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Income and Oral and General Health-Related Quality of Life: The Modifying Effect of Sense of Coherence, Findings of a Cross-Sectional Study

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Abstract

Objectives To investigate whether a strong sense of coherence (SOC) modifies the association between low-income and oral and general health-related quality of life (OHRQoL and HRQoL, respectively) among a South Australian population sample; and to explore the main and interaction effects of income and SOC on OHRQoL and HRQoL.

Methods Baseline data from the Dental Care and Oral Health Study (DCOHS, a South Australian representative study, 2015–2016) were used for cross-sectional analysis (n = 3,786). Four multivariable factorial ANOVA models were applied to assess the effect measure modification, main effects, and interaction of income and SOC on OHRQoL (measured using the OHIP-14) and HRQoL (measured using the EQ-5D-3L).

Results Income and SOC had small main effects on OHRQoL. Income had a small effect and SOC had an intermediate effect on HRQoL, meaning that individuals with strong SOC had better OHRQoL and HRQoL in all income categories. Also, high-income participants had better OHRQoL and HRQoL. The interaction between income and SOC was statistically significant on HRQoL. Among participants from low-income group, those with strong SOC had better OHRQoL (mean = 8.8, 95% CI[7.9, 9.7]) and HRQoL (mean = 1.1, 95% CI[1.0, 1.3]) than others with weak SOC (OHIP-14 mean = 12.7, 95% CI[11.7, 13.6]) and (EQ-5D-3L mean = 2.0, 95% CI[1.9, 2.2]).

Conclusion The findings showed the main effects and interaction between SOC and income on OHRQoL and HRQoL. Income had different effects on OHRQoL and HRQoL depending on whether SOC was strong or weak. Findings suggested that strong SOC modified the association between low-income and OHRQoL and HRQoL.

Keywords Sense of Coherence · Oral health · Socioeconomic status · Health-related quality of life

Extended author information available on the last page of the article

Introduction

Many studies have shown income gradients in health (Bernabé et al., 2015; Sabbah et al., 2007). However, it is unclear how some people who face income-related health adversity can escape this cycle and have good health. Since low-income individuals are faced with many barriers and stressors that impact their health, psychosocial factors enhancing their coping abilities could be beneficial for them (Atal & Cheng, 2016; Chen et al., 2011; Mizuta et al., 2020). Researchers use Aaron Antonovsky's salutogenic theory to explain why some individuals are more resilient to diseases, are able to maintain good health, can thrive under adverse conditions, and cope with severe stressors (Antonovsky, 1979, 1987, 1995). Sense of coherence (SOC), as this theory's central concept, reflects a person's outlook on life and the ability to respond to strained conditions (Antonovsky, 1993). People with strong SOC find life more manageable, structured, meaningful and comprehensible. SOC has three components: comprehensibility, manageability, and meaningfulness (Antonovsky, 1987, 1993).

Strong SOC is associated with better emotional functioning and less perceived anxiety (Sawma & Sanjab, 2022). On the other hand, there is evidence associating weak SOC with depression and high levels of anxiety (Erim et al., 2011; Lindblad et al., 2016). It should be noted that weak SOC does not necessarily indicate a depressive mood (Sawma & Sanjab, 2022). Although low SOC shares some similar characteristics with depression, a strong SOC prevents depression (Siglen et al., 2007). Those with a strong SOC also have better health outcomes (Eriksson & Lindström, 2006) and coping capacity for daily stressors (Super et al., 2016) than others. An individual's SOC is influenced by their mindset, performance and behaviours, which help them find and use resources to improve their well-being, health and quality of life (Eriksson & Lindström, 2006). The other component of the salutogenic theory is general resistance resources (GRRs), which are those life experiences that shape SOC (such as social support, intellectual, physical, cultural and financial factors, and coping strategies) (Antonovsky, 1979, 1987; Horsburgh & Ferguson, 2012; Idan et al., 2016). GRRs facilitate recovery from diseases faster by choosing healthy habits (e.g., healthy eating, physical activity, regular check-ups) and avoiding unhealthy behaviours (e.g., smoking, unhealthy lifestyle, excessive drinking) (Savolainen et al., 2009).

While low-income people face many challenges and stressors in their lives, some "beat the odds" and manage to have better health through strong SOC (Mizuta et al., 2020; Speirs et al., 2016). Strong SOC enables low-income families to adopt healthy behaviours regardless of the limited resources available (Speirs et al., 2016). SOC could efficiently promote dental health, especially among those individuals living below the poverty line (Mizuta et al., 2020). The association between the guardians' SOC and caries prevalence among low-income children has been reported (Mizuta et al., 2020). Also, SOC was associated with adults' better oral health behaviours, independent of socioeconomic status (SES) or demographic characteristics (Bernabé et al., 2009). While financial factors and SES are considered as essential GRRs and manageability resources, they are

not the only factors contributing to people's resilience in socioeconomic adversity related to health and quality of life (such as income-health disparity). People's SOC was found to be different according to their healthy lifestyle choices regardless of their SES (Wainwright et al., 2007). It should be noted that SOC is explained by other factors that go beyond income and SES. These include hereditary, environmental, financial, knowledge, religious, ritualistic beliefs, healthy behaviours, mindset, and social factors (Antonovsky, 1979, 1987; Horsburgh & Ferguson, 2012; Idan et al., 2016; Super et al., 2016). According to a study of unemployed migrant women, strong SOC was related to the meaningfulness of what they had gone through and GRRs such as social support, religion, and exchanging empowerment stories (Slootjes et al., 2017).

