

RESEARCH ARTICLE

The longer you stay, the bigger you get? Evidence from an Australian longitudinal study

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ABSTRACT Using data on 11,726 respondents from waves 6 (2006) to 21 (2021) of the Household Income and Labour Dynamics in Australia survey and multi-level group mean-centred logistic regression models, we investigated differences in obesity levels among immigrants from English-speaking and non-English-speaking countries relative to those among non-immigrants in Australia, and how those differences changed with duration of residence and age at arrival. When duration of residence was not included, we found significantly smaller odds of being obese among immigrants from both English-speaking and non-English-speaking countries than among non-immigrants. When duration of residence was included, immigrants from non-English-speaking countries had an obesity advantage compared to non-immigrants with up to 19 years of residence in Australia. However, they lost their obesity advantage after 20 years of residence. In contrast, we found no significant difference in the level of obesity between immigrants from English-speaking countries and non-immigrants by duration of residence. We did not find a substantial modification in the association between nativity status and obesity by age at arrival for either non-English-speaking or English-speaking immigrants. In summary, longer residence in the host country was associated with unhealthy weight gain, especially among immigrants from non-English-speaking countries. As the proportion of immigrants from these countries increases in Australia, our findings highlight the need for tailored health and healthcare utilisation services that consider the varying obesity risk profiles of different immigrant groups over time.

KEYWORDS Nativity • Longitudinal studies • Obesity • Australia

Introduction

Obesity, defined by the WHO as having a body mass index (BMI) of 30 or higher (World Health Organization, 1995), is one of the five leading global risks for mortality

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(Murray et al., 2020). It is a major determinant of cardiovascular diseases, diabetes and certain types of cancer (Hruby et al., 2016), and it poses a significant international public health concern due to its substantial social, health and economic costs. There has been an unprecedented increase in overweight and obesity rates all over the globe, including in Australia (Australian Bureau of Statistics, 2018b; World Obesity Federation, 2023). For example, the prevalence of overweight and obesity among Australians aged 18 years and over increased from 56% in 1995 to 67% in 2017–18. This increase was mainly driven by the proportion of people in the obese category, which rose from 19% in 1995 to 28% in 2014 and 31% in 2018 (Australian Bureau of Statistics, 2018a, b).

In general, foreign-born (FB) individuals appear to have lower body mass index (BMI) and are less likely to be overweight or obese upon arrival in the host country than native-born (NB) people (for a review, see Goulão et al., 2015; Murphy et al., 2017; Oza-Frank and Cunningham, 2010). However, an increase in obesity levels with increased duration of residence (DoR) in the host country has been noted among various immigrant groups in the USA (e.g. Antecol and Bedard, 2006; Bates et al., 2008; Commodore-Mensah et al., 2016; Goel et al., 2004; Gordon-Larsen et al., 2003; Himmelgreen et al., 2004; Kaplan et al., 2004; Kaushal, 2009; Oza-Frank and Narayan, 2010; Sanchez-Vaznaugh et al., 2008), Canada (e.g. McDonald and Kennedy, 2005; Setia et al., 2009), Australia (e.g. Hauck et al., 2011; Menigoz et al., 2018; Menigoz et al., 2016), Germany (e.g. Sander, 2008) and Norway (e.g. Gele and Mbalilaki, 2013). Past research has also shown that immigrants who arrive at younger ages are at higher risk of being overweight or obese with increasing length of residence than immigrants who arrive at older ages (Kaushal, 2009; Oza-Frank and Narayan, 2010a; Roshania et al., 2008). However, the heterogeneity in weight and obesity rates among immigrant populations upon arrival and over time as a result of actual differences between groups, such as gender, age at the time of migration and duration of residency in the host country, have also been acknowledged and documented (e.g. Antecol and Bedard, 2006; Delavari et al., 2013b; Gordon-Larsen et al., 2003; Himmelgreen et al., 2004; Kaushal, 2009; Murphy et al., 2017; Sanchez-Vaznaugh et al., 2008).

Menigoz et al. (2016, 2018) explored the influence of origin (i.e. region of birth), duration of residence and age at arrival on BMI and obesity patterns, but did not account for variations in body weight due to differing durations of residence and ages at arrival among immigrants from the same region. Hauck et al. (2011) studied the influence of generational status on BMI, yet this approach confounded the effects of acculturation in the different environments (i.e. country of origin for the first generation and Australia for the second generation) experienced by first- and second-generation immigrants. Exposure to different environments will likely result in different habits and views associated with factors influencing body weight. Our paper advances this body of Australian work by examining the influence of duration of stay and age of arrival on obesity patterns among immigrants from different origins and comparing these patterns with those of non-immigrants. This fills a critical gap not addressed by previous studies.

A significant limitation in much of the previously published research concerning immigration and obesity is that, until recently, a substantial portion of both international and national research evidence relied on single or repeated cross-sectional datasets

(e.g. Antecol and Bedard, 2006; Gele and Mbalilaki, 2013; Hauck et al., 2011; Menigoz et al., 2016; Sanchez-Vaznaugh et al., 2008). These datasets offer only snapshots in time, showcasing differences in health outcomes between immigrants and non-immigrants. However, processes such as immigration are dynamic, and several years may need to pass before their full impact on health can be observed. Consequently, assessing the effect of immigration on obesity becomes more challenging when relying solely on cross-sectional data. Additionally, estimating the effects of immigration introduces additional complexities because exposure to immigration is not a random occurrence. Immigrants and non-immigrants may differ significantly due to self-selection and other underlying processes. For example, immigration to a new country initiates a labour market adjustment process that non-immigrant workers do not undergo. This adjustment process can introduce confounding factors that bias the estimation of the exposure-outcome relationship (Rothman et al., 2008). Likewise, many factors influencing obesity, such as diet and exercise, can change over time for individuals, and particularly for immigrants as they assimilate to the host culture (Delavari et al., 2013b). Failing to account for these individual-level changes can result in biased estimates. In contrast, Setia et al. (2009) employed longitudinal data and mixed-effects models to compare 12-year changes in BMI among White and non-White immigrants with those among Canadian-born individuals. However, Setia et al. (2009) did not measure the changes in BMI over time for various immigrant groups relative to those for Canadian-born individuals. Without this crucial comparison, it becomes difficult to attribute the distinct trajectories in obesity among immigrants solely to their immigrant status.

Furthermore, it is important to note that many longitudinal studies have employed balanced panels, often overlooking potential biases stemming from panel attrition (Chiswick et al., 2008; De Maio and Kemp, 2010; Kim et al., 2013; Setia et al., 2011). Additionally, the pathways and mechanisms responsible for changes in obesity over time remain poorly understood, limiting the development of effective policies aimed at improving the health of all individuals, including immigrants.

Such methodological and theoretical considerations motivated this paper. Longitudinal data can be used to help identify differences in causal relationships between obesity and potential determinants for FB and NB people. Longitudinal data are preferred over cross-sectional data, even when the latter include information on age and time of arrival, due to several key advantages. First, observing the same individuals at multiple points in time allows for a more detailed investigation of causal relationships. It also accounts for individual differences, clarifying how unique traits influence outcomes, which is crucial for designing effective interventions. Furthermore, using longitudinal data reduces bias and confounding by controlling for these individual differences, isolating effects within participants. Finally, longitudinal data can be used to track changes in individuals' obesity status over time, providing a dynamic view of how immigration affects health outcomes. This is crucial for understanding the temporal relationship between immigration and obesity, which cross-sectional data cannot capture.

The present study builds upon the methodological framework and dataset of Jatrana et al. (2018) to explore a distinct research question: namely that of the relationship between nativity, duration of residence and obesity. Our study advances the immigrant health literature by (i) using a nationally representative longitudinal dataset, the Household, Income

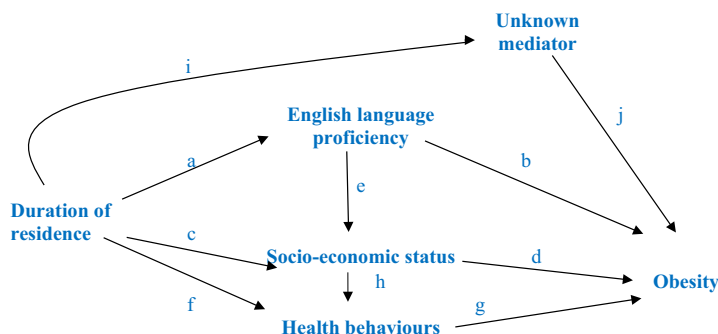
and Labour Dynamics in Australia (HILDA), with 16 years of follow-up data to provide estimates of the nativity/DoR gap in obesity (i.e. nativity/DoR effects are measured relative to native Australians); (ii) providing a baseline for future fixed effects obesity analyses of HILDA data using the same method as the one used in this paper; and (iii) recognising that confounding is not an issue for nativity/DoR exposures, as no factor has a causal influence on an individual's nativity status since that status was determined at birth. However, nativity status can causally influence a range of socio-economic and cultural factors (see below). Similarly, duration of residence is fixed in this study at the first wave, meaning that it cannot be causally influenced by other variables that occur at a later time. Furthermore, we (iv) reduce bias from loss to follow-up by using the unbalanced panel and (v) explore some possible mechanisms through which obesity changes over time post-immigration.

