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ORIGINAL ARTICLE

Mediation of the effect of childhood socioeconomic position by educational attainment on adult chronic disease in Chile

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Abstract
Objectives We estimated the roles of childhood socioeconomic position (ChSEP) and education attainment on chronic diseases in Chilean adults, mediated through structural determinants and health behaviors, to identify potential pro-equity interventions.
Methods We analyzed Chile's longitudinal Social Protection Surveys, a national sample of 14,788 adults with follow-up to 2009. Controlled direct effects (CDE) and natural effects (NDE and NIE) of ChSEP and education on number of chronic diseases were estimated with negative binomial models.
Results CDE of low ChSEP with education fixed at 12 years showed a 12% increase with 4% indirect effects. CDEs at favorable levels of BMI, smoking, alcohol use, and physical activity were similar. CDE estimates for education adjusted for ChSEP were larger with negligible mediation. CDEs for women were generally larger.
Conclusions Low ChSEP exerts a primarily direct effect on later chronic disease, modestly mediated by education. Education attainment showed larger direct effects with minimal mediation by behaviors. Strengthening current–early child development and education policies, particularly gender aspects, may reduce social inequalities and key pathways for reducing chronic disease inequalities in Chile.

Keywords Chile · Childhood socioeconomic condition · Non-communicable disease · Behavioral risk factors · Mediation · Health disparities

Introduction

Though once considered diseases of affluence, today non-communicable diseases (NCD) are global challenges, disproportionately affecting low-and-middle income countries. Many studies, mainly from Europe and the United States, have shown that NCD rates and risk factors are "striking along the fault lines of social inequality" (Levesque et al. 2013; Di Cesare et al. 2013). The association between education attainment and adult health is one of the most consistently robust over time and across vastly different contexts, suggesting diverse and dynamic underlying causal mechanisms, which still need to be elucidated (Montez 2015). Some studies have found that the education–health association is mediated through material circumstances, such as income, or the effect on health behaviors (Singh-Manoux et al. 2004). Other authors theorize that the distribution of psychosocial resources in different education groups might explain education-related health inequalities, while social stress epidemiology maintains that material and structural aspects lead to psychosocial stress (Granstrom et al. 2014). Differences by race and gender in education-mortality associations point to the complexity of underlying social stratification processes (Zajacova and Hummer 2009; Montez 2015).

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Regardless of current socioeconomic conditions, adverse childhood circumstances are associated with higher adult disease and mortality (Galobardes et al. 2008; Loucks et al. 2011). Early childhood socioeconomic circumstances influence later trajectories, experiences, and opportunities through different pathways, which in turn mediate health (Kuh et al. 2003; Pollitt et al. 2005; McKenzie et al. 2011). Favorable family backgrounds increase chances of higher education attainment, associated with better jobs and income, and measures of adult socioeconomic position (SEP). In addition, healthy behaviors are shaped in childhood and adolescence (Ben-Shlomo and Kuh 2002; Kuhn Barrientos and Castillo Riquelme 2013).

Less is known about how childhood (ChSEP) and adult socioeconomic position (SEP) influence inequalities in adult health outcomes outside Europe and the United States, particularly in Latin America (Guimarães et al. 2014; Sheikh et al. 2014). It is logical that the multiple mediators and pathways involved in these relationships vary in different socio-historic contexts (Mackenbach et al. 2013). In this scenario, the case of Chile is of particular interest. Since the 1980s, the country has experienced profound demographic, socioeconomic, political, and environmental changes, which have transformed the epidemiologic profile, now characterized by an increasingly aging population and the predominance of NCD, representing 84% of the burden of disease (Ministerio de Salud 2008). Despite impressive economic growth and social policy action, Chile is the OECD country with the highest income inequality reflected by a Gini coefficient of 0.50, significantly greater than the OECD average of 0.31 (OECD 2014). In the last decade, innovative policy responses were implemented to tackle the pressures of NCDs and of social inequalities, including universal systems of guaranteed care for priority diseases, early child development programs, and education reform, all with explicit equity objectives (Helmke 2011; Frenz et al. 2014).

Our study aim was to understand if and to what extent the influences of childhood socioeconomic position (ChSEP) and of education attainment on chronic disease in Chilean adults are mediated by factors susceptible to modification through public policies, including material/structural aspects and health behaviors. No previous study has formally tested mediators of socioeconomic inequalities in chronic disease risk in Chile.

Conceptual framework

We use a counterfactual approach to mediation analysis to compare the number of medically diagnosed non-communicable diseases reported by Chilean adults in different scenarios and values of mediators to estimate the controlled direct effects (CDE), natural direct effects (NDE), natural indirect effects (NIE), and marginal total effects (MTE) of SEP exposures, controlling for measured confounders (Valeri and Vanderweele 2013).