There is some inconsistent evidence about the association between SOC and health. In a cross-sectional study by Speirs et al. (2016), data from 321 low-income families were used to examine whether a strong family SOC was a protective factor against obesity in low-income preschoolers. According to their results, SOC was not associated with children's healthy weight and limiting health-damaging behaviours. Also, a four-year prospective study found no correlation between SOC and periodontal disease (Kanhai et al., 2014). However, there are significant findings supporting the association between strong SOC with oral and general health-promoting behaviours, oral and general health-related quality of life (OHRQoL and HRQoL) (Flensborg-Madsen et al., 2005; Nammontri et al., 2013; Savolainen et al., 2009). Also, the modifying effect (previously known as the moderating effect (Knol & VanderWeele, 2012)) of SOC on OHRQoL and HRQoL (Asaba & Okawa, 2021; Machado et al., 2017) and the interaction between SOC and SES on objective oral health, i.e., clinical examinations (among low-income groups) have been reported (Mizuta et al., 2020). Effect modification refers to different effects of the exposure on the outcome variable across strata of another exposure (VanderWeele, 2009), while interaction refers to the specific combined effect of both exposures on the outcome variable that neither exposure alone can explain (VanderWeele, 2009).

A study that investigated factors related to coping with health challenges in Cameroon found that the coping skills of people living in poverty (determined mainly by low income) against diseases were strongly related to the individual's dispositional factors (such as SOC) (Makoge et al., 2019). Interestingly, their coping was not associated with income or social factors (Makoge et al., 2019). However, the effect of income on oral and general health-related quality of life (OHRQoL and HRQoL) is evident (Brennan & Spencer, 2014; Sun et al., 2018). Therefore, it will be beneficial to identify the factors associated with coping abilities related to income-health disparities among low-income individuals, aiming to address such disparities. Consequently, further investigation into the role of SOC as a possible modifier of the association between low-income and OHRQoL and HRQoL is required. Thus, this study aimed to estimate: First, the main effects and interaction between income and SOC on OHRQoL and HRQoL separately; Second, whether the association between low-income and OHRQoL and HRQoL is modified by strong SOC among a South Australian population sample. The hypotheses were: 1- SOC is associated with better OHRQoL and HRQoL; 2- there are interaction effects (joint effects) between SOC and income with OHRQoL and HRQoL; and 3- strong SOC modifies

the association between low income and OHRQoL and HRQoL. We hypothesized that in participants from the low-income group, those with strong SOC have better OHRQoL and HRQoL.

Methods

The baseline data of the Dental Care and Oral Health Study (DCOHS) were used for cross-sectional analysis. DCOHS is a South Australian survey collected in 2015–2016. The sample size for DCOHS was calculated using the oral health estimates derived from the National Survey of Adult Oral Health in Australia (power = 80% and statistical significance level $\alpha = 0.05$) (Zakershahrak & Brennan, 2022a; Zakershahrak & Brennan, 2022b). The outcome variables used in the power analyses were the Oral Health Impact Profile (OHIP-14) and the European Quality of Life indicator or EuroQol (EQ-5D) scores. The power analysis calculations were based on detecting differences in OHIP of 1.60 and EQ-5D of 0.03 units in their scale scores. DCOHS used a simple random sample without any stratification for the sampling procedure. Mail surveys were sent to 12,245 randomly selected individuals from the Electoral Roll (a comprehensive sample frame), aged 18 years old and above. A total of 4,494 responses were received. The response used in the analysis comprised 30.9% of the original sample when out-of-scope persons were included (those who did not receive the survey due to address changes). Also, some surveys were returned by the post office indicating that individuals no longer lived at the address. Ethics approval was provided by the University of Adelaide Human Research Ethics Committee (H-288–2011) (Song et al., 2020a, b).