Using so-called hybrid regression models (explained in the next section) that separate within-person and between-person variations over time, we examine the associations of nativity (NB and immigrants from ES (English-speaking) and NES (non-English-speaking) countries of origin) and DoR with the prevalence of obesity, and whether the association between nativity/DoR and obesity prevalence is modified over time by age at arrival (AA) in Australia. We also examine the mediating roles of English language proficiency, socio-economic status (SES) and health behaviour factors in the association between nativity/DoR and obesity.

Examining differences in obesity levels between immigrants and Australian-born individuals, and how these differences evolve over time, is a crucial policy concern in Australia, which has one of the world's highest proportions of immigrants in the population (McAuliffe and Triandafyllidou, 2021). Almost 30% of the total population in Australia were born overseas, and net overseas immigration is a significant driver of population growth (Australian Bureau of Statistics, 2023a, b). Additionally, almost half of Australians have at least one parent born overseas (Australian Bureau of Statistics, 2022). As the number of immigrants in Australia continues to rise, it has become increasingly important to comprehend the variations in health risk factors, such as BMI and obesity, between FB and NB individuals. Understanding how these factors change over time is essential, as it aids in the identification of vulnerable immigrant populations. Immigrant health has gained additional significance due to Australia's evolving immigration program, which now focuses on meeting the labour market needs of the Australian economy (Parliament of Australia, 2021). It is worth noting that good health plays a pivotal role in fully realising the social and economic potential of immigrants. Moreover, under the Australian point-based immigration system, applicants earn points based on their age and English language proficiency (Mence et al., 2017). Consequently, it is important to gain a more comprehensive understanding of how AA and English language proficiency are connected with obesity prevalence, nativity and DoR.

Migration and obesity: Explanatory mechanisms

The BMI of immigrants is influenced by many factors as their host country DoR increases. While many researchers attribute changes in BMI and obesity levels to acculturation

Figure 1 Directed acyclic graph of the relationship between duration of residence and obesity

Source: Adapted from Jatrana et al. (2018) with permission from Springer Nature.

(Delavari et al., 2013b), the reality is more complex. The interplay of genetic predisposition, physiological and epigenetic changes, lifestyle factors such as physical activity and the pressures of assimilation all contribute to these changes. Additionally, public attitudes towards immigrants, alongside individual factors like English language proficiency, stress levels and socio-economic status, further shape these health outcomes (Murphy et al., 2017). This study adapts and extends the conceptual framework of Jatrana et al. (2018), applying its focus on social, economic and behavioural factors to examine obesity-related outcomes within the broader context of health inequalities between FB and NB individuals. We use DoR as a proxy for acculturation and examine how English language proficiency, SES and health behaviours mediate the relationship between nativity, country of birth, DoR and obesity.

Figure 1 presents a conceptual framework for the causal relationship between acculturation/DoR and obesity, structured as a directed acyclic graph (DAG). DAGs serve as powerful tools for visualising hypothesised causal relationships among variables (Greenland et al., 1999; Gunasekara et al., 2014; Van der Weele and Robins, 2007). In this framework, which is the foundation of our modelling decisions, DoR is hypothesised to influence obesity through four primary causal pathways.

1. Language proficiency pathway: The first set of DoR-obesity paths are mediated by English language proficiency, i.e. $a + b$, $a + e + d$, $a + e + h + g$, using the path labels from Figure 1.
2. Socio-economic pathway: The second set of paths are mediated by socio-economic factors such as income, employment and education, i.e. $c + d$, $c + h + g$.
3. Health behaviour pathway: The third path is mediated by health behaviours, i.e. $f + g$.
4. Unmeasured mediators: The fourth pathway involves unmeasured factors such as discrimination and racism, i.e. $i + j$. To simplify the DAG, the “unmeasured mediator” node includes the null mediator, such that the direct effect of DoR on obesity is a subset of $i + j$.

The DAG explicitly assumes no confounding between DoR and health outcomes, since no variable has causal arrows that point to both DoR and obesity. This structured approach clarifies the pathways through which acculturation and duration of residence may shape obesity trends, guiding our analytical framework.

The English language proficiency pathway

The pathway through which language proficiency is associated with obesity is complex and operates through several mechanisms (Akresh, 2007; Himmelgreen et al., 2004). Language may affect obesity through its association with psychological stress (Dallman et al., 2003). For example, among both Latinos and Asians, English proficiency has been associated with increased psychological distress (Zhang et al., 2012), and poorer mental health is, in turn, associated with increased BMI (Rosmond et al., 1996). Lack of proficiency in the language can affect obesity through other pathways, such as discrimination, lack of access to jobs or low health literacy. For example, the inability to speak the host country's language may invite discrimination (Yoo et al., 2009), which, in turn, has been shown to be associated with increased body mass index (Hunte and Williams, 2009). Similarly, proficiency in the language of the receiving country is a necessary resource that enhances an immigrant's ability to navigate the host culture (Gee et al., 2010). Alternatively, low English proficiency may affect the relationship between nativity and obesity via SES (employment, income), as language proficiency is a prerequisite for labour market and educational attainment (Gee et al., 2010). English proficiency could also be a marker for exposure to an unhealthy diet and lifestyle (Gee et al., 2010). Having proficient language skills can enhance immigrants' access to health information, healthcare services and social integration, and may thus lead to better health literacy and healthier behaviours (Nutbeam, 2000; Paasche-Orlow and Wolf, 2007). Studies have shown that immigrants with limited language proficiency tend to have poorer health outcomes (Sentell and Braun, 2012) and higher obesity rates because they face barriers in accessing preventive care and health education (Wang et al., 2016).

The SES pathway

Socio-economic status is a well-documented determinant of health. The relationship between SES and obesity (path c + d) is complex (Dinsa et al., 2012; Kinge et al., 2015; McLaren, 2007; Pampel et al., 2012) and is mediated by various factors, including knowledge of disease aetiology and causes of obesity, as well as barriers related to having the money, time and opportunities to maintain a healthy diet (Murphy et al., 2017) and to engage in physical activity within local neighbourhoods (Albrecht et al., 2015). Individuals with higher SES typically have better access to resources, healthier food options and environments conducive to physical activity (Adler and Newman, 2002). Conversely, those with lower SES tend to have higher stress levels, limited access to healthcare and unhealthy dietary patterns, which, in turn, contribute to higher obesity rates (Drewnowski and Darmon, 2005; Puhl and Heuer, 2010). Economic drivers can influence food choices and associated obesity rates, with migrant populations often purchasing low-cost, readily

available, high-calorie food (Alidu and Grunfeld, 2018). Thus, SES may influence the association between duration of residence and obesity by shaping health behaviours, as represented by the path $c + h + g$.

The health behaviour pathway

Health behaviours, such as dietary habits, physical activity and smoking, play pivotal roles in mediating the relationship between DoR and obesity. As immigrants adapt to their host country, these behaviours often shift due to acculturation stress, changes in the food environment and lifestyle adjustments (Oza-Frank and Narayan, 2010a). Acculturation theories suggest that over time, immigrants may replace their healthier traditional diets with processed and fast foods, reduce their physical activity and adopt other high-risk behaviours. This gradual transition can lead to the erosion of any initial health advantage, ultimately aligning immigrant obesity rates with those of the host population (Abraído-Lanza et al., 2005; Gerber et al., 2012; Lara et al., 2005). Over time, these shifts in behaviour contribute significantly to changes in obesity levels (Hyman, 2001). While acculturation theory provides a useful framework for understanding health disparities between immigrants and native-born populations, it oversimplifies the intricate mechanisms driving these changes. A key limitation is its inherent assumption that immigrants' countries of origin always promote healthier behaviours, and that migration to Western nations inevitably leads to negative behavioural changes. However, this perspective requires careful scrutiny, as the relationship between migration, health behaviours and obesity is far more nuanced than simply indicating a linear decline in well-being. We revisit this critical issue later in the discussion.

The relationship between DoR and obesity unfolds through distinct and simultaneous processes that are shaped by factors such as English language proficiency, SES and health behaviours. These pathways reveal both positive and negative health trajectories for immigrants, highlighting the complex and dynamic nature of immigrant health trajectories, and demonstrating that acculturation is neither universally beneficial nor detrimental, but rather a multifaceted process with both risks and opportunities.

Data and method

Data

This study used data from HILDA, a longitudinal survey of Australian residents occupying private dwellings. The HILDA survey began in 2001 with a large and nationally representative sample of 7682 households that included at least one eligible member aged 15 years or older. Individuals aged 15 years and over were interviewed in each of the subsequent waves, and some non-respondents in wave 1 were successfully interviewed and followed in later waves. Additionally, new individuals entering the sample as a result of structural changes in the households were followed in all subsequent waves.