Figure 1 presents a directed acyclic graph (DAG), illustrating the relationships between variables and the chain of processes through directed arrows (Robins 2002). The DAG shows the mediator in the causal chain between the SEP exposure and adult NCD. When the exposure was ChSEP, the mediators analyzed were education attainment and a set of health-related behaviors, including body mass index, smoking, heavy alcohol consumption, and lack of physical activity. Education is a pathway or mediator, because it is strongly predicted by ChSEP and, in turn, forecasts ensuing health outcomes. In turn, educational attainment determines employment conditions and income, related to an array of material and social resources, exposures, vulnerabilities, and access to services that influence health, including modifying or potentiating health-related behaviors (Galobardes et al. 2008; Smith et al. 2011). Education is often selected as a proxy of adult SEP, because it is relatively stable at this stage in life and it is also suitable for adults who are not working (Krieger et al. 1997). Several studies indicate that education may be more strongly associated with increased risk of NCD than occupation or income, in part because of the significant link to health-related behaviors (Galobardes et al. 2006; Ernstsen et al. 2012). Thus, we used education attainment as the exposure in the second part of the analysis of the effect on NCDs mediated through income and health-related behaviors.

Age and sex are measured confounders of the exposure–outcome, exposure–mediator–outcome, and/or the mediator–outcome pathways, so were included in all of the mediation models.

Methods

Data source and study population

The Social Protection Survey (Encuesta de Protección Social, EPS) is a national longitudinal survey, conducted in Chile in 2002, 2004, 2006, and 2009 (Centro de Microdatos 2009). As of 2004, it follows a nationally representative panel of adults who were at least 18 years old in December 2003. The survey includes questions on health behaviors, health outcomes, and extensive information on the respondents' socioeconomic status at each point in time. From a total of 18,803 individuals, the combined panel for this analysis consists of 14,788 distinct individuals observed for the three periods or at least with a measure in

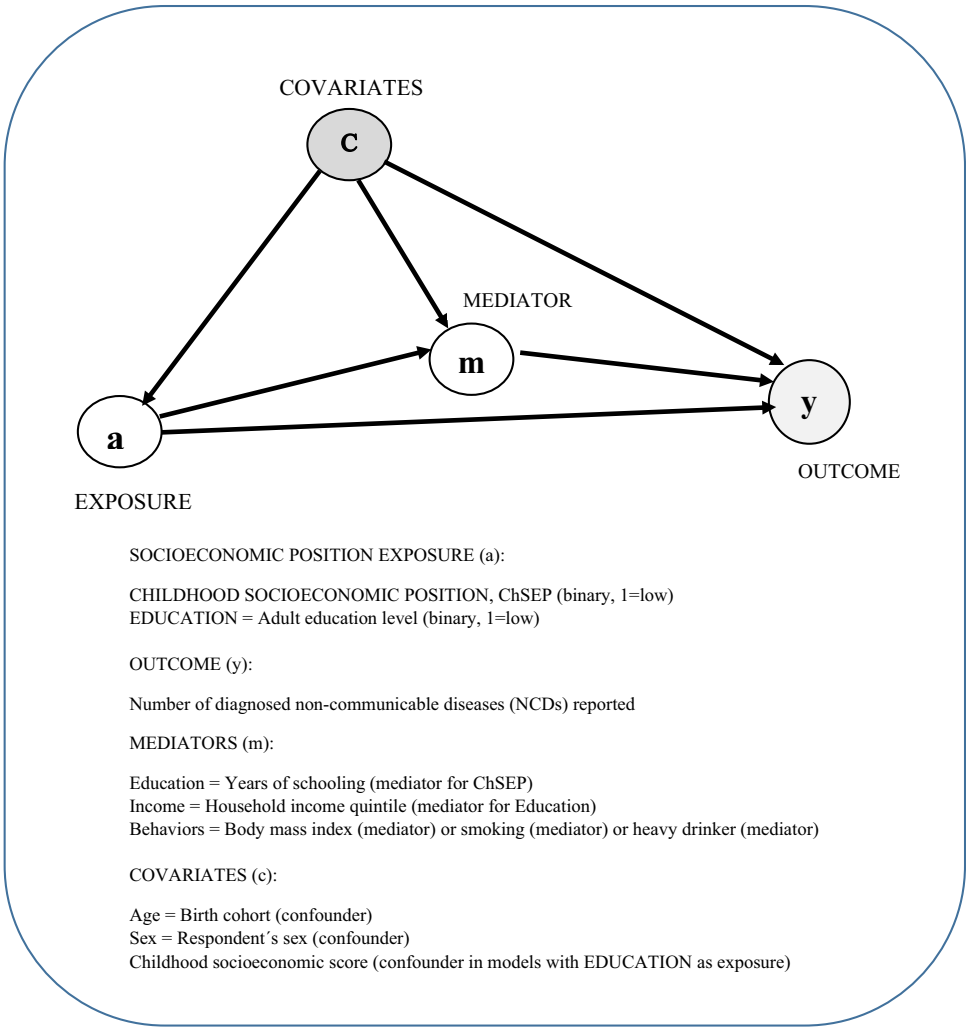

Fig. 1 Directed acyclic graph of the total and mediated effect of socioeconomic position on adult chronic disease, Social Protection Surveys 2004, 2006, and 2009, Chile

2009, to insure complete follow-up on the outcome, and the number of self-reported medical diagnoses of non-communicable diseases.