The outcome variables were the OHIP-14 to assess OHRQoL and the EQ-5D to evaluate HRQoL. The OHIP-14 is an oral health instrument that reflects patients' oral health and the social impacts of their oral health on their OHRQoL in seven dimensions (functional limitation, physical pain, psychological discomfort, physical, psychological and social disability, and handicap) using 14 items (Slade, 1997). This OHRQoL measure has been validated in Australia with high reliability (Slade, 1997). Responses were coded using a Likert-type scale (0 = never to 4 = very often) with summed scores ranging from 0 to 56 (higher scores reflecting poorer OHRQoL). The EQ-5D is a self-reported instrument measuring the health status in five dimensions of mobility, self-care, usual activities, pain/discomfort, and anxiety/depression according to a 3-level response (EQ-5D-3L) (Van Reenen et al., 2018). Recent validation of EQ-5D-3L has been conducted in a general Australian population (using DCOHS), showing acceptable reliability and good discrimination between health states (Zakershahrak et al., 2022). To be consistent with the OHIP-14 (as an impact score), the EQ-5D-3L was rescaled with answers coded 0 = No problems to 2 = Extreme problems (Brennan, 2013). Therefore, those with no problems were anchored at zero scores with summed scores ranging from 0 to 10. The higher summed scores indicate poor HRQoL.

The explanatory variable was the total household income collected in 10 categories (< $20,000 to > $180,000 in Australian Dollars). Income was coded into

approximate tertiles (approximately equal-sized groups): ≤ $40,000, more than $40,000 to $100,000 and > $100,000.

The effect modifier was the three-item scale SOC (SOC-3). Lundberg and Peck (1995) developed SOC-3 to be used in large population surveys. SOC-3 has demonstrated strong predictive validity for mortality rates related to cardiac disease and cancer (Surtees et al., 2003) and satisfactory reliability (Lundberg & Peck, 1995). Chiesi et al. (2018) showed that SOC-3 is a validated, low-loading and fast version of the SOC instrument suitable for large population surveys. Each item is designed to evaluate one of SOC's dimensions. The comprehensibility dimension was evaluated using the question, "Do you usually feel that the things that happen to you in your life are hard to understand?". The manageability dimension was evaluated using the question, "Do you usually see solutions to problems and difficulties that other people find hopeless?". The meaningfulness dimension was evaluated using the question, "Do you usually feel that your daily life is a source of personal satisfaction?". The answers to meaningfulness and manageability were scored as Yes, usually = 0, Yes, sometimes = 1, and No = 2. Responses to comprehensibility were reverse-coded to match the order of the other two dimensions' answers. The total index score was calculated (0 to 6), where higher scores equate to lower coherence (weak SOC). The total scores were dichotomised into strong (0 to 2) and weak (3 to 6) based on previous research (Lundberg & Peck, 1994).

Other variables included in the models to adjust for their effects comprised: demographics (age, sex, place of birth and main language spoken at home) and health behaviours (dental insurance, smoking status, tooth brushing, and last dental visit). Age was coded into three approximately equal-sized age groups (approximate tertiles): 18–45, 46–60, and 61 years and older. The place of birth was grouped as Australia or other countries. Dental insurance was dichotomised as insured and uninsured. The language was coded as those who mainly spoke English and those who mainly spoke other languages at home. Smoking status was classified into three groups: current smokers, former smokers and those who never smoked. Tooth brushing was categorised as participants who brushed twice a day or more and others who brushed their teeth less than twice a day. The last dental visit was coded as individuals who visited the dentist less than 12 months ago or 12 months ago and more.

A total of 3,786 respondents, with complete answers to outcome variables (OHIP-14 and EQ-5D-3L), effect modifier (SOC) and explanatory variable (income) were included in the analysis. As there may be response bias (difference between dropout individuals' responses and respondents), the final sample was compared with participants with missing responses. Also, a comparison between the final study sample ($n = 3{,}786$) and census data was conducted to assess the representativeness.

First, skewness and kurtosis of the outcome variables were calculated to verify assumptions of the factorial ANOVA (which are applied to the residual values). The Estimated Resident Population from the Australian Bureau of Statistics were used for weighting the responses to be representative of the age and sex distribution of South Australians. Four factorial ANOVA models (general linear models) were designed to evaluate the main effect and interaction between different levels of income and SOC on the OHIP-14 and later on the EQ-5D-3L (each outcome was

analysed and modelled separately). The analyses comprised the simplest interaction between SOC and income groups (model 1), followed by a structured approach (models 2 to 4) that included putative confounders in consecutive blocks of conceptually related variables (demographics and health behaviour variables). Therefore, models 2 to 4 adjusted for different sets of variables (Model 2: sex and age, Model 3: all demographics, Model 4: all demographics and health behaviour variables). These models evaluated: 1-whether the associations between the OHIP-14 and the EQ-5D-3L with income were modified by strong SOC, and 2- the main effect and the interaction between SOC and income on each health outcome (Figures S1-S3). The partial Eta-squared (partial η^2, as the most common standardised effect size statistic for factorial ANOVA) of the main effect and interaction between SOC and income adjusted for different covariates were estimated using general linear models. Based on the benchmark literature (Richardson, 2011), the partial η^2 greater than 0.0099 and lower than 0.0588 was interpreted as a small effect size, and between 0.0588 to 0.1379 was considered an intermediate effect size. Values lower than 0.0099 were indicated as having no effect.

The analyses were repeated using transformed outcomes (log) to correct any skewness (if existing) that may have affected the result. Statistical analyses were performed using SPSS version 28 (IBM Corp.) with 95% confidence intervals.