Although HILDA collected information on waist circumference, this study did not use it as the data were only collected in waves 13, 17 and 21 (Summerfield et al., 2021). Instead, this study used BMI data, which were available from wave 6 (2006) to wave 21 (2021). Information on height and weight was obtained from each respondent as a part of the self-completion questionnaire. This information was used to calculate BMI using the formula $BMI = \text{weight}/\text{height}^2$, based on the World Health Organisation's definition. Analyses were conducted on an unbalanced panel of individuals who responded in wave 6 and in at least one wave between waves 7 (2007) and 21 (2021). The flow of study respondents between waves is depicted in Figure S.1 in the Supplementary material (available online at <https://doi.org/10.1553/p-7gcp-6eab>). A total of 12,902 respondents with non-missing information on country of birth (CoB) responded in wave 6, with 11,726 responding at least once between waves 7 and 21. Altogether, there were 156,195 responses from these 11,726 respondents between waves 6 and 21. The average number of times a survey member responded out of the 16 waves (6 to 21) was similar among NB people (13.35) and FB people from ES and NES countries (13.31 and 13.14, respectively, in Figure S.1 of the Supplementary material).

In HILDA, attrition from wave 6 to wave 21 was higher for FB respondents from English-speaking countries (43.8%) and NES countries (42.6%) than for NB respondents (39.7%). Furthermore, the number of responses from participants over waves 6 to 21 was associated with obesity. However, statistical associations are agnostic about the direction of causality, and causal reasoning had to be used to infer this information. As previously noted, there could be no paths entering CoB, DoR or age from any measured quantity, including the number of responses. On the other hand, there could be a causal arrow from the number of responses into obesity, since the former was a measure of how long a respondent had lived in Australia. This suggests that the number of responses might have mediated the path from CoB to obesity, as well as the path from DoR and AA to obesity. Controlling for the number of responses blocked this path, allowing for the analysis to focus on the effect of the remaining paths. Using an unbalanced panel provided a larger sample size and enhanced precision in the parameter estimates. Therefore, we decided to use an unbalanced panel and to control for the number of responses in our analyses.

The main outcome variable, obesity, was measured using BMI as defined above. An individual was classified as obese if their BMI exceeded 30 (World Health Organization, 1995). This threshold is based on the correlation between chronic disease, mortality and BMI, and is widely adopted internationally (WHO Consultation, 2000). BMI has been criticised as a poor measure of body composition due to its inability to differentiate lean and fat mass (Romero-Corral et al., 2010), potentially leading to misleading diagnoses of obesity and predictions of health risks associated with excess body weight among athletes (Provencher et al., 2018), older people (Chang et al., 2012) or people of Asian background (Jih et al., 2014). However, it remains a useful tool for identifying individuals and groups at risk of morbidity and mortality, and for developing interventions at the community level (WHO Consultation, 2000). Furthermore, a clear relationship between obesity and increased mortality and morbidity has been established (Abdelaal et al., 2017). Age at wave 6 (henceforth age) and sex were the main time-invariant control variables. English language proficiency, household equivalised income, current marital status, level of

education and employment status were the time-varying control variables used in the analysis. Since they may also mediate the relation between immigrant status and obesity, models that included and excluded these variables were fitted. Temporal effects were accounted for by including dummy variables for waves 7–21. Physical activity, smoking and drinking were the health behaviour variables used in the regression analysis to test the mediating role of such variables in the association between immigrant status and obesity.

Nativity and DoR in Australia were the main exposure variables considered in this study. Nativity status was categorised as NB, FB from ES countries and FB from NES countries. Immigrants from the United Kingdom (65.8%), the United States of America (3.5%), New Zealand (20.3%), Canada (1.9%), Ireland (3.0%) and South Africa (5.4%) made up the ES group, and other immigrants comprised the NES group. Similar categorisations of nativity status have been used by others in the immigrant health literature (e.g. Setia et al., 2009, 2012).

DoR was based on the question: “In what year did you first come to Australia to live for 6 months or more (even if you have spent time abroad since)?” It was then calculated as the year of survey minus the year of arrival for each immigrant. DoR was categorised as less than 10 years, 10–19 years and greater than or equal to 20 years in Australia, and combined with the nativity status variable described above. The main exposure variable for the DoR analysis therefore had the following levels: “ES: DoR < 10 years”, “ES: DoR 10–19 years”, “ES: DoR $\geq$ 20 years”, “NES: DoR < 10 years”, “NES: DoR 10–19 years”, “NES: DoR $\geq$ 20 years” and “NB”. AA was grouped into two categories: less than 25 years and greater than or equal to 25 years. The cut points for DoR were chosen to: (1) reflect the empirical evidence suggesting that after 10 years an initial health advantage is lost (Gee et al., 2004); (2) ensure sufficient statistical power and enable reasonable estimates of uncertainty; and (3) allow for the adoption of the host country lifestyle and diet to affect obesity. The cut point for AA (25 years) was chosen to differentiate between early and late exposures to the host country’s culture while ensuring sufficient statistical power. To test the sensitivity of our results to the BMI cut points used, we performed additional analyses for obesity, defined as BMI $\geq$ 27 and BMI $\geq$ 33. Sensitivity tests of our AA and DoR categorisations were also done.

Statistical methods

The statistical approach used in this study closely followed the methodology outlined in Jatrana et al. (2018), including the selection of covariates and modelling strategy, with adaptations made to suit the obesity-related outcomes examined here. The analysis was done in two stages. First, we focused on a descriptive analysis of the observed trends in obesity, separately by nativity and DoR, to see whether there were differences in the levels of obesity by CoB and DoR. Second, we used “hybrid” logistic regression models (Allison, 2005), known as multi-level group-mean-centred logistic regression models in the multi-level modelling literature, to investigate the longitudinal association between nativity, DoR, AA and levels of obesity.

Four models were used. In Model I, age, sex, wave (year) and number of times a person responded between waves 6 and 21 were the variables included in the model, along with the main exposure variables nativity/CoB (Table 2), nativity and DoR (Table 3), nativity and AA (Table 4) and DoR and AA (Table 5). Model II added English language proficiency to the covariates of Model I. In Model III, in addition to the variables in Model II, level of education, marital status, employment status and household equivalised income were added. Model IV also added health behaviour variables to the Model III variables. Thus, the mediating roles of English language proficiency, SES variables and health behaviour were tested by including them as covariates with the variables of Model I (Hafeman, 2009).

The hybrid logistic models used in this study have the following form:

$$\text{logit}(P_{it}) = \alpha_i + \beta_1(X_{it} - \bar{X}_{i.}) + \beta_2\bar{X}_{i.} + \gamma Z_i + \varepsilon_{it} \quad (1)$$

where P_{it} is the probability that the i th respondent ($i = 1 \dots n$, where n is sample size) in the t th wave ($t = 6$ to 21) is obese. In the above regression models α_i represents a random effect to account for clustering at the individual level, $X_{it} - \bar{X}_{i.}$ represents within person variability of covariate X_{it} , $\bar{X}_{i.}$ is the corresponding person-level mean (over time) of X_{it} , Z_i is a vector of time-invariant covariates, and β_1 , β_2 and γ are coefficient vectors to be estimated. Note that wave (time) effects are included in X_{it} and the terms $\bar{X}_{i.}$ and Z_i only change between people. All analyses were done by using Statistical Analysis Software (SAS) package version 9.3. In particular, we used the Glimmix procedure for regression analyses. To guard against possible inconsistencies due to the choice of covariance structure, we obtained robust standard errors for the parameters by using a sandwich estimator, i.e. specifying the “empirical = MBN” option in Glimmix (Diggle, 2002; Huber, 1967; Liang and Zeger, 1986; White, 1980). The design-adjusted sandwich estimator used in this study is less biased than the classical sandwich estimator (Morel, 1989; Morel et al., 2003).

We received institutional review exemption from the “X” Human Research Ethics Committee, reference number “A”. Respondents in the HILDA survey do not give written consent, but consent is implied when they agree to be interviewed. When children (15–17 years old) are interviewed, verbal consent is given by their parent/guardian (or written consent is provided if the children are away at a boarding school). Clinical records are not used in the HILDA study.

Results

Characteristics of the study respondents at baseline (wave 6)

A total of 11,726 respondents with non-missing information on CoB responded in wave 6 and at least once more between waves 7 and 21. Of them, 9256 respondents (78.9%) were NB, 1128 (9.6%) were born in ES countries, and the remaining 1342 (11.4%) were born in NES countries (Table 1). There were more females (53.1%) in the sample than males (46.9%). Most of the FB respondents (64.4%) had been in Australia for more than 20 years.