Childhood SEP

Studies show that recall of ChSEP is reasonably accurate (Krieger et al. 1998). The baseline EPS survey asked subjects to assess family socioeconomic circumstances during childhood as very good, good, and poor. We used additional EPS data on mother's education, father's occupation, and the presence of the father during infancy, variables accepted in the literature, to generate a logistic regression model-based score of ChSEP built on the odds ratios of these factors in relation to the subjective ChSEP assessment outcome (1 = low self-reported family circumstances). The score ranged from 2 to 16, with a higher score reflecting worse socioeconomic background. The score showed a bimodal distribution with a cutoff around 11 points. We generated a binary variable in which 11 points and over were coded as 1, low ChSEP.

Number of self-reported diagnoses of adult chronic diseases

Diagnoses of chronic disease were determined by asking for each of 10 NCD—hypertension, diabetes, heart problems, stroke, cancer, asthma, depression, mental illness, kidney problems, and arthritis: Have you been diagnosed with [insert disease] by a doctor? We generated a count measure of morbidity burden based on the number of medical diagnoses of NCD reported by respondents up to 2009, which ranged from 0 to 8 (Huntley et al. 2012).

Education level

Education was measured as years of schooling as a mediator. A binary exposure variable of education attainment

was coded as low (1) for respondents with less than secondary education, consistent with Chile's mandatory education laws and employment context.

Income

The annual per capita household income quintile for 2006 or 2009 was considered low (1) for quintiles 1–3 and high for quintiles 4 and 5, consistent with social policy in Chile. Household per capita income includes respondent and family member wages, bonuses, subsidies, and other income, divided by the number of household members.

Health behaviors: BMI, smoking, alcohol use, and physical activity

Height and weight were reported by respondents in the three waves and BMI was calculated. The maximum BMI across the three measures was considered. For smoking, respondents who had reported smoking in any of the survey waves were classified at smokers (1) and those had never smoked as non-smokers (0).

In each survey wave, the intensity of alcohol consumption was measured in the number of monthly drinks, which we transformed into grams of alcohol, and then categorized by level (abstemious, light, moderate, and heavy) following international guidelines validated in Chile (Alvarado et al. 2009). For alcohol consumption over the period, a binary variable was created with heavy drinkers coded 1 and non- or light/moderate drinkers coded 0.

Respondents were also asked whether they exercised at least 1–2 times per week. For the survey period, these data were used to generate a variable, sedentary (1) if their response was no in all waves, and 0 if they had reported yes at least once).

Covariates

Age, a confounder of the exposures (ChSEP and education attainment) and outcome, as well as the exposure–mediator–outcome and mediator–outcome pathways, was measured in years. Sex was considered a mediator–outcome confounder for all the mediating factors, coded as 1 for men and 0 for women. In the mediation analysis for education attainment, the ChSEP score was included as a covariate.

Statistical analysis

All statistical analysis was carried out using Stata version 14 (Statacorp 2015). Descriptive statistics were used to study the distribution of sociodemographic and health characteristics in the study population. The average number of NCD was calculated by categories of these characteristics.

The mediation analysis was performed with the *paramed* command in Stata (Emsley and Liu 2013). *Paramed* extends the traditional Baron and Kenny mediation procedure (Baron and Kenny 1986) to allow for the presence of exposure–mediator interactions in the outcome regression and uses counterfactual definitions of direct and indirect effects (Emsley and Liu 2013). The command estimates two models: (1) a model for the mediator (m) conditional on exposure (a) and any specified covariates (c), and (2) a model for the outcome (y) conditional on exposure (a), the mediator (m), and the same covariates (c). For the mediator component, we specified linear or logistic regression models to analyze the effect of binary exposures (low ChSEP or education) on each mediator (continuous or binary), adjusted by co-variates, for example:

$$\text{logit}\{P(M = 1|A = a, C = c)\} = \beta_0 + \beta_1 a + \beta_2' c$$

where a = exposure, m = mediator, and c = covariates.

The second model used negative binomial regression for the count health outcome:

$$\begin{aligned}\text{negbin}\{E(Y|A = a, M = m, C = c)\} \\ = \theta_0 + \theta_1 a + \theta_2 m + \theta_3 a * m + \theta_4' c.\end{aligned}$$

Negative binomial models are appropriate for count data with under and over-dispersion, including positive correlation between response counts and a large proportion of zeros, which may be the case for chronic ailments. We checked the negative binomial model against a zero-inflated negative binomial model of count outcomes and SEP predictors and found no differences (Hilbe 2011; Allison 2012). Parameters from these two regression models are used to construct CDE, NDE, NIE, and MTE estimates with respect to each mediator, conditional on the measured covariates, and expressed on the ratio scale, according to the following formulae (Valeri and Vanderweele 2013):

$$\text{RR}^{\text{CDE}} = \exp\{(\theta_1 + \theta_3 m)(a - a^*)\}$$

$$\text{RR}^{\text{NDE}} = \frac{\exp(\vartheta_1 a)\{1 + \exp(\vartheta_2 + \vartheta_3 a + \beta_0 + \beta_1 a^* + \beta_2' c\}}{\exp(\vartheta_1 a^*)\{1 + \exp(\vartheta_2 + \vartheta_3 a^* + \beta_0 + \beta_1 a^* + \beta_2' c\}}$$

$$\text{RR}^{\text{NIE}} = \frac{1 + \exp(\beta_0 + \beta_1 a + \beta_2' c)\{1 + \exp(\vartheta_2 + \vartheta_3 a + \beta_0 + \beta_1 a^* + \beta_2' c)\}}{1 + \exp(\beta_0 + \beta_1 a + \beta_2' c)\{1 + \exp(\vartheta_2 + \vartheta_3 a^* + \beta_0 + \beta_1 a^* + \beta_2' c)\}}.$$