Result

Participants with complete responses (complete answers to all items) to, the OHIP-14, EQ-5D-3L, SOC and income were analysed ($n = 3{,}786$). Due to the possibility of response bias, the final sample was compared with missing cases (Table S1). Both samples had similar compositions with differences in dental insurance and age groups; the missing cases were more likely to be older and without dental insurance.

To evaluate the representativeness of the final sample, we compared it with the population data from the South Australian census (Table S2). The composition of the final sample and census data was similar, with slight variations in place of birth, age groups and income groups. In the final sample, respondents were mostly born in Australia, younger, and had a higher percentage of high-income households.

Just over half of the sample were female (55.7%), aged 61 years and older (35.8%, mean age = 52.9), had a strong SOC (71.4%), had dental insurance (68.7%), were in the middle-income threshold (41.2%), and had never smoked (54.5%) (Table 1). The mean (SD) score for the OHIP-14 was 6.3 (8.6) and for the EQ-5D-3L was 0.9 (1.3). The lowest means for the OHIP-14 and the EQ-5D-3L (better OHRQoL and HRQoL) were observed for those from the high-income level, strong SOC, the age group 18–45 years old, the Australian-born, dentally insured adults and non-smokers. Also, the OHIP-14 and the EQ-5D-3L had kurtosis of 5.32 and 3.53, respectively. The OHIP-14's skewness was 2.17, and the EQ-5D-3L's was 1.81.

The main effects of income and SOC on the OHIP-14 were statistically significant in all models (Table 2). The magnitude of effect sizes of SOC and income on the OHIP-14 was small ($0.0099 < \text{partial } \eta^2 < 0.0588$) across all models. There was a statistically significant interaction between SOC and income

Table 1 Characteristics of the study participants by the OHIP-14 and the EQ-5D-3L

	N (%)	OHIP- 14 Mean (SD)		EQ-5D-3L Mean (SD)
Total	3786	6.3 (8.6)		0.9 (1.3)
Health behaviour variables				
Last Dental Visit	3782			
Less Than A Year Ago	2315 (61.2)	5.8 (8.2)	0.8 (1.2)	
A Year Ago And More	1467 (38.8)	6.9 (9.2)	1.0 (1.4)	
Dental insurance	3742			
Insured	2571 (68.7)	4.8 (6.8)	0.8 (1.1)	
Uninsured	1171 (31.3)	9.2 (10.9)	1.2 (1.5)	
Smoking Status	3763			
Non-Smoker	2049 (54.5)	5.0 (7.2)	0.7 (1.2)	
Former Smoker	1282 (34.1)	6.8 (8.7)	1.1 (1.4)	
Current Smoker	432 (11.5)	11.1 (12.3)	1.3 (1.5)	
Tooth Brushing	3705			
Twice A Day Or More	2023 (54.6)	5.6 (8.2)	0.8 (1.2)	
Less Than Twice A Day	1682 (45.4)	6.8 (8.9)	1.0 (1.4)	
Demographics				
Place of Birth	3757			
Australia	2964 (78.9)	5.9 (8.3)	0.9 (1.2)	
Other	793 (21.1)	7.7 (9.7)	1.1 (1.4)	
Main Language Spoken At Home	3724			
English	3559 (95.6)	6.1 (8.6)	0.9 (1.3)	
Other	165 (4.4)	8.0 (8.9)	1.0 (1.4)	
Sex	3786			
Male	1678 (44.3)	6.0 (8.41)	0.8 (1.2)	
Female	2108 (55.7)	6.6 (9.1)	1.0 (1.3)	
Age Groups (Mean = 52.9) (range 18–86)	3786			
18–45 years	1202 (31.7)	5.9 (8.1)	0.6 (1.1)	
46–60 years	1229 (32.5)	6.8 (9.3)	1.0 (1.3)	
≥ 61 years	1355 (35.8)	6.5 (9.0)	1.3 (1.5)	
Sense of Coherence	3786			
Higher Coherence (Strong SOC*)	2703 (71.4)	5.1 (7.4)	0.7 (1.1)	
Lower Coherence (Weak SOC)	1083 (28.6)	8.9 (10.4)	1.4 (1.6)	
Income Groups (range $0 to > $180,000)	3786			
≤ $40 000	1117 (29.5)	9.5 (11.3)	1.6 (1.6)	
$40 001—$100 000	1559 (41.2)	5.9 (7.7)	0.8 (1.2)	
> $100 000	1110 (29.3)	4.0 (6.1)	0.5 (0.8)	