Table 1 Baseline (wave 6) characteristics of the study respondents by country of birth (CoB)

Factor	Nativity					p-value	
	All	Only FB	Australia	ES countries	NES countries		
<i>Gender</i>							
Male	5503 (46.9%)	1159 (46.9%)	4344 (46.9%)	558 (49.5%)	601 (44.8%)	0.067	
Female	6223 (53.1%)	1311 (53.1%)	4912 (53.1%)	570 (50.5%)	741 (55.2%)		
<i>Age group</i>							
15–29 years	2976 (25.4%)	308 (12.5%)	2668 (28.8%)	88 (7.8%)	220 (16.4%)	<0.001	
30–44 years	3313 (28.3%)	662 (26.8%)	2651 (28.6%)	304 (27.0%)	358 (26.7%)		
45–59 years	2975 (25.4%)	800 (32.4%)	2175 (23.5%)	384 (34.0%)	416 (31.0%)		
>= 60 years	2462 (21.0%)	700 (28.3%)	1762 (19.0%)	352 (31.2%)	348 (25.9%)		
<i>Duration of residence</i>							
Australia	9256 (79.0%)		9256 (100.0%)	0 (0.0%)	0 (0.0%)	<0.001	
< 10 years	268 (2.3%)	268 (10.9%)	0 (0.0%)	98 (8.7%)	170 (12.7%)		
10–19 years	610 (5.2%)	610 (24.7%)	0 (0.0%)	185 (16.4%)	425 (31.7%)		
>= 20 years	1589 (13.6%)	1589 (64.4%)	0 (0.0%)	843 (74.9%)	746 (55.6%)		
*Missing values	3 (<1%)		0 (0.0%)	2 (0.2%)	1 (0.1%)	<0.001	
<i>English proficiency</i>							
Proficient	10585 (90.3%)	1566 (63.4%)	9019 (97.4%)	1104 (97.9%)	462 (34.4%)		
Good	1014 (8.6%)	777 (31.5%)	237 (2.6%)	24 (2.1%)	753 (56.1%)		
Not good	127 (1.1%)	127 (5.1%)	0 (0.0%)	0 (0.0%)	127 (9.5%)		
<i>(table continues)</i>							

(table continues)

Table 1 (continued)

Factor	Nativity				p-value
	All	Only FB	Australia	ES countries	NES countries
Level of education					
< 12 years of schooling	4322 (36.9%)	721 (29.2%)	3601 (38.9%)	340 (30.1%)	381 (28.4%)
12 years of schooling	1736 (14.8%)	391 (15.8%)	1345 (14.5%)	143 (12.7%)	248 (18.5%)
Diploma/certificate	3233 (27.6%)	698 (28.3%)	2535 (27.4%)	361 (32.0%)	337 (25.1%)
University education	2431 (20.7%)	660 (26.7%)	1771 (19.1%)	284 (25.2%)	376 (28.0%)
*Missing values	4 (<1%)		4 (<1%)	0 (0.0%)	0 (0.0%)
Current marital status					
Married/in de facto relationship	7284 (62.1%)	1759 (71.2%)	5525 (59.7%)	819 (72.6%)	940 (70.0%)
Separated/widowed	1650 (14.1%)	406 (16.4%)	1244 (13.4%)	196 (17.4%)	210 (15.6%)
Never married/in de facto relationship	2792 (23.8%)	305 (12.3%)	2487 (26.9%)	113 (10.0%)	192 (14.3%)
Employment status					
Full-time employed	5198 (65.5%)	1049 (68.2%)	4149 (64.8%)	517 (70.7%)	532 (65.9%)
Part-time employed	2411 (30.4%)	431 (28.0%)	1980 (30.9%)	190 (26.0%)	241 (29.9%)
Unemployed	330 (4.2%)	58 (3.8%)	272 (4.2%)	24 (3.3%)	34 (4.2%)
*Missing values	3787 (32.3%)	932 (37.7%)	2855 (30.8%)	397 (35.2%)	535 (39.9%)
Equivalised income					
<= 20,000	2515 (21.4%)	624 (25.3%)	1891 (20.4%)	210 (18.6%)	414 (30.8%)
(20,000–40,000)	5297 (45.2%)	1033 (41.8%)	4264 (46.1%)	481 (42.6%)	552 (41.1%)
(40,000–60,000)	2551 (21.8%)	506 (20.5%)	2045 (22.1%)	257 (22.8%)	249 (18.6%)
> 60,000	1363 (11.6%)	307 (12.4%)	1056 (11.4%)	180 (16.0%)	127 (9.5%)

(table continues)

Table 1 (continued)

Factor	All	Nativity			p-value
		Australia	ES countries	NES countries	
Smoking					<0.001
Never smoked	5513 (52.1%)	4440 (52.7%)	438 (41.7%)	635 (57.0%)	
Former smoker	2874 (27.1%)	2155 (25.6%)	417 (39.7%)	302 (27.1%)	
Current smoker	2201 (20.8%)	1828 (21.7%)	195 (18.6%)	178 (16.0%)	
*Missing values	1138 (9.7%)	833 (9.0%)	78 (6.9%)	227 (16.9%)	
Drinking					<0.001
Never drunk	1116 (10.5%)	827 (9.8%)	40 (3.8%)	249 (22.3%)	
Former drinker	691 (6.5%)	550 (6.5%)	79 (7.5%)	62 (5.6%)	
Current drinker	8796 (83.0%)	7059 (83.7%)	933 (88.7%)	804 (72.1%)	
*Missing values	1123 (9.6%)	820 (8.9%)	76 (6.7%)	227 (16.9%)	
Physical activity					<0.001
< 3 times per week	4213 (39.5%)	3361 (39.6%)	381 (36.0%)	471 (41.9%)	
>= 3 times per week	5375 (50.4%)	4313 (50.9%)	565 (53.4%)	497 (44.2%)	
Not at all	1073 (10.1%)	805 (9.5%)	112 (10.6%)	156 (13.9%)	
*Missing values	1065 (9.1%)	777 (8.4%)	70 (6.2%)	218 (16.2%)	

(table continues)

Table 1 (continued)

Factor	All	Only FB	Nativity			p-value
			Australia	ES countries	NES countries	
Obesity status						0.004
Non-obese	8072 (79.1%)	1711 (81.2%)	6361 (78.6%)	816 (79.4%)	895 (82.9%)	
Obese	2127 (20.9%)	396 (18.8%)	1731 (21.4%)	212 (20.6%)	184 (17.1%)	
*Missing values	1527 (13.0%)	363 (14.7%)	1164 (12.6%)	100 (8.9%)	263 (19.6%)	
Total (n)	11,726	2,470	9,256	1,128	1,342	

Note: *Number of missing values, if any, alongside their percentage (with respect to total sample size n) are shown below each variable. Missing values were neither imputed nor included in any analysis, including in the bivariate analysis done in this table.

Percentage values for non-missing values were computed with respect to the column totals of non-missing values for each variable. For example, the proportion of obese respondents = $2127/(8072+2127) = 20.9\%$.

Chi-square tests were performed to estimate the significance of the bivariate associations between the covariates and the country of birth.

Country of birth (CoB) is categorised as NB (native-born), FB (foreign-born) from English-speaking (ES) countries and FB from non-English-speaking (NES) countries.

Roughly two-thirds of the FB from NES countries were not proficient in English. More NB (38.9%) than FB respondents (29.2%) had less than 12 years of schooling. Fewer NB people were married or in a de facto relationship (59.7%) than FB (71.2%) people. Similarly, 13.4% of the NB were either separated or widowed, compared with 16.4% of the FB. Similar proportions of the NB and FB were unemployed (4.2% and 3.8%, respectively). Fewer of the NB than the FB had equivalised incomes of less than \$20,000.

While 16.0% of FB respondents from NES countries were current smokers, the corresponding proportions for the FB from ES countries and the NB were 18.6% and 21.7%. Similarly, 72.1% of the FB from NES countries were current drinkers, compared to 88.7% of the FB from ES countries and 83.7% of the NB. In contrast, the share of respondents who reported engaging in sufficient physical activity was smaller among the FB from NES countries (44.2%) than among the FB from ES countries (53.4%) and the NB (50.9%). Around 21.4% of the NB, 20.6% of the FB from ES countries and 17.1% of the FB from NES countries were obese at wave 6 (Table 1).

Descriptive findings

Table S.1 (Supplementary material) shows the empirical obesity transition probabilities between successive waves used in this analysis: on average, 94.8% of people who were not obese at wave t remained not obese in wave $t + 1$, and 84.5% of people who were obese at wave t remained obese in wave $t + 1$. Approximately 5.2% of people moved from the not-obese to the obese category, and 15.2% moved from the obese to the not-obese category, suggesting that off-diagonal transitions were an important component of longitudinal obesity dynamics during the 16-year period of this study.

Figure 2(A) shows that FB people had significantly lower levels of obesity than NB people over the study period, with an increasing trend in the levels of obesity for both groups. However, FB people from NES countries had lower levels of obesity than FB people from ES countries (Figure 2(B)).

Figure 2(C), on the other hand, shows that, with the exception of FB people with DoR ≥ 20 years between about 2006 and 2010, FB people had significantly lower levels of obesity than NB people, irrespective of their DoR. The obesity advantage (relative to NB people) was smallest for FB people with DoR ≥ 20 years. For most of the study period obesity levels were not significantly different between the DoR < 10 and 10–19 groups, but were significantly lower than those for both NB people and FB people with DoR ≥ 20 years.