95% confidence intervals were calculated using the default delta method, after verifying that bootstrapped intervals were essentially identical.

The CDE for the each SEP exposure (ChSEP or education attainment) indicates the direct effect on the relative rate (RR) of chronic conditions if the exposure is contrasted, while the mediator is set uniformly at the designated level. When BMI was modeled as a continuous variable, 24 kg/m^2 was used as the healthy target value. Similarly, education was controlled to 12 years of completed schooling.

The NDE shows the relative change if SEP is contrasted, but the mediator is kept at the level it would have taken in the absence of deleterious exposure. The indirect effect, NIE, compares the change on the relative scale of contrasting the mediator, if the exposure is fixed at the deleterious level. The marginal total effects (MTE) are the overall change on the ratio scale for a contrast of SEP from high to low. The sum of the NDE and the NIE equals the total effect, even when interaction between exposure and mediator or nonlinearities are present (Valeri and Vanderweele 2013). The estimates can be considered as age- and sex-adjusted associations, and will take a causal interpretation only in the absence of any important residual confounding. Controlled direct effects require no unmeasured common causes of the exposure and outcome, as well as the mediator and the outcome. In addition, for natural effects, there must be no unmeasured common causes of exposure and mediator. Given the likelihood of residual confounding for these exposures and mediators, our interpretation of the results emphasizes the direction of the findings rather than the precise magnitudes of estimated effects. We also performed a sensitivity analysis for selection bias correction using proportions in each exposure and outcome group who were lost to follow up. Then, we calculated crude odds ratios for having low SEP relative to high, and adjusted the odds ratios for selection bias using the sampling fractions to determine the percent of potential bias (Orsini et al. 2008; Lash et al. 2009).

Because of potentially differential effects of socioeconomic exposures by gender, verified using the Mantel–Haenszel test of homogeneity, we fit separate analysis for men and for women (Cummings 2009).

Results

The sociodemographic and health characteristics of the study sample are presented in Electronic Supplementary Material, ESM Table 1. Almost half the sample (48.8%) were older than 50 years (median age = 49, ranging from 24 to 108). The proportion with low-and-medium–high ChSEP was 22.5 and 77.5%, respectively, and 39.6% had less than 12 years of schooling.

Table 1 Mean number of chronic conditions for each covariate, exposure, and mediator category of the cohort with follow-up to 2009

Characteristics	Mean (sd)
Total average	1.04 (1.34)
Sex	
Male	0.77 (1.16)
Female	1.30 (1.45)
Age (birth decade)	
1910	2.43 (1.59)
1920	2.42 (1.60)
1930	2.12 (1.51)
1940	1.65 (1.51)
1950	1.13 (1.30)
1960	0.66 (0.79)
1970	0.41 (0.75)
1980	0.33 (0.64)
Childhood socioeconomic position (ChSEP)	
Lower	1.45 (1.51)
Higher	0.92 (1.26)
Education	
Less than secondary	1.51 (1.53)
Secondary or more	0.74 (1.10)
Income	
Low income quintile (1–3)	1.12 (1.38)
High income quintile (4–5)	0.98 (1.28)
BMI	
Low/normal	0.84 (1.22)
Overweight/obese	1.12 (1.57)
Smoker	
No	1.22 (1.43)
Yes	0.73 (1.08)
Alcohol consumption	
None to moderate	1.20 (1.18)
Heavy	0.67 (1.05)
Physical activity	
At least 1–2 times per week	0.82 (1.17)
Sedentary	1.23 (1.42)

Social protection surveys 2004, 2006, and 2009, Chile

The mean number of chronic conditions with medical diagnosis for the exposure, covariate, and mediator categories is presented in Table 1.