* Sense of Coherence

Table 2 Partial Eta squared from adjusted models of the OHIP-14

	Model 1[1]	Model 2[2]	Model 3[3]	Model 4[4]
	Partial η^2 (90% CI)	Partial η^2 (90% CI)	Partial η^2 (90% CI)	Partial η^2 (90% CI)
SOC [a]	0.026**(0.018,0.035)	0.024**(0.016,0.032)	0.024**(0.016,0.033)	0.019**(0.012,0.027)
Income Groups [b]	0.044**(0.034,0.055)	0.046**(0.035,0.056)	0.045**(0.035,0.056)	0.023**(0.015,0.031)
Income Groups * SOC	0.003**(0.001,0.007)	0.003**(0.000,0.006)	0.003**(0.001,0.006)	0.003**(0.000,0.006)
Model Adjusted R-squared	0.086	0.090	0.094	0.141
F value of interaction between Income Groups and SOC	6.312	5.396	5.732	4.892

** $P < 0.01$

* $P < 0.05$

aSense of Coherence; OHIP- 14 Mean (SD) = 6.3 (8.6); Higher Coherence/Strong SOC (n = 2703 (71.4%)), Lower Coherence /Weak SOC (n = 1083 (28.6%))

bIncome groups: ≤ $40,000 (n = 1117 (29.5%)); $40,001—$100,000 (n = 1559 (41.2%)); ≥ 100,000 (n = 1110 (29.3%)); (range $0 to > $180,000); OHIP- 14 Mean (SD) = 6.3 (8.6)

1: Model 1, with only the interaction term between SOC and different income groups and main effects of income and SOC

2: Model 2 adjusted the analyses of Model 1 for sex and age

3: Model 3 adjusted the analyses of Model 1 for sex, age, the main language spoken at home and place of birth

4: Model 4 adjusted the analyses of Model 1 for sex, age, the main language spoken at home, place of birth, daily tooth brushing, smoking, dental insurance and last dental visit

on the OHIP-14 in all models (model 1, $F(2, 3780) = 6.312$, $p < 0.01$, partial $\eta^2 = 0.003$, Adjusted $R^2 = 0.086$); model 2 ($F(2, 3777) = 5.396$, $p < 0.01$, partial $\eta^2 = 0.003$, Adjusted $R^2 = 0.090$); model 3 ($F(2, 3686) = 5.732$, $p < 0.01$, partial $\eta^2 = 0.003$, Adjusted $R^2 = 0.094$); and model 4 ($F(2, 3545) = 4.892$, $p < 0.01$, partial $\eta^2 = 0.003$, Adjusted $R^2 = 0.0141$).

Income and SOC had statistically significant main effects on the general health outcome (all models). The magnitude of effect sizes of SOC (model 2) and income (model 1) on the EQ-5D-3L was intermediate ($0.0588 <$ partial $\eta 2 < 0.1379$). The effect size of SOC in models 1, 3 and 4, and income in models 2 to 4 on general health outcome was small. The interaction between income and SOC on the EQ-5D-3L (Table 3) was statistically significant in all models (model 1, $F(2, 3780) = 5.540$, $p < 0.01$, partial $\eta^2 = 0.003$, Adjusted $R^2 = 0.156$); model 2, $F(2, 3777) = 10.166$, $p < 0.001$, partial $\eta^2 = 0.005$, Adjusted $R^2 = 0.185$); model 3, $F(2, 3686) = 9.697$, $p < 0.001$, partial $\eta^2 = 0.005$, Adjusted $R^2 = 0.184$); model 4, $F(2, 3545) = 9.319$, $p < 0.001$, partial $\eta^2 = 0.005$, Adjusted $R^2 = 0.190$).

Table 3 Partial Eta squared from adjusted models of the EQ-5D-3L

	Model 1[1]	Model 2[2]	Model 3[3]	Model 4[4]
	Partial η^2 (90% CI)	Partial η^2 (90% CI)	Partial η^2 (90% CI)	Partial η^2 (90% CI)
SOC [a]	0.047**(0.036,0.058)	0.059**(0.047,0.071)	0.058**(0.047,0.071)	0.054**(0.043,0.067)
Income Groups [b]	0.086**(0.072,0.100)	0.055**(0.044,0.067)	0.057**(0.045,0.069)	0.043**(0.032,0.054)
Income Groups * SOC	0.003**(0.001,0.006)	0.005**(0.002,0.010)	0.005**(0.002,0.009)	0.005**(0.002,0.010)
Model Adjusted R-squared	0.156	0.185	0.184	0.190
F value of interaction between Income Groups and SOC	5.540	10.166	9.697	9.319

** $P < 0.01$

* $P < 0.05$

a: Sense of Coherence; OHIP- 14 Mean (SD) = 6.3 (8.6); Higher Coherence/Strong SOC (n = 2703 (71.4%)), Lower Coherence /Weak SOC (n = 1083 (28.6%))

b: Income groups: ≤ $40,000 (n = 1117 (29.5%)); $40,001—$100,000 (n = 1559 (41.2%)); ≥ 100,000 (n = 1110 (29.3%)); (range $0 to > $180,000); EQ-5D-3L Mean (SD) = 0.9 (1.3)

1: Model 1, with only the interaction term between SOC and different income groups and main effects of income and SOC

2: Model 2 adjusted the analyses of Model 1 for sex and age

3: Model 3 adjusted the analyses of Model 1 for sex, age, the main language spoken at home and place of birth

