year of receiving the FTC (over the 7-year study period) and SRH at wave 7, using unstabilized inverse probability of treatment weights (IPTWs). We preferred this MSM over an always treat/never treat MSM, because it better accommodated the substantial change in FTC receipt over time and provided a more generalizable estimate (association per additional year rather than, specifically, over 7 years). We computed the unstabilized IPTWs for the exposure to create a pseudopopulation that was exchangeable with the study population within levels of confounders, as described in detail by Cole and Hernán (29). The unstabilized IPTWs were constructed using the time-invariant confounding variables measured at wave 1 baseline, the 3 CAPTs (i.e., equivalized total gross annual family income (minus FTC), number of dependent children, and family type) measured at wave−1, and SRH and FTC receipt measured at all previous waves. The unstabilized IPTWs ranged between 1.00 and 212.875 (see Web Figure 1, available at http://aje.oxfordjournals.org/, for distribution). We capped the weights at the 1st and 99th percentiles to eliminate extreme outliers (29), which reduced their range to 1.01–1,273. Finally, an MSM was fitted with total number of years of FTC receipt as the exposure and SRH at wave 7 as the outcome, weighted using the unstabilized IPTWs. This model adjusted for measured time-invariant confounders, measured CAPTs, health selection, and treatment history.

Model 4 was an MSM estimating the same causal relationship as model 3 but using stabilized IPTWs. We stabilized the previously calculated unstabilized IPTWs to improve the precision of the MSM (29). The stabilized IPTWs ranged between 0.03 and 368 (see Web Figure 2 for distribution). When capped at the 1st and 99th percentiles (29), they ranged from 0.08 to 6.33. As with model 3, we fitted an MSM with the total number of years of FTC receipt as the exposure and SRH at wave 7 as the outcome, adjusted for time-invariant confounders, CAPTs, health selection, and treatment history. Both MSMs adjusted for household-level clustering and used the 4,014 (58.2%) participants without any missing data on any variable at any wave (exclusions were largely due to missing income data at 1 or more waves; see Web Table 1 for characteristics of excluded participants). The IPTWs were computed and the MSM models fitted using the GENMOD procedure of SAS Enterprise Guide, version 9.3 (SAS Institute, Inc., Cary, North Carolina), computer software (see Web Appendix 1 for SAS code).

Sensitivity analysis. The MSMs necessarily used only the 58.2% of participants with complete data on all waves. Selection bias may have occurred if the FTC-SRH association differed between all participants and only those with complete data. To assess possible selection bias, we compared results from the adjusted regression analysis conducted on 84.4% of participants (model 2a) with those from the same analysis rerun on the 58.2% of participants with complete data (model 2b), expecting different results if selection bias occurred.

RESULTS

Sample characteristics

Table 1 shows the characteristics of the study sample of 6,900 participants at wave 1 baseline according to the total number of years of FTC receipt over the 7-year study period. Of the sample participants, 15.4% were not in a family at wave 1 but were included due to their being in a family in subsequent waves. Most participants (71.4%) did not receive the FTC over the 7-year study period. Between 5.1% and 6.8% of participants received the FTC for 1–3 years, and 1.8%–3.6% received it for 4–7 years. Initial survey nonresponse in SoFIE was 77% (20), and attrition in the study sample was 26.3% (30) (Figure 3).

Unadjusted and adjusted linear regression models

The unadjusted linear regression model (model 1 in Table 2) suggested that each additional year of receiving the FTC was associated with a small, statistically significant (P < 0.001) decrease in SRH at wave 7 (β = −0.033 unit, 95% CI: −0.047, −0.019; central estimate equivalent to 3.7% of 1 standard deviation (SD) of SRH). The adjusted linear regression model (model 2a) found a smaller but still statistically significant decrease in SRH (β = −0.026 unit, 95% CI: −0.041, −0.010; 2.9% of 1 SD of SRH).

MSMs using unstabilized and stabilized IPTWs

The MSM using unstabilized IPTWs (model 3 in Table 2) also found a small average decrease in SRH at wave 7 stemming from each additional year of FTC receipt (β = −0.039 unit, 95% CI: −0.058, −0.020; 4.3% of 1 SD of SRH). The MSM that used stabilized IPTWs (model 4) confirmed the small average decrease in SRH at wave 7 (β = −0.031 unit, 95% CI: −0.050, −0.007; 3.4% of 1 SD of SRH). These estimates of the ACTE were similar to the measure of association from the conventional regression analyses, suggesting no bias from lack of adjustment for potential CAPTs, health selection, and treatment history in conventional regression analyses.
Sensitivity analysis

When the adjusted conventional regression model was re- fitted with only the participants included in MSM analyses (n = 4,104; model 2b in Table 2), the strength of the association with SRH was −0.031 unit (95% CI: −0.049, −0.014), similar to the model 2a (n = 5,823) finding of −0.026 unit (95% CI: −0.041, −0.010). Thus, there was no evidence of selection bias due to missing data.