The relationship of age, shown as birth decade, with ChSEP and education is shown in Fig. 2, which also compares the mean number of NCD by birth decade and separately by sex. Average ChSEP scores decrease and years of schooling increase for individuals born after the 1950s, showing a secular trend towards improved SEP, but

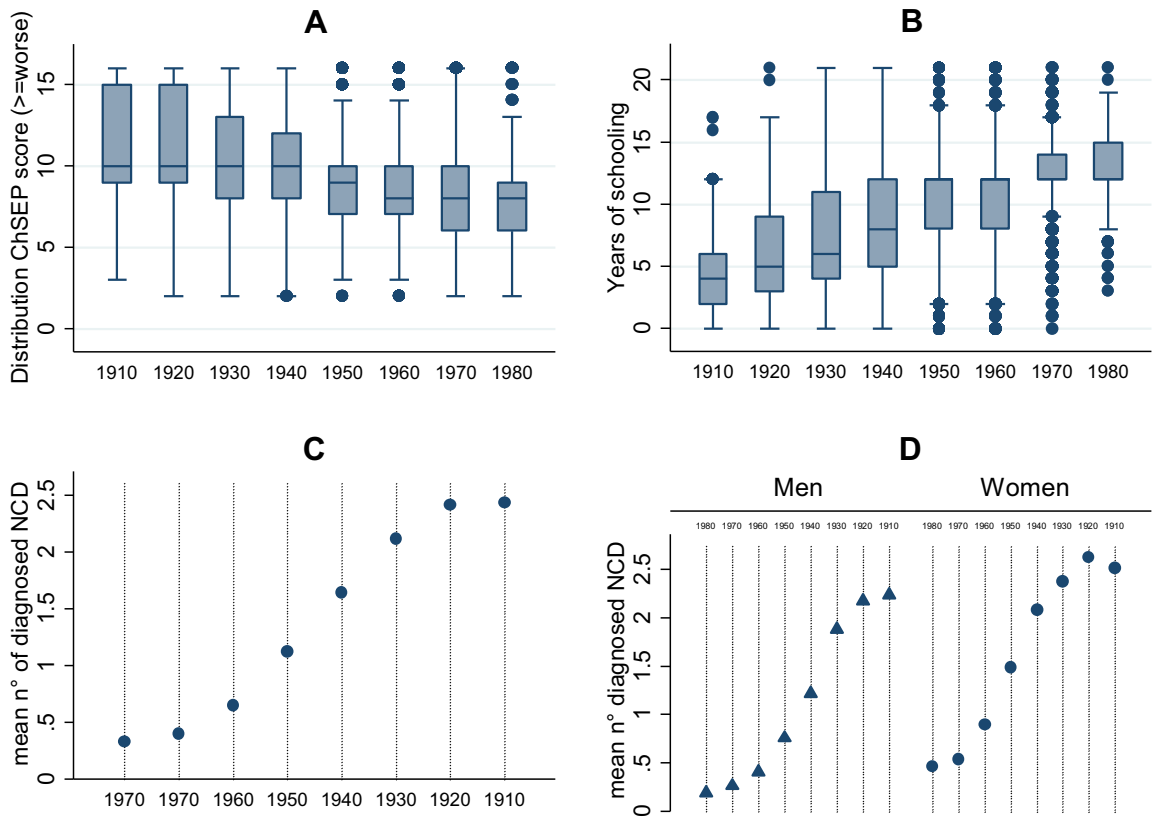

Fig. 2 Distribution of childhood disadvantage (ChSEP) score, years of schooling, and mean diagnosed non-communicable diseases (NCD) by birth decade and by sex of the cohort. Social Protection Surveys 2004, 2006, and 2009, Chile. **a** Distribution of childhood socioeconomic position (ChSEP) score by birth decade (>score = higher disadvantage). **b** Distribution of years of schooling by birth decade. **c** Mean number of reported non-communicable diseases (NCD) by birth decade. **d** Mean number of reported non-communicable diseases (NCD) by birth decade and sex

with wide dispersion. The average number of NCD increases with age, with women generally showing earlier and higher averages across the life course.

Table 2 shows the coefficients and odds ratios of the linear and logistic models for the mediators conditional on the SEP exposures, adjusted by age and sex for ChSEP. The mediator–exposure models for education attainment were also adjusted by ChSEP.

Low ChSEP was associated with almost 3 years less schooling. It was also associated with an increase of 0.26 (95% CI 0.08, 0.40) in BMI, as well as increased an increased OR of sedentary behavior (OR 1.22; 95% CI 1.12, 1.34). Low education attainment, adjusted by age, sex and ChSEP, was more strongly associated with increased BMI (0.57; 95% CI 0.39, 0.75). A robust association of education attainment with income is also observed (OR 2.80; 95% CI 2.56, 3.06).

Table 3 presents the CDEs, NDEs, NIEs, and MTEs of ChSEP and education on the number of NCD and Table 4 shows these results separately for men and women.

The CDE of ChSEP, controlling for age and sex and holding education at 12 years of schooling, showed an increased count of chronic conditions of 14% with 4% indirectly mediated by education (NIE) for women. For the behavioral mediators, the CDE ranged from RR 1.11 (95% CI 106, 1.16) to RR 1.21 (95% 1.12, 1.31) for alcohol use and physical activity, respectively, but all of the NIE estimates were approximately null.

The CDEs of education attainment, controlling for age, sex, and ChSEP and fixing the mediators at the favorable levels, represented an increased risk ranging from 21 to 29%, with only a modest indirect effect of BMI (RR 1.02; 95% CI 1.01, 1.02). In general, the CDE of women for both exposures was higher, but the differential effect of gender was only statistically heterogeneous for ChSEP mediated through education and for education mediated through income (Cochran's Q p values = 0.05 and 0.03, respectively) (Kaufman and MacLehose 2013).