4: Model 4 adjusted the analyses of Model 1 for sex, age, the main language spoken at home, place of birth, daily tooth brushing, smoking, dental insurance and last dental visit

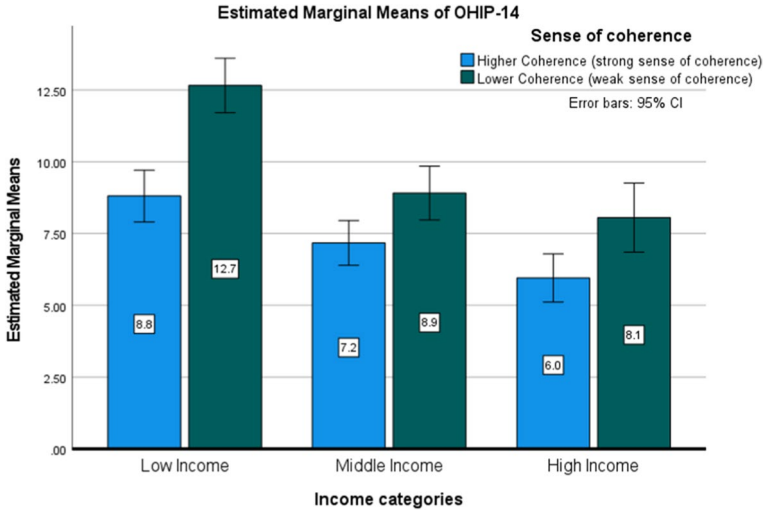

Fig. 1 OHRQoL by Income groups SOC in Model 4 (fully adjusted model; adjusted the analyses for sex, age, the main language spoken at home, place of birth, daily tooth brushing, smoking, dental insurance and last dental visit.)

Figure 1 demonstrates the effect modification of SOC on the OHIP-14 at different levels of income in model 4 with a statistically significant interaction. OHRQoL of those with low-income and strong SOC (mean = 8.8, 95% CI[7.9, 9.7]) were slightly better than those at middle income (mean = 8.9, 95% CI[8.0, 9.8]) and were

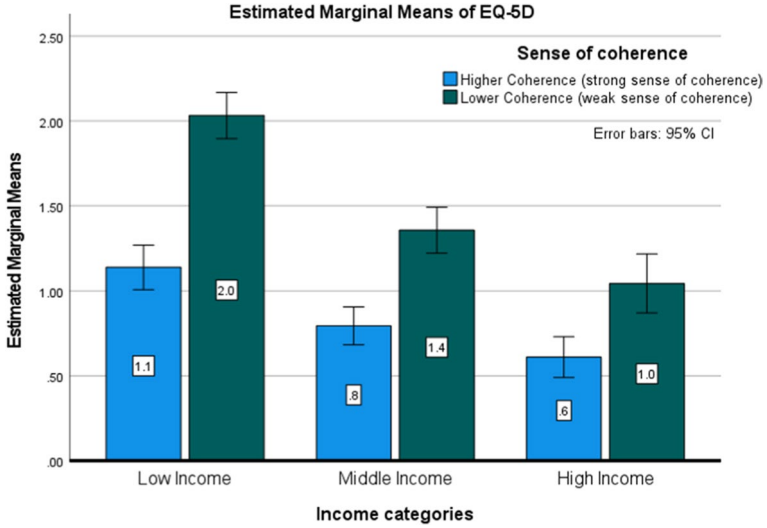

Fig. 2 HRQoL by Income groups SOC in Model 4 (fully adjusted model; adjusted the analyses for sex, age, the main language spoken at home, place of birth, daily tooth brushing, smoking, dental insurance and last dental visit.)

comparable to those at high-income level (mean = 8.1, 95% CI[6.9, 9.3]) with weak SOC. Figure 2 shows the effect modification of SOC on the EQ-5D-3L in model 4 (with statistically significant interaction). The HRQoL of low-income respondents with strong SOC (mean = 1.1, 95% CI[1.0, 1.3]) were comparable to high-income individuals with weak SOC (mean = 1.0, 95% CI[0.9, 1.2]) and better than those at middle income with weak SOC (mean = 1.4, 95% CI[1.2, 1.5]). Also, among low-income respondents, the absolute differences in both the OHIP-14 and the EQ-5D-3L means between strong and weak SOC were greater than among high-income respondents (3.9 vs 2.1 for OHRQoL, 0.9 vs 0.4 for HRQoL).

To explore the impact of possible violations of the normality assumptions, the analyses were repeated with log-transformed outcome variables. The results were similar to those obtained using the original data.

Discussion

This study investigated the main effects of SOC and income, their interaction, and the effect modification of strong SOC in the association between income and OHRQoL and HRQoL. Across all models, the associations between strong SOC and better OHRQoL and HRQoL, and the interactions between SOC and income were observed. The modifying effects of strong SOC on the associations between income and OHRQoL and HRQoL indicate the greater potential health gains from strong SOC for low-income individuals than high-income respondents (i.e., greater absolute differences between strong and weak SOC in OHRQoL and HRQoL at the low-income level than at high-income level). Low-income individuals with strong SOC had comparable OHRQoL and HRQoL to high and middle-income respondents with weak SOC.