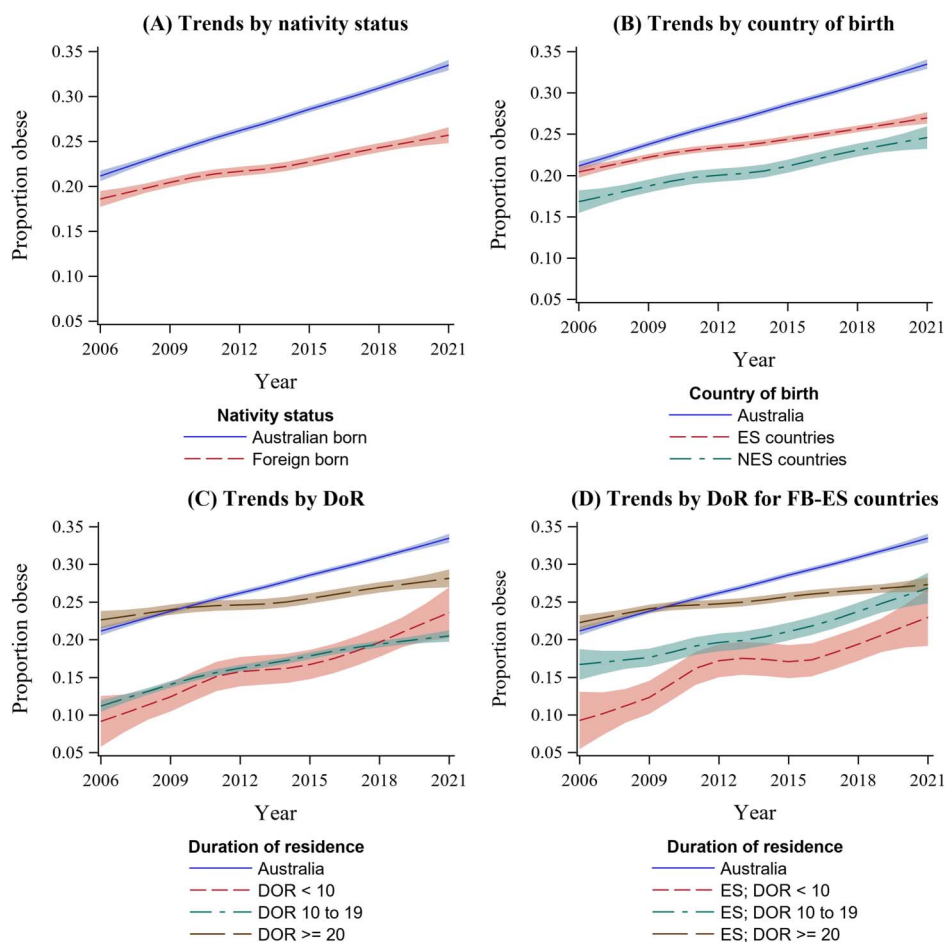
The picture was similar for FB people from NES countries (Figure 2(E)), except for one to two years around 2020, when the DoR 10–19 years group had significantly lower obesity levels than the DoR < 10 years group.

For FB people from ES countries (Figure 2(D)), a slightly different pattern was observed, as significantly lower levels of obesity (relative to NB people) were also found for both the DoR < 10 and DoR 10–19 years groups. However, obesity levels were significantly lower

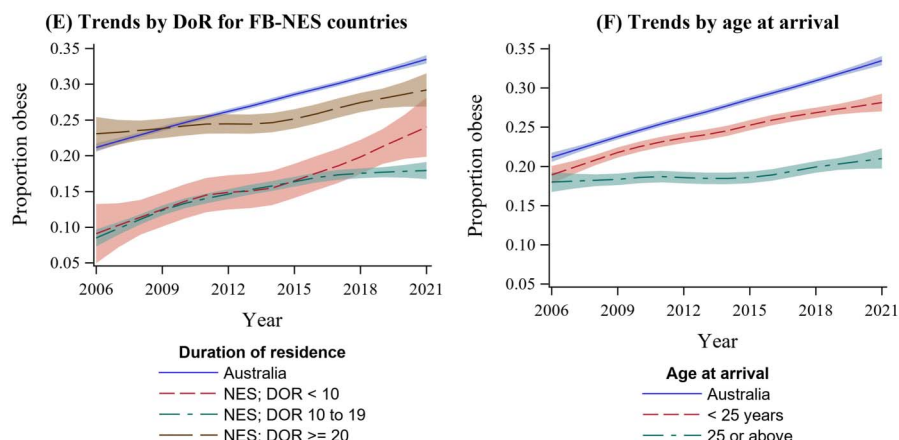
for the DoR < 10 years group, except around 2012 and 2021, when the difference between the DoR < 10 and DoR 10–19 years groups may not have been significant.

FB people from both ES and NES countries had lower levels of obesity relative to NB people irrespective of their AA. However, FB people from both ES and NES countries who arrived in Australia after age 25 had significantly lower levels of obesity than those who arrived before age 25 (Figure 2(F)).

Figure 2 Trends in obesity by calendar year by (A) nativity, (B) country of birth, (C) nativity combined with duration of residence (DoR) for all foreign-born (FB) individuals, (D) nativity combined with DoR for the FB from English-speaking (ES) countries, (E) nativity combined with DoR for the FB from non-English-speaking (NES) countries and (F) age at arrival



(figure continues)

Figure 2 (continued)

Notes: The coloured band around a line indicates a 95% confidence interval for the smoothed proportion of obese people. All these graphs and 95% CIs were produced using a common smoothing parameter of 0.5. Non-overlapping CIs indicate a significant difference between the trends for those years in which CIs do not overlap, such as in Figure 2(A), and for most years in both Figure 2(B) and Figure 2(F). Conversely, there is no significant difference between trends when CIs completely overlap, as in Figure 2(C) for FB people with DoR < 10 and DoR 10–19 years between 2006 and 2019, and in Figure 2(E) for NES people with DoR < 10 and DoR 10–19 years between 2006 and 2018. The significance of the differences between the trends is less clear when CIs partly overlap, as in Figure 2(D) for ES people with DoR < 10 and DoR 10–19 years around 2012 and 2021. The trends may or may not be significantly different, but without further testing it is not possible to say.

In summary, our descriptive analysis of obesity trends showed that: (1) FB people had lower levels of obesity than NB people; (2) levels of obesity increased with DoR such that after 20 years of stay in Australia FB people had levels of obesity similar to those of NB people; and (3) FB people from both ES and NES countries had lower levels of obesity relative to NB people regardless of their AA. The differences across groups shown in Figures 2(A) to 2(F) could not have arisen from the influence of other variables associated with both obesity and nativity (DoR and AA) since both main exposures were time-invariant and could not have been causally influenced by covariates defined at later times, as discussed previously. However, there were (potentially) several causal pathways between the main exposures and obesity, and the group differences shown in Figure 2 might have arisen from such mediation effects. We investigate this hypothesis below.

Regression results

Effect of nativity and duration of residence in Australia: Regression results

Results from Model I in Table 2 indicate that after controlling for age and sex, wave effects and the number of times a person responded out of 16 waves, the odds of being obese were

Table 2 Multilevel hybrid logistic regression results showing the odds ratios and their 95% confidence intervals (CI) for obesity with nativity as the main exposure variable

Factor	Model I			Model II			Model III			Model IV		
	Odds ratio	95% CI		Odds ratio	95% CI		Odds ratio	95% CI		Odds ratio	95% CI	
Intercept	0.00**	(0.00,0.00)		0.00**	(0.00,0.00)		0.00**	(0.00,0.00)		0.00**	(0.00,0.00)	
ES countries	0.45**	(0.29,0.69)		0.48**	(0.32,0.74)		0.55**	(0.36,0.84)		0.55**	(0.36,0.83)	
NES countries	0.32**	(0.22,0.47)		0.55*	(0.31,0.97)		0.46**	(0.26,0.81)		0.47**	(0.27,0.82)	
NB (R)												
Age group												
15–29 years (R)												
30–44 years	4.20**	(3.04,5.81)		3.90**	(2.83,5.38)		4.04**	(2.84,5.77)		3.25**	(2.29,4.61)	
45–56 years	5.12**	(3.64,7.19)		4.52**	(3.22,6.34)		3.33**	(2.25,4.92)		2.82**	(1.91,4.16)	
>= 60 years	2.07**	(1.45,2.95)		1.77**	(1.24,2.52)		0.48**	(0.28,0.81)		0.38**	(0.22,0.64)	
Gender												
Female	1.34*	(1.06,1.70)		1.35*	(1.06,1.71)		1.10	(0.85,1.41)		0.92	(0.71,1.18)	
Male (R)												
Wave number	1.12**	(1.11,1.13)		1.12**	(1.11,1.13)		1.11**	(1.10,1.12)		1.11**	(1.09,1.12)	
Number of times responded	1.05**	(1.02,1.09)		1.06**	(1.02,1.09)		1.07**	(1.04,1.11)		1.07**	(1.04,1.11)	
English proficiency												
Not good (W)				1.17	(0.58,2.36)		1.24	(0.62,2.48)		1.26	(0.63,2.55)	
Not good (B)				2.08	(0.39, 11.10)		1.48	(0.28,7.89)		1.06	(0.20,5.60)	
Good (W)				0.95	(0.75,1.20)		0.97	(0.76,1.23)		1.00	(0.79,1.27)	
Good (B)				0.44*	(0.22,0.88)		0.50	(0.25,1.02)		0.36**	(0.18,0.73)	
Proficient (R)												
Equivalent income (W)							1.02*	(1.00,1.03)		1.02*	(1.00,1.03)	
Equivalent income (B)							0.85**	(0.81,0.90)		0.89**	(0.84,0.94)	