Discussion

The effects of childhood and adult socioeconomic position on chronic diseases have been little studied in the Chilean population. One exception is the multicity study of elderly

Table 2 Associations of childhood and adult socioeconomic position binary measures with continuous and binary mediators in the cohort with follow-up to 2009

Childhood socioeconomic position (ChSEP)[a] = exposure (adjusted by age and sex)	
Continuous mediator	Difference (95% CI)[c]
Education (years of schooling, level 12 years)	−2.90 (−3.04, −2.76)
BMI (kg/m^2, level 24 kg/m^2)	0.26 (0.08, 0.45)
Binary mediator (1 = risk, 0 = reference, no risk)	Odds ratio (95% CI)
Smoker	0.84 (0.76, 0.91)
Heavy drinker	0.95 (0.86, 1.06)
Physical inactivity	1.22 (1.12, 1.34)
Education attainment[b] = exposure (adjusted by age, sex and ChSEP)	
Continuous mediator	Difference (95% CI)[c]
BMI (kg/m^2, level 24 kg/m^2)	0.57 (0.39, 0.75)
Binary mediator (1 = risk, 0 = reference, no risk)	Odds ratio (95% CI)
Low income	2.80 (2.56, 3.06)
Smoker	0.88 (0.80, 0.96)
Heavy drinker	1.14 (1.03, 1.27)
Physical inactivity	1.22 (1.12, 1.32)

Social protection surveys 2004, 2006, and 2009, Chile

[a] Binary variable from the bimodal distribution of a score generated from logistic regression odds ratios of mother's education, father's occupation, and father's presence in relation to subjective, self-reported assessment of childhood family circumstances (1 = poor)

[b] Binary variable, <12 years = low (1)

[c] Coefficient from linear regression, binary exposure 1 = low

Table 3 Direct and indirect effects of childhood and adult socioeconomic position on relative number of chronic conditions through different mediators in the cohort with follow-up to 2009

Mediator	CDE (RR, 95% CI)	NDE (RR, 95% CI)	NIE (RR, 95% CI)	MTE (RR, 95% CI)
Low childhood socioeconomic position = binary exposure (controlling for age and sex)				
Education (level 12 years)	1.12 (1.05, 1.19)	1.10 (1.04, 1.16)	1.04 (1.01, 1.06)	1.14 (1.09, 1.19)
BMI (level 24 kg/m^2)	1.14 (1.08, 1.21)	1.12 (1.07, 1.16)	1.01 (1.00, 1.02)	1.13 (1.08, 1.18)
Smoker (reference = no)	1.13 (1.08, 1.18)	1.12 (1.08, 1.17)	1.00 (0.99, 1.01)	1.13 (1.08, 1.18)
Heavy drinker (reference = no)	1.11 (1.06, 1.16)	1.12 (1.07, 1.16)	1.00 (0.99, 1.00)	1.12 (1.07, 1.17)
Physical inactivity (reference = active)	1.21 (1.12, 1.31)	1.13 (1.08, 1.17)	1.00 (0.99, 1.00)	1.13 (1.08, 1.17)
Low education = binary exposure (controlling for age, sex, and childhood socioeconomic position				
Low income (reference high)	1.24 (1.16, 1.33)	1.22 (1.16, 1.27)	1.01 (0.99, 1.02)	1.23 (1.17, 1.28)
BMI (level 24 kg/m^2)	1.29 (1.22, 1.37)	1.20 (1.14, 1.25)	1.02 (1.01, 1.02)	1.22 (1.16, 1.27)
Smoker (reference = no)	1.21 (1.15, 1.27)	1.22 (1.17, 1.28)	1.00 (0.99, 1.00)	1.22 (1.17, 1.28)
Heavy drinker (reference = no)	1.25 (1.19, 1.31)	1.23 (1.18, 1.28)	0.99 (0.99, 0.99)	1.23 (1.17, 1.28)
Physical inactivity (reference = active)	1.28 (1.20, 1.37)	1.23 (1.17, 1.28)	1.00 (0.99, 1.01)	1.23 (1.18, 1.28)

Social protection surveys 2004, 2006, and 2009, Chile

CDE controlled direct effects, *NDE* natural direct effects, *NIE* natural indirect effects, *MTE* marginal total effects

Latin Americans, using the Survey on Health, Well-being and Aging in Latin America and the Caribbean (Project SABE), which includes a sample from Santiago, Chile ($N = 1301$). This study examined through logistic regression models various measures of childhood and adult SEP on the risk of cardiovascular disease. The specific findings

Table 4 Direct and indirect effects of childhood and adult socioeconomic position as relative number of chronic conditions through different mediators, by sex in the cohort with follow-up to 2009