DISCUSSION

Summary of findings

This study found that each additional year of receiving an unconditional tax credit for families marginally decreased SRH among adults in New Zealand. Both conventional linear regression models (estimating associations unadjusted for potential measured CAPTs) and an MSM (estimating ACTEs more fully adjusted for potential measured CAPTs) suggested a statistically significant small reduction in SRH from the tax credit. The size of the association was too small to be clinically meaningful (cutoff 0.25-unit change in SRH) (31), but over a population it might be considered nontrivial. No evidence was found for any net bias from the 3 CAPTs. Most likely, the association of exposure at wave t with CAPTs at wave t+1 (arrow C in Figure 1) was too weak to “activate” sizeable bias. Additional research is required to determine the strength and direction of each CAPT’s confounding and mediation pathways. Guidance for when MSMs are actually necessary is needed.

Relationship to previous studies

To our knowledge, no previous study has examined the association between cumulative receipt of a financial credit and health. We previously reported results from a fixed-effects
regression analysis looking at change in eligibility status for the FTC and the amount of additional income derived from the FTC, respectively (4). Neither becoming eligible for the FTC nor a $1,000 increase in the amount of FTC that a participant’s family was eligible for was associated with changes in SRH, at least in the short term (5). The present study differed from the previous study in that it assessed the cumulative association with the FTC (over a period of 7 years), as opposed to short-term associations (over the course of 1 year). The present study also focused on actual receipt of the FTC, as opposed to eligibility for the benefit. Despite these differences, the estimates from both studies were small in size, suggesting little change in SRH from the unconditional tax credit.

Limitations

MSM estimates are only unbiased under the 5 assumptions specified above (9, 10). In our study, the exchangeability assumption may have been violated, since treated and untreated persons may not have been fully comparable. For example, prospective parents who were unaware of the FTC were more likely to be expecting their first child (as opposed to later children) and more likely to reside in deprived areas than those who knew about the FTC (26). In addition, residual confounding from unmeasured variables (e.g., personality type, fertility) may have occurred.

Positivity was probably not violated on theoretical grounds, considering that the imperfect administration of the FTC resulted in eligible participants’ erroneously receiving the tax credit (27). Formal diagnostics for identifying structural violations (or near-violations) of the practical positivity assumption in MSMs that use exposures measured at 2 or more time points are currently being developed but are not yet available (Dr. Maya L. Petersen, University of California, Berkeley, personal communication, 2015). Our informal investigation of practical positivity identified a small number of potential violations, suggesting a low risk of bias (Web Appendix 2, Web Figure 3).

Consistency was probably not violated, since treatment variation was likely irrelevant. For example, variation in the amount of FTC received seems irrelevant, because even small amounts of additional income from financial credits can considerably influence social outcomes (1, 21, 22). Model(s) misspecification may have occurred, since we treated SRH as continuous rather than ordinal despite the potentially unequally spaced response categories of SRH (32). However, previous SoFIE studies suggested that such bias was probably small, if any (4, 5, 28). Furthermore, misspecification from including continuous variables as simple linear terms rather than flexible terms (e.g., splines) may have occurred. The assumption of no measurement error may have been violated. In a validation study, survey participants underreported their receipt of financial credits (33), suggesting the risk of measurement error in the exposure. Although difficult to estimate, this bias was probably small and, if non-differential and independent, acted towards the null.

Furthermore, SRH has several well-documented limitations (34) that may have introduced measurement error in the

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<td>Very good</td>
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<td>Excellent</td>
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a All numbers of participants in this table are rounded to the nearest multiple of 3 and a minimum value of 3, as per Statistics New Zealand confidentiality protocols.

b Equivalized total gross annual family income (minus the Family Tax Credit) in New Zealand dollars (NZ$). Quintile 1: <NZ$23,534; quintile 2: NZ$23,534–NZ$37,671; quintile 3: NZ$37,672–NZ$50,999; quintile 4: NZ$51,000–NZ$73,669; quintile 5: >NZ$73,669.

c Note that 15.4% of the sample were not in a family at wave 1, but they were included in the sample due to being in a family in subsequent waves.

d Data on self-rated health were missing for 3 participants.