(table continues)

Table 2 (continued)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Marital status								
Never married (W)			0.32**	(0.26,0.40)			0.33**	(0.26,0.41)
Never married (B)			0.57*	(0.36,0.88)			0.74	(0.48,1.14)
Widowed (W)			0.57**	(0.46,0.69)			0.58**	(0.47,0.71)
Widowed (B)			1.23	(0.84,1.81)			1.00	(0.68,1.46)
Currently married (R)								
Level of education								
Less than 12 years (W)			0.52**	(0.32,0.84)			0.56*	(0.35,0.91)
Less than 12 years (B)			8.79**	(5.97, 12.92)			6.70**	(4.57,9.82)
Exactly 12 years (W)			0.59*	(0.39,0.89)			0.61*	(0.41,0.92)
Exactly 12 years (B)			3.90**	(2.46,6.16)			3.45**	(2.21,5.38)
Diploma (W)			1.05	(0.70,1.57)			1.07	(0.72,1.59)
Diploma (B)			4.98**	(3.46,7.15)			4.47**	(3.13,6.37)
University education (R)								
Employment status								
Employed (R)								
Not working (W)			0.92	(0.82,1.03)			0.93	(0.82,1.04)
Not working (B)			2.18**	(1.39,3.41)			1.33	(0.84,2.09)
Unemployed (W)			0.89	(0.75,1.06)			0.91	(0.76,1.09)
Unemployed (B)			5.33*	(1.19, 23.94)			8.06**	(1.83, 35.39)
Employed (R)								

(table continues)

Table 2 (continued)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Smoking								
Former smoker (W)							1.31**	(1.11,1.54)
Former smoker (B)							2.70**	(1.97,3.69)
Current smoker (W)							0.66**	(0.53,0.81)
Current smoker (B)							0.72	(0.50,1.05)
Never smoked (R)								
Drinking								
Former drinker (W)							0.96	(0.78,1.17)
Former drinker (B)							1.20	(0.57,2.53)
Current drinker (W)							1.06	(0.87,1.29)
Current drinker (B)							0.68	(0.41,1.13)
Never drunk (R)								

(table continues)

Table 2 (continued)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Physical activity								
Sufficient (R)							1.48**	(1.39, 1.59)
Insufficient (W)							25.80**	(16.90, 39.38)
Insufficient (B)							1.61**	(1.45, 1.79)
Not at all (W)							120.70**	(69.00, 211.14)
Not at all (B)								

Note: (R) indicates reference group, (W) indicates within person exposure effect (i.e. $X_{it} - \bar{X}_i$ for a time-varying variable X) and (B) indicates between person exposure effect (i.e. $\bar{X}_i$ for a time-invariant variable X).
 Nativity is categorised as NB (native-born), FB (foreign-born) from English-speaking (ES) countries and FB from non-English-speaking (NES) countries.
 Widowed stands for widowed/separated/divorced.
 Model I includes age, sex, wave effects and number of responses out of the sixteen waves (waves 6 to 21) as the covariates.
 Model II adds ELP to the covariates of Model I.
 Model III adds household equivalised income, marital status, level of education and labour force participation status to the covariates of Model II.
 Model IV adds health behaviour variables to the covariates of Model III.

* $p < 0.05$; ** $p < 0.01$.

significantly lower among FB people from ES countries (odds ratio (OR) 0.45, 95% CI 0.29 to 0.69) and from NES countries (OR 0.32, CI 0.22 to 0.47) than those among NB people. Adjusting for suspected mediators including English language proficiency (Model II), level of education, marital status, employment status and household equivalised income (Model III) and health behaviour variables (Model IV) did not alter this conclusion or substantially change the magnitude of the nativity effect. This suggests that mediation of the relationship between nativity and obesity by English language proficiency and the socio-demographic and health behaviour variables used in the analysis was unimportant.

Results from Model I (Table 3) show that after controlling for age, sex, wave effects and the number of times a person responded out of 16 waves, the odds of being obese were significantly lower among FB people from NES countries than among NB people when DoR was less than 10 years (OR 0.24, CI 0.09 to 0.62) and 10 to 19 years (OR 0.08, CI 0.04 to 0.17). After 20 years of DoR, however, the obesity levels of FB people from NES countries were not significantly different from those of NB people. There was no significant difference in the odds of obesity between FB people from ES countries and NB people irrespective of their DoR.

Additionally, adjusting for English language proficiency and SES factors (Model II and Model III) did not change the conclusions for the FB from NES countries, but for the FB from ES countries (ES; DoR > 20 in Model II, and ES; DoR 10–19 in Model III), the fitted coefficients became significant, though only just. Furthermore, in the final model (Model IV), adding health behaviour variables (smoking, drinking and physical activity) to Model III did not alter the conclusion from Model I, suggesting that the case for mediation by English language proficiency and SES factors for FB from ES countries was not compelling, i.e. no definitive conclusion was possible using these data.

Differential effect of nativity and duration of residence by age at arrival in Australia

Table 4 shows the results of regression analysis with nativity/AA as the main exposure, and Table 5 does the same with DoR/AA as the main exposure. The results of Models I, II, III and IV in Table 4 show that FB people from ES and NES countries had significantly lower odds of being obese relative to NB people for those that arrived in Australia aged 25 years or older. For FB people from NES countries who arrived in Australia before age 25, after adjusting for ELP (Model II), the odds of being obese became non-significant, with no change after additionally adjusting for SES (Model III) and health behaviour variables (Model IV). This suggests that ELP could have played a mediating role in this group of immigrants.

The results shown in Table 5 indicate that except for the youngest and the most recent immigrants (DoR < 10 years and AA < 25 years), FB people with DoR of less than 20 years had significantly lower odds of being obese than NB people, regardless of their AA. However, there was no significant difference between longstanding immigrants (20+ years of residence) and NB Australians by AA. These conclusions remained the same even in

Table 3 Multilevel hybrid logistic regression results showing the odds ratios and their 95% confidence intervals (CI) for obesity with duration of residence by nativity as the main exposure variable

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Intercept	0.00**	(0.00,0.00)	0.00**	(0.00,0.00)	0.00**	(0.00,0.00)	0.00**	(0.00,0.00)
DoR/nativity								
ES; DOR < 10 years	0.42	(0.11,1.56)	0.43	(0.12,1.57)	0.48	(0.13,1.82)	0.49	(0.13,1.81)
ES; DOR 10 to 19	0.38	(0.14,1.07)	0.39	(0.14,1.08)	0.36*	(0.13,1.00)	0.39	(0.14,1.09)
ES; DOR 20	0.63	(0.39,1.03)	0.60*	(0.37,0.98)	0.66	(0.40,1.07)	0.63	(0.39,1.01)
NES; DOR < 10	0.24**	(0.09,0.62)	0.29*	(0.10,0.86)	0.22**	(0.07,0.65)	0.15**	(0.05,0.45)
NES; DOR 10 to 19	0.08**	(0.04,0.17)	0.13**	(0.05,0.29)	0.14**	(0.06,0.32)	0.12**	(0.05,0.28)
NES; DOR ≥ 20	0.99	(0.60,1.63)	1.51	(0.82,2.79)	1.03	(0.56,1.92)	0.86	(0.47,1.58)
Australia (R)								
Age group								
15–29 years								
30–44 years	3.71**	(2.69,5.11)	3.72**	(2.70,5.13)	4.00**	(2.81,5.70)	3.12**	(2.20,4.42)
45–56 years	4.05**	(2.88,5.69)	4.02**	(2.86,5.65)	3.14**	(2.12,4.65)	2.60**	(1.76,3.84)
>= 60 years	1.51*	(1.05,2.17)	1.44*	(1.00,2.07)	0.42**	(0.25,0.72)	0.35**	(0.21,0.60)
Gender								
Female	1.41**	(1.11,1.78)	1.40**	(1.10,1.78)	1.10	(0.85,1.41)	0.95	(0.74,1.22)
Male (R)								
Wave number	1.12**	(1.11,1.13)	1.12**	(1.11,1.13)	1.11**	(1.10,1.12)	1.11**	(1.09,1.12)
Number of times responded	1.06**	(1.03,1.10)	1.06**	(1.02,1.09)	1.07**	(1.04,1.11)	1.08**	(1.05,1.12)

(table continues)