Mediator	Men				Women			
	CDE (RR, 95% CI)	NDE (RR, 95% CI)	NIE (RR, 95% CI)	MTE (RR, 95% CI)	CDE (RR, 95% CI)	NDE (RR, 95% CI)	NIE (RR, 95% CI)	MTE (RR, 95% CI)
Low childhood socioeconomic position (ChSEP) = exposure (controlling for age)								
Education (level = 12 years)	1.07 (0.97, 1.18)	1.07 (0.98, 1.16)	1.03 (0.99, 1.07)	1.10 (1.02, 1.18)	1.14 (1.06, 1.24)	1.12 (1.04, 1.20)	1.05 (1.01, 1.08)	1.17 (1.11, 1.24)
BMI (level = 24 kg/m^2)	1.14 (1.04, 1.25)	1.10 (1.03, 1.18)	0.99 (0.99, 1.00)	1.10 (1.02, 1.17)	1.14 (1.06, 1.22)	1.12 (1.07, 1.18)	1.03 (1.02, 1.04)	1.16 (1.10, 1.22)
Smoker (reference = no)	1.10 (1.01, 1.18)	1.09 (1.02, 1.17)	1.00 (0.99, 1.01)	1.10 (1.02, 1.18)	1.15 (1.09, 1.22)	1.15 (1.08, 1.21)	1.00 (0.99, 1.01)	1.15 (1.09, 1.21)
Heavy drinker (reference = no)	1.06 (0.98, 1.15)	1.10 (1.03, 1.18)	1.00 (0.99, 1.00)	1.10 (1.03, 1.18)	1.14 (1.08, 1.20)	1.13 (1.07, 1.19)	1.00 (0.99, 1.01)	1.13 (1.08, 1.19)
Physical activity (reference = active)	1.18 (1.05, 1.32)	1.11 (1.03, 1.18)	1.00 (0.99, 1.01)	1.11 (1.03, 1.18)	1.22 (1.10, 1.35)	1.14 (1.08, 1.20)	0.99 (0.99, 1.00)	1.14 (1.08, 1.20)
Low education = exposure (controlling for age and childhood socioeconomic position)								
Low income (reference = high)	1.15 (1.03, 1.27)	1.15 (1.07, 1.24)	1.01 (0.99, 1.03)	1.16 (1.08, 1.25)	1.31 (1.20, 1.43)	1.27 (1.20, 1.34)	1.00 (0.99, 1.02)	1.27 (1.21, 1.35)
BMI (level = 24 kg/m^2)	1.26 (1.15, 1.38)	1.17 (1.08, 1.25)	0.99 (0.99, 1.00)	1.16 (1.08, 1.25)	1.32 (1.24, 1.42)	1.22 (1.15, 1.29)	1.04 (1.03, 1.05)	1.27 (1.20, 1.34)
Smoker (reference = no)	1.18 (1.09, 1.29)	1.15 (1.07, 1.24)	0.99 (0.99, 1.00)	1.15 (1.07, 1.24)	1.24 (1.16, 1.31)	1.28 (1.21, 1.35)	0.99 (0.99, 1.00)	1.27 (1.21, 1.35)
Heavy drinker (reference = no)	1.23 (1.13, 1.34)	1.17 (1.09, 1.25)	0.99 (0.98, 0.99)	1.15 (1.07, 1.24)	1.28 (1.21, 1.35)	1.27 (1.20, 1.34)	1.00 (0.99, 1.01)	1.27 (1.21, 1.35)
Physical activity (reference = active)	1.20 (1.08, 1.34)	1.16 (1.08, 1.25)	1.00 (0.99, 1.01)	1.17 (1.09, 1.25)	1.33 (1.22, 1.46)	1.27 (1.21, 1.35)	1.00 (0.99, 1.00)	1.28 (1.21, 1.35)

Social protection surveys 2004, 2006, and 2009, Chile

CDE controlled direct effects, *NDE* natural direct effects, *NIE* natural indirect effects, *MTE* marginal total effects

for Chile only showed an association with income and purchasing power (Jones et al. 2014). However, this traditional approach does not consider interaction between the SEP measures or decomposition of direct and indirect effect pathways.

Pathway-specific inference can be useful for identifying proximal targets for policy intervention. Alternatively, if a large proportion of the socioeconomic difference operates through educational disparity, then strengthening low-cost public education to increase quality and retention has a plausible role in reducing overall inequalities (Nandi et al. 2014). The alternative approach is one that is more fundamental, according to the social determinants of health framework (World Health Organization 2008). Our results are broadly supportive of a perspective of action on wider determinants, given that we observed only trivial degrees of mediation by measured behavioral variables. Of course, logically, some mechanistic pathways must exist, but our results show only that the obvious candidates, measured and modeled crudely, do not offer strong evidence to support other specific health behavior policy targets.

The CDE of the childhood and adult socioeconomic position in our analysis shows the effect of these SEP exposures on the relative count of chronic conditions in adulthood that would be observed if the mediator was controlled uniformly at positive values. Thus, this measure represents the difference in risk due to the SEP exposure in the counterfactual situation that we had acted on the mediators to obtain positive values. When years of schooling was the mediator, we see an increased relative number of adult chronic conditions associated with low ChSEP of 7% for men and 14% for women, even if all the population had 12 years of schooling. However, this value is qualitatively similar to the disparity observed when no intervention is made on education. When income was the mediator of the effect of education, holding the population at high income levels, the relative number of chronic conditions increased 15% for men and 31% for women.