<table>
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<tr>
<th>Model 1(^a) (n = 6,897)(^b)</th>
<th>Model 2a(^c) (n = 5,823)(^d)</th>
<th>Model 2b(^e) (n = 4,014)(^f)</th>
<th>Model 3(^g) (n = 4,014)(^h)</th>
<th>Model 4(^i) (n = 4,014)(^j)</th>
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<td>4.638(^k)</td>
<td>4.473, 4.802</td>
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<td>-0.125(^m)</td>
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**Abbreviations:** CI, confidence interval; FTC, Family Tax Credit; IPTWs, inverse probability of treatment weights.

\(^a\) Self-rated health could range from 1 (poor) to 5 (excellent).

\(^b\) Model 1: unadjusted linear regression model.

\(^c\) Participants without any missing data on the exposure and the outcome measured at wave 7.

\(^d\) Models 2a and 2b: fully adjusted linear regression models.

\(^e\) Results were adjusted for time-invariant confounders measured at wave 1 baseline (age, sex, ethnicity, and education) and confounders affected by prior treatment measured at wave 1 (family income, number of dependent children, and family type).

\(^f\) Participants without any missing data on the exposure, the outcome measured at wave 7, and the time-invariant confounders and confounders affected by prior treatment measured at wave 1.

\(^g\) Participants without any missing data on any variable measured at any wave.

\(^h\) Model 3: marginal structural model with unstabilized IPTWs.

\(^i\) Results were adjusted for potential time-invariant confounders measured at wave 1 (age, sex, ethnicity, and education), confounders affected by prior treatment measured at each wave (family income, number of dependent children, and family type), treatment history (FTC receipt measured at each wave), and health selection (self-rated health measured at each wave) using IPTWs.

\(^j\) Model 4: marginal structural model with stabilized IPTWs.

\(^k\) \(P < 0.001\).

\(^l\) \(P < 0.01\).

\(^m\) \(P < 0.05\).

\(^n\) Equivalized total gross annual family income (minus the FTC) in New Zealand dollars (NZ$), scaled at NZ$10,000.
outcome. Additionally, if the FTC-SRH association increased with additional years of FTC receipt, the potentially relatively larger associations that may have appeared beyond the 7-year study period were not captured. Finally, if participants who left the SoFIE study differed from those who remained with respect to the receipt of FTC and SRH, the current study may have been influenced by selection bias. However, attrition in this study was comparable with that in similar studies (20) and nondifferential (30). Our sensitivity analysis provided no evidence of selection bias from missing data.

Generalizability

The findings of this study can be generalized to the general New Zealand resident population of adults in noninstitutionalized households. It can also be generalized (with some uncertainty) to comparable populations in other high-income countries with a similar social policy context.

Implications for theory, policy, and research

This study does not support the theory (4, 5, 7) that financial credits improve SRH cumulatively over time. Rather, it provides modest support for the theory (35) that financial credits may not improve individual- and population-level SRH or equity in SRH. Additional research is required to establish which of the several hypothesized causal pathways between financial credits and SRH (1) are active and in which direction they operate to produce no association.

The World Health Organization (36) and other experts (37, 38) have recommended using financial credits as policy tools for addressing the social determinants of health (primarily income) in order to improve population health and health equity. However, the findings of this study suggest that the association between unconditional tax credits and SRH may be small or nil, at least among adults in high-income countries. Additional research is required to assess the potential impact of other financial credit interventions (e.g., cash transfers that are conditional (39) or that address climate change (40)) and other cumulative measures of tax credit receipt (e.g., total dollar amount received) on SRH and other health outcomes. Conducting MSMs alongside conventional regression analyses can provide important insights into the presence and magnitude of bias from potential CAPTs in studies that investigate the cumulative health associations of financial credits or other social interventions, although improved guidance for researchers as to when MSMs are likely to be warranted seems justified.

In conclusion, this study found that receiving an unconditional tax credit for families for an additional year statistically— but only modestly—reduced the cumulative association with SRH among adults in New Zealand. The estimated associations from conventional regression models unadjusted for CAPTs and ACTEs from MSMs adjusted for CAPTs were similar, providing no evidence of any bias from CAPTs.

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Conflict of interest: none declared.


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