The findings are congruent with previous studies, emphasising the importance of SOC as a beneficial psychological component affecting coping mechanisms in health adversities caused by low income (Makoge et al., 2019; Mizuta et al., 2020; Speirs et al., 2016). Since low-income people have limited resources, strong SOC plays an important role in their coping ability with health challenges (Makoge et al., 2019). Strong SOC helps them re-interpret and cope with the stressors in a more manageable, comprehensible, and meaningful manner. Despite limited resources, low-income families with strong SOC tend to have healthier lifestyles, engage in healthier activities, and cope with stress more effectively (Speirs et al., 2016). Wainwright et al. (2007) reported a positive association between strong SOC and healthy behaviours independent of social class or level of education. Despite the importance of income and SES in shaping SOC, neither completely explains it. From a holistic perspective, SOC is more likely related to psycho-emotional factors (e.g. social relationships, family life, childhood living conditions, and employment quality), reflecting people's interpretations of their lives (Volanen et al., 2004). Bernabe et al. (2009) showed that childhood SES had a relatively small effect on adults' SOC. Their findings suggest that adults' SOC is influenced by factors other than childhood SES. Among low-income Japanese guardians (Mizuta et al., 2020), those with stronger SOC had children with lower caries prevalence.

A minimally important difference of 4–5 OHIP-14 units has been suggested (Locker et al., 2004), similar to the main effects observed for SOC and income in this study. As an impact score, the EQ-5D-3L values < 1 have been equated to small to moderate effects in discriminating between different oral health conditions (Brennan, 2013). In our study, the EQ-5D-3L values of around one unit were observed for the main effects of SOC and income. Similar minimally important differences of 4–5 units for OHIP-14 and around 1 for EQ-5D-3L were observed between low and high-income groups in the present study. Also, the effect size should be labelled according to the research field and the studied phenomenon (Durlak, 2009). Despite the small effect size found in this study, the findings are still meaningful on a practical level in social and behavioural studies (practical significance of the effect size). In other words, if the exposure is common, the small effect on the individual level could still have an extensive impact on the population. The cumulative effect of small psychological factors over time can be significant, especially if they affect behaviours and activities (Funder & Ozer, 2019).

Even though many conceptually related covariates were included in the models, not all relevant factors were considered. The explanatory power of the models could potentially be enhanced in further studies through the inclusion of health behaviour variables such as diet and alcohol consumption. The covariates in our study were selected based on the general concept of health behaviours to cover their different dimensions without overlapping. Each represents a conceptual factor: preventive behaviours (tooth brushing), risky behaviours (smoking), health service utilisation (last dental visit), and enabling factors (dental insurance). Such variables rarely occur separately, rather they tend to cluster together (Alzahrani et al., 2014; Sanders et al., 2005). Also, in social and behavioural science, no model can encompass all relevant predictors of outcome (Neter et al., 1996). Models should include covariates that provide unique information (to maximize their predictive value) while avoiding multicollinearity (having too few or too many variables) or overlap (Marill, 2004). It is important to avoid correlated covariates since they increase the standard error of the estimated regression coefficients [39]. Limiting the covariates to the most important ones simplifies interpretation and multiple testing (Krzywinski & Altman, 2015). Additionally, it prevents overfitted models, which have poor predictions despite their good fit (Krzywinski & Altman, 2015). Also, in social and behavioural studies, the model fit statistics (R-Squared values) tend to be small; because it is impossible to include all possible predictors of an outcome in a model. Cohen suggested (1988) R-Squared values of 0.02, 0.13, and 0.26 for small, medium, and large model fit. Our models had R-Squared values ranging from 0.086 to 0.190, showing a good model fit.

Addressing income-related health adversities through broader SES interventions and policies to reduce poverty is important but challenging. However, strengthening individual dispositional factors (e.g. SOC) related to better health could effectively improve low-income people's health and quality of life. This empowerment approach could include salutogenic interventions that improve coping skills. The Salutogenesis framework is a promising approach that emphasises the importance of "upstream" determinants and health-promoting strategies rather than being restricted to changing health behaviours (Antonovsky, 1979; Watt, 2007). By gaining a

better insight into the stressors they face and the GRRs available in their lives, these approaches help people, vulnerable groups, and communities find the appropriate GRRs and empower them to manage the socioeconomic factors that influence their health (Super et al., 2016; Watt, 2007). The majority of the salutogenic interventions (85%) reported positive findings regarding health outcomes (Álvarez et al., 2021). The interventions included: (i) group interventions (comprising health education programs and a variety of psychotherapies, such as "Cognitive Behavioural Therapy, Psychodynamic, Holistic, and Community"); (ii) mixed interventions (comprising a combination of approaches/actions at both the individual and group levels); (iii) intersectoral interventions (implementing interventions both in the community and in the environment with an emphasis on self-care programs, health behaviour approaches, and social participation, among others) (Álvarez et al., 2021). The implementation of these approaches can be achieved through large-scale health promotion programs similar to the WHO healthy city project (easy and free access to psychological services and mental health promotion centres) for vulnerable groups.