Education attainment is a proxy of adult SEP, but its level is influenced by childhood circumstances and the opportunities provided by family and public policies, which may also be affected by gender norms and roles. In turn, education level is associated with employment opportunities, material resources, and prestige, so low education would mean precarious employment, deprivation, and discrimination, leading to what has been called toxic stress and other mechanisms of illness (Shonkoff and Garner 2012). Intergenerational social mobility is strongly related to employment mobility. The heterogeneous effects observed by gender may be related to the relatively low female participation in the work force in Chile, even in the Latin American context. In 2009, it was 42.3% versus 70.7% for men (Ministerio de Desarrollo Social 2013).

Our findings suggest that for both sexes, the pathways between socioeconomic position and NCD are not predominately through health behaviors, at least as they were measured and modeled in our study. If these null mediation results are not explained by methodologic limitations such as measurement error and residual confounding, then they would discourage targeting these specific pathways for the purpose of reducing adult health outcome inequalities, although such interventions could have other salubrious effects. Representing complex behaviors such as smoking and physical activity as simple binary indicators could substantially reduce their explanatory potential in mediation models (Smith et al. 2015). Nevertheless, data from the national health surveys confirm the relatively high prevalence of smoking in Chile, which continues to grow especially for well-educated women. Despite being one of the first countries in the Americas to implement the tobacco framework law, it is still the country with the highest prevalence of smoking in the region (World Health Organization 2015). Our findings that people with low ChSEP and education have lower odds of smoking are in accordance with data from other Chilean surveys, such as the 2009/2010 National Health Survey (Encuesta Nacional de Salud, ENS) (MINSAL 2010). Alcohol consumption also showed lower odds for low ChSEP and was not associated with education,

Several limitations should be considered when interpreting the results of this study. Differential loss to follow up in people with higher SEP may lead to selection bias. We carried out a quantitative sensitivity analysis using a deterministic correction formula based on the proportions in each exposure and outcome group lost to follow up (Lash et al. 2009). The results indicated that our reported estimates could be inflated by 8–20%, but even this magnitude of bias would not change our qualitative conclusions. The self-reported nature of the data may give rise to misclassification bias, for example the outcome of diagnosed health conditions does not mean the absence of disease and may be more related to access to health care. In other contexts with few health care barriers, agreement between self-report and physician diagnosis of cardiovascular, non-insulin dependent diabetes, cancer, and asthma is high but lower for arthrosis and mental health conditions (Baumeister et al. 2010). In contrast, Chile's 2009/2010 national health examination survey (ENS) applied by trained nurses reports that 60% of adults were aware of somatic health conditions such as hypertension and diabetes, similar to the prevalence self-reported by the EPS cohort. However, the prevalence of diagnosed depression was lower in EPS, which may be explained by a reluctance to report mental health conditions to non-health professional interviewers.

The estimation and causal interpretation of NDE and NIE also require that there were no unmeasured exposure–mediator confounding, implausible assumptions in this data set. For example, childhood illness and parental health problems are not measured. Therefore, our interpretation of our results is more qualitative focusing on CDE, which have fewer identification conditions and more concrete policy interpretations. Nonetheless, the natural and controlled effects were largely consistent in this analysis in indicating trivial degrees of mediation.

The *paramed* command offers a simple, straightforward technique for modern mediation analysis, but it is somewhat limited. Specifically, it uses the same set of covariates in both models and simplifies the situation of multiple mediators by considering such factors one at a time. In reality, the causal mediators that we considered may have important causal or confounding relations and interactions, which are ignored in our one-by-one approach (VanderWeele and Vansteelandt 2014). While we acknowledge the need for further analysis to better account for confounders and model identification, these assumptions are important considerations for all observational studies and are not unique to mediation models.

Conclusions

Our findings confirm a robust association between childhood and adult socioeconomic position with adult chronic disease in Chile, even after considering potential bias. With respect to the mediators studied, structural pathways such as education and income opportunities offered the greatest suggestion of mediating disparities, with health behaviors playing almost no observed role. These findings support the current social policy focus on early child development and free, quality education as critical components of universal policies to tackle the challenges of the NCD burden and overall well-being through action on social inequities. The heterogeneous effects of the education and income pathways for women suggest that gender norms, relations, and roles, reflected in lower female participation in the workforce, lower wages and autonomy, may play an important role in increasing chronic health risks for women despite their greater contact with the health system. Thus, gender transformative social policies and strengthening of gender aspects in current policies on early child development and education are salient for the promotion of healthy lives and well-being at all stages of life.

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Compliance with ethical standards

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study, using anonymized data from the Chilean Social Protection Survey (Encuesta de Protection Social), which is publically available from Chile's Ministry of Labor and Social Prevision (Ministerio de Trabajo y Previsión Social), was approved by the Ethics Committee for Research on Human Subjects of the Faculty of Medicine of the University of Chile.

Informed consent Informed consent was obtained from all individual participants included in the Social Protection Survey (Encuesta de Protección Social).

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