Table 3 (continued)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
English proficiency								
Not good (W)	1.18	(0.58,2.40)	1.25	(0.62,2.51)	1.27	(0.63,2.58)		
Not good (B)	2.33	(0.46, 11.73)	1.58	(0.31,7.92)	1.13	(0.22,5.85)		
Good (W)	0.95	(0.75,1.20)	0.97	(0.76,1.22)	1.00	(0.78,1.26)		
Good (B)	0.39**	(0.19,0.79)	0.68	(0.34,1.36)	0.54	(0.27,1.10)		
Proficient (R)								
Equivalentised income (W)			1.02*	(1.00,1.03)	1.02*	(1.00,1.03)		
Equivalentised income (B)			0.85**	(0.81,0.90)	0.90**	(0.85,0.94)		
Marital status								
Never married (W)				0.32**	(0.26,0.40)	0.33**	(0.26,0.42)	
Never married (B)				0.58*	(0.37,0.90)	0.70	(0.46,1.08)	
Widowed (W)				0.57**	(0.46,0.70)	0.58**	(0.47,0.71)	
Widowed (B)			1.22	(0.83,1.79)	1.00	(0.68,1.46)		
Currently married (R)								
Level of education								
Less than 12 years (W)			0.52**	(0.32,0.84)	0.55*	(0.34,0.90)		
Less than 12 years (B)			8.40**	(5.72, 12.33)	6.46**	(4.42,9.44)		
Exactly 12 years (W)			0.60*	(0.39,0.90)	0.60*	(0.40,0.91)		
Exactly 12 years (B)			3.76**	(2.38,5.93)	3.13**	(2.01,4.87)		
Diploma (W)			1.06	(0.71,1.58)	1.07	(0.72,1.60)		
Diploma (B)			4.70**	(3.28,6.74)	4.06**	(2.85,5.78)		
University education (R)								

(table continues)

Table 3 (continued)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Employment status								
Not working (W)					0.92	(0.82, 1.03)	0.92	(0.82, 1.04)
Not working (B)					2.14**	(1.37, 3.35)	1.26	(0.80, 1.99)
Unemployed (W)					0.89	(0.75, 1.06)	0.90	(0.75, 1.07)
Unemployed (B)					5.66*	(1.27, 25.25)	9.57**	(2.20, 41.58)
Employed (R)								
Smoking								
Former smoker (W)							1.31**	(1.11, 1.55)
Former smoker (B)							2.49**	(1.82, 3.40)
Current smoker (W)							0.66**	(0.53, 0.81)
Current smoker (B)							0.68*	(0.47, 0.98)
Never smoked (R)								
Drinking								
Former drinker (W)							0.96	(0.78, 1.18)
Former drinker (B)							1.22	(0.58, 2.56)
Current drinker (W)							1.07	(0.88, 1.29)
Current drinker (B)							0.67	(0.41, 1.12)
Never drunk (R)								

(table continues)

Table 3 (continued)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Physical activity								
Sufficient (R)							1.48**	(1.39, 1.59)
Insufficient (W)							24.29**	(15.93, 37.03)
Insufficient (B)							1.61**	(1.44, 1.79)
Not at all (W)							117.44**	(67.34, 204.83)
Not at all (B)								

Note: (R) indicates reference group, (W) indicates within person exposure effect (i.e. $X_{it} - \bar{X}_i$ for a time-varying variable X) and (B) indicates between person exposure effect (i.e. $\bar{X}_i$ for a time-invariant variable X).
 Nativity is categorised as NB (native-born), FB (foreign-born) from English-speaking (ES) countries and FB from non-English-speaking (NES) countries.
 Widowed stands for widowed/separated/divorced.
 Nativity is categorised as NB (native-born), FB (foreign-born) from English-speaking (ES) countries and FB from non-English-speaking (NES) countries. Duration of residence is categorised into less than 10 years, 10–19 years, and greater than or equal to 20 years in Australia, and is combined with the nativity variable described above.
 Model I includes age, sex, wave effects and number of responses out of the sixteen waves (waves 6 to 21) as the covariates.
 Model II adds ELP to the covariates of Model I.
 Model III adds household equivalised income, marital status, level of education and labour force participation status to the covariates of Model II.
 Model IV adds health behaviour variables to the covariates of Model III.
 * $p < 0.05$; ** $p < 0.01$.

Table 4 Multilevel hybrid logistic regression results showing the odds ratios and their 95% confidence intervals (CI) for obesity with age at arrival (AA) by nativity as the main exposure variable

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Intercept	0.00**	(0.00,0.00)	0.00**	(0.00,0.00)	0.00**	(0.00,0.00)	0.00**	(0.00,0.00)
Nativity and AA								
ES; AA < 25	0.59	(0.35,1.00)	0.57*	(0.34,0.97)	0.65	(0.39,1.10)	0.69	(0.41,1.15)
ES; AA ≥ 25	0.35**	(0.18,0.68)	0.34**	(0.17,0.68)	0.39**	(0.20,0.76)	0.41**	(0.22,0.79)
NES; AA < 25	0.51**	(0.31,0.82)	0.83	(0.46,1.49)	0.64	(0.35,1.17)	0.58	(0.32,1.04)
NES; AA ≥ 25	0.16**	(0.09,0.30)	0.23**	(0.10,0.54)	0.22**	(0.10,0.50)	0.23**	(0.10,0.52)
Australia (R)								
Age group								
15–29 years (R)								
30–44 years	3.92**	(2.84,5.42)	3.94**	(2.86,5.44)	4.27**	(2.99,6.10)	3.28**	(2.31,4.66)
45–56 years	4.71**	(3.35,6.61)	4.68**	(3.33,6.57)	3.66**	(2.47,5.43)	2.97**	(2.01,4.39)
≥ 60 years	1.94**	(1.36,2.78)	1.89**	(1.32,2.70)	0.54*	(0.32,0.92)	0.44**	(0.26,0.75)
Gender								
Female	1.39**	(1.10,1.76)	1.36*	(1.07,1.72)	1.10	(0.85,1.41)	0.95	(0.74,1.21)
Male (R)								
Wave number	1.12**	(1.11,1.13)	1.12**	(1.11,1.13)	1.11**	(1.10,1.12)	1.11**	(1.09,1.12)
Number of times responded	1.06**	(1.03,1.10)	1.06**	(1.03,1.10)	1.07**	(1.04,1.11)	1.08**	(1.05,1.12)
English proficiency								
Not good (W)			1.17	(0.58,2.37)	1.24	(0.62,2.47)	1.26	(0.62,2.54)
Not good (B)			3.10	(0.53, 17.99)	2.36	(0.41, 13.52)	1.76	(0.31, 10.06)
Good (W)			0.95	(0.75,1.20)	0.97	(0.76,1.23)	1.00	(0.79,1.27)
Good (B)			0.43*	(0.21,0.87)	0.60	(0.30,1.22)	0.46*	(0.23,0.93)

(table continues)

Table 4 (continued)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Equivalised income (W)					1.02*	(1.00, 1.03)	1.02*	(1.00, 1.03)
Equivalised income (B)					0.85**	(0.81, 0.90)	0.89**	(0.85, 0.94)
Marital status								
Never married (W)					0.32**	(0.26, 0.40)	0.33**	(0.26, 0.42)
Never married (B)					0.56*	(0.36, 0.88)	0.70	(0.46, 1.08)
Widowed (W)					0.57**	(0.46, 0.70)	0.58**	(0.47, 0.71)
Widowed (B)					1.20	(0.81, 1.76)	0.99	(0.68, 1.45)
Currently married (R)								
Level of education								
Less than 12 years (W)					0.52**	(0.32, 0.85)	0.55*	(0.34, 0.90)
Less than 12 years (B)					8.53**	(5.79, 12.56)	6.58**	(4.49, 9.64)
Exactly 12 years (W)					0.59*	(0.39, 0.89)	0.60*	(0.40, 0.90)
Exactly 12 years (B)					3.97**	(2.51, 6.28)	3.26**	(2.09, 5.08)
Diploma (W)					1.06	(0.71, 1.59)	1.08	(0.72, 1.61)
Diploma (B)					4.93**	(3.43, 7.09)	4.16**	(2.92, 5.93)
University education (R)								
Employment status								
Not working (W)					0.92	(0.82, 1.03)	0.92	(0.82, 1.04)
Not working (B)					2.16**	(1.38, 3.39)	1.26	(0.80, 1.98)
Unemployed (W)					0.88	(0.74, 1.06)	0.89	(0.75, 1.07)
Unemployed (B)					5.77*	(1.28, 26.01)	9.32**	(2.12, 40.91)
Employed (R)								

(table continues)

Table 4 (*continued*)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Smoking								
Former smoker (W)							1.31**	(1.11, 1.54)
Former smoker (B)							2.56**	(1.87, 3.50)
Current smoker (W)							0.66**	(0.54, 0.81)
Current smoker (B)							0.70	(0.48, 1.02)
Never smoked (R)								
Drinking								
Former drinker (W)							0.96	(0.78, 1.18)
Former drinker (B)							1.29	(0.61, 2.73)
Current drinker (W)							1.06	(0.88, 1.29)
Current drinker (B)							0.73	(0.44, 1.21)
Never drunk (R)								

(table continues)

Table 4 (continued)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Physical activity								
Insufficient (W)							1.48**	(1.39, 1.59)
Insufficient (B)							24.04**	(15.76, 36.65)
Not at all (W)							1.61**	(1.45, 1.79)
Not at all (B)							116.28**	(66.48, 203.39)
Not at all (R)								

Note: (R) indicates reference group, (W) indicates within person exposure effect (i.e. $X_{it} - \bar{X}_i$ for a time-varying variable X) and (B) indicates between person exposure effect (i.e. $\bar{X}_i$ for a time-invariant variable X).