With easier application in large-scale population-based studies, Lundberg's short three-item SOC (Lundberg & Peck, 1995) was validated and verified in different settings, with significant predictive validity (Lundberg, 1997; Surtees et al., 2003). The relationship of SOC-3 with other variables was similar to Antonovsky's report using SOC-29 (Antonovsky, 1993; Lundberg & Peck, 1995; Surtees et al., 2003). No "dramatic" difference in the corrected reliability correlations between SOC-3 and SOC-29 was indicated, showing that low reliability is actually a problem for the main instrument (Schumann et al., 2003). The shortest form of SOC (SOC-3) eases its utilisation in large-scale population-based studies. Thus, it will help the assessment of Antonovsky's suggested model (Antonovsky, 1987) for different health outcomes.

The strengths of this study comprised: 1-using validated psychometric measures for oral and general health and SOC, 2-using a large South Australian representative sample, 3-analyses based on four multivariate models to assess the persistent effects and modifications among them, and 4- using two outcome variables to compare the models for any consistent patterns across oral and general health. The low response rate may be considered a limitation. However, according to the average survey response rates for over 30 years, our study's response rate was in line with other large surveys (which consistently were below 50%) (Baruch & Holtom, 2008). On the other hand, DCOHS participants were selected randomly from the Electoral Roll, an extensive comprehensive sampling frame. Comparison of the final study sample (n = 3,786) with general South Australian population data found similar composition with slight differences in the younger and older age groups (probably due to different categorisation) and place of birth. Recent comparisons against population data confirmed that DCOHS is generally representative of the South Australian population (Song et al., 2020a, b). Additionally, due to the possibility of response bias, DCOHS was also compared with the final sample and participants with missing responses. The characteristics of the final sample and those excluded due to missing responses were highly representative of DCOHS. The final sample (n = 3,786) provided a large dataset (highly representative of the DCOHS (n = 4,494)) despite a slight reduction in sample size because of missing answers to the items of SOC, income, and both outcome variables. Also, the normality of

the data was checked and based on benchmark literature for large sample sizes, outcome variables' kurtosis and skewness indicated adequate normality (Kim, 2013). However, the analysis was repeated (as suggested by previous research (Kim, 2013)) using the transformed outcome variables (log) to correct for skewness (if applicable) and the results were consistent with those of the original data.

Finally, social desirability should be considered when using self-report measures. Social desirability is when respondents alter or bias their responses to appear socially desirable (Paulhus, 1991), resulting in skewed findings. Nevertheless, respondents' interpretation and understanding of their health (i.e., subjective health) strongly affect their health-related behaviours (Lee et al., 2019) and quality of life (Elran-Barak et al., 2019). Besides, as noted above, we used a large and state-representative sample with randomly selected participants and valid self-reported measures. Also, in DCOHS, the participants' responses remained anonymous and confidential, reducing the fear of judgment and concerns about social expectations.

Conclusion

Our findings suggested that strong SOC modified the association between low-income and OHRQoL and HRQoL in a representative sample of South Australian adults. Strong SOC was associated with better OHRQoL and HRQoL among low-income respondents. Also, this study highlighted the main effects and interactions between SOC and income on OHRQoL and HRQoL. This study presents promising findings on the possibility of reducing income-related health disparities, which will contribute to future health services planning and policy-making. Taken together, these findings suggest the importance of strengthening SOC at a population level, specifically for low-income people as the vulnerable groups, which could improve their OHRQoL and HRQoL. Further, population-based studies are needed to evaluate whether SOC modifies the effect of other SES components (such as social support, education, and employment) on health outcomes.

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Author Contribution M.Z. and D.B. conceived the idea, designed the model and the computational framework. M.Z. developed the study, analysed the data and wrote the manuscript with D.B.'s input. D.B. verified the analysis and has supervised the work. S.C., L.L and L.J. contributed to the writing and editing and critically reviewed the manuscript. All authors have discussed the results and contributed to the final manuscript.

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Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request. The data are not publicly available due to privacy or ethical restrictions.

Declarations

Ethics Approval Approval was granted by the Human Research Ethics Committee of the University of Adelaide (H-288–2011). This study was performed in line with the principles of the Declaration of Helsinki.

Consent to Participate The participants' information for this study remained confidential. Also, the participant's identity was protected through the reporting of results in aggregate form. Informed consent from all participants included in the study was obtained through the questionnaire.

Consent to Publish Respondents' participation in this study was voluntary and confidential. Consent for publication was provided through the questionnaire by respondents.

Competing Interests The authors have no competing interests to declare that are relevant to the content of this article.

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