Nativity is categorised as NB (native-born), FB (foreign-born) from English-speaking (ES) countries and FB from non-English-speaking (NES) countries.

Widowed stands for widowed/separated/divorced.

Age at arrival (AA) is categorised into less than 25 years and greater than or equal to 25 years.

Model I includes age, sex, wave effects and number of responses out of the sixteen waves (waves 6 to 21) as the covariates.

Model II adds ELP to the covariates of Model I.

Model III adds household equivalised income, marital status, level of education and labour force participation status to the covariates of Model II.

Model IV adds health behaviour variables to the covariates of Model III.

* $p < 0.05$; ** $p < 0.01$.

Table 5 Multilevel hybrid logistic regression results showing the odds ratios and their 95% confidence intervals (CI) for obesity with duration of residence by age at arrival (DoR/AA) as the main exposure variable

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Intercept	0.00**	(0.00,0.00)	0.00**	(0.00,0.00)	0.00**	(0.00,0.00)	0.00**	(0.00,0.00)
Country of birth								
DoR < 10; AA < 25	0.55	(0.16,1.98)	0.68	(0.18,2.47)	0.68	(0.19,2.38)	0.59	(0.16,2.13)
DoR < 10; AA ≥ 25	0.16**	(0.06,0.46)	0.17**	(0.06,0.50)	0.19**	(0.07,0.53)	0.15**	(0.06,0.43)
DoR 10–19; AA < 25	0.21**	(0.09,0.47)	0.28**	(0.12,0.65)	0.31**	(0.14,0.69)	0.29**	(0.13,0.67)
DoR 10–19; AA ≥ 25	0.07**	(0.03,0.17)	0.08**	(0.03,0.21)	0.11**	(0.05,0.27)	0.11**	(0.05,0.27)
DoR ≥ 20; AA < 25	0.69	(0.45,1.05)	0.72	(0.46,1.11)	0.74	(0.48,1.15)	0.71	(0.46,1.10)
DoR ≥ 20; AA ≥ 25	0.69	(0.36,1.31)	0.77	(0.40,1.50)	0.79	(0.41,1.53)	0.75	(0.40,1.43)
Australia (R)								
Age group								
15–29 years								
30–44 years	4.71**	(3.39,6.54)	4.88**	(3.51,6.79)	4.22**	(2.95,6.04)	3.34**	(2.35,4.76)
45–56 years	5.38**	(3.80,7.64)	5.37**	(3.79,7.62)	3.39**	(2.28,5.06)	2.85**	(1.92,4.23)
≥ 60 years	1.97**	(1.36,2.84)	1.95**	(1.35,2.82)	0.45**	(0.26,0.77)	0.38**	(0.22,0.64)
Gender								
Female	1.34*	(1.06,1.70)	1.32*	(1.04,1.68)	1.09	(0.85,1.40)	0.95	(0.74,1.22)
Male (R)								
Wave number	1.12**	(1.11,1.13)	1.12**	(1.11,1.13)	1.11**	(1.10,1.12)	1.11**	(1.09,1.12)
Number of times responded	1.05**	(1.02,1.09)	1.05**	(1.02,1.08)	1.07**	(1.04,1.11)	1.08**	(1.05,1.11)

(table continues)

Table 5 (continued)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
English proficiency								
Not good (W)			1.21	(0.59, 2.45)	1.25	(0.63, 2.51)	1.27	(0.63, 2.58)
Not good (B)			3.32	(0.67, 16.51)	1.82	(0.37, 8.83)	1.27	(0.25, 6.39)
Good (W)			0.96	(0.76, 1.22)	0.97	(0.76, 1.22)	1.00	(0.78, 1.26)
Good (B)			0.59	(0.33, 1.07)	0.69	(0.39, 1.23)	0.51*	(0.28, 0.91)
Equivalentised income (W)					1.02*	(1.00, 1.03)	1.02*	(1.00, 1.03)
Equivalentised income (B)					0.86**	(0.81, 0.91)	0.90**	(0.85, 0.94)
Marital status								
Never married (W)					0.32**	(0.26, 0.40)	0.33**	(0.26, 0.41)
Never married (B)					0.57*	(0.37, 0.89)	0.69	(0.45, 1.06)
Widowed (W)					0.57**	(0.46, 0.70)	0.58**	(0.47, 0.71)
Widowed (B)					1.23	(0.84, 1.80)	1.00	(0.68, 1.46)
Currently married (R)								
Level of education								
Less than 12 years (W)					0.52**	(0.32, 0.84)	0.56*	(0.34, 0.90)
Less than 12 years (B)					8.51**	(5.79, 12.49)	6.48**	(4.43, 9.49)
Exactly 12 years (W)					0.59*	(0.39, 0.90)	0.60*	(0.40, 0.91)
Exactly 12 years (B)					3.79**	(2.40, 5.99)	3.14**	(2.01, 4.89)
Diploma (W)					1.05	(0.70, 1.57)	1.07	(0.72, 1.60)
Diploma (B)					4.81**	(3.35, 6.90)	4.08**	(2.86, 5.82)
University education (R)								

(table continues)

Table 5 (continued)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Employment status								
Not working (W)					0.92	(0.82, 1.03)	0.92	(0.82, 1.04)
Not working (B)					2.15**	(1.37, 3.36)	1.24	(0.79, 1.96)
Unemployed (W)					0.89	(0.75, 1.06)	0.90	(0.75, 1.07)
Unemployed (B)					5.49*	(1.23, 24.52)	9.18**	(2.10, 40.01)
Smoking								
Former smoker (W)							1.31**	(1.11, 1.54)
Former smoker (B)							2.51**	(1.84, 3.44)
Current smoker (W)							0.66**	(0.54, 0.81)
Current smoker (B)							0.69	(0.47, 1.00)
Never smoked (R)								
Drinking								
Former drinker (W)							0.96	(0.78, 1.18)
Former drinker (B)							1.21	(0.58, 2.56)
Current drinker (W)							1.06	(0.88, 1.29)
Current drinker (B)							0.69	(0.41, 1.14)
Never drunk (R)								

(table continues)

Table 5 (continued)

Factor	Model I		Model II		Model III		Model IV	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Physical activity								
Sufficient (R)							1.48**	(1.39, 1.59)
Insufficient (W)							23.69**	(15.53, 36.15)
Insufficient (B)							1.61**	(1.45, 1.79)
Not at all (W)							114.87**	(65.77, 200.65)
Not at all (B)								

Note: (R) indicates reference group, (W) indicates within person exposure effect (i.e. $X_{it} - \bar{X}_i$ for a time-varying variable X , and (B) indicates between person exposure effect (i.e. $\bar{X}_i$ for a time-invariant variable X).

Widowed stands for widowed/separated/divorced.

Duration of residence is categorised into less than 10 years, 10–19 years and greater than or equal to 20 years in Australia, and is combined with the nativity status variable described above. Age at arrival is categorised into less than 25 years and greater than or equal to 25 years.

Model I includes age, sex, wave effects and number of responses out of the sixteen waves (waves 6 to 21) as the covariates.

Model II adds ELP to the covariates of Model I.

Model III adds household equivalised income, marital status, level of education and labour force participation status to the covariates of Model II.

Model IV adds health behaviour variables to the covariates of Model III.

* $p < 0.05$; ** $p < 0.01$.

Models II, III and IV, indicating that ELP, SES and health behaviour variables played no significant mediating role in these immigrant groups.

Sensitivity analyses

Changing the definition of obesity (Supplementary material Tables S.2 and S.3) by reducing or increasing the BMI cut-off generally had little effect on the odds ratio estimates and no effect on the overall conclusions for DoR/nativity or DoR/AA (compare with Tables 3 and 5).

A finer categorisation of DoR (compare Table 3 for DoR/nativity and Supplementary material Table S.4) suggested that among immigrants from ES countries, only the DoR ≥ 30 years group had measurably lower odds of obesity than the NB. However, among immigrants from NES countries, measurably lower odds of obesity relative to the NB were observed across most DoR categories of between five and 30 years of residence in Australia.

Increasing the number of AA categories (compare Table 4 for AA/nativity and Supplementary material Table S.5) showed that among immigrants from ES countries, the odds of obesity relative to the NB were measurably reduced for arrival ages between 15 and 45 years. Among immigrants from NES countries, the odds of obesity were measurably lower than those among the NB for arrival ages between 25 and 44 years.

Sensitivity analyses suggested that our conclusions were reasonably robust to changes in the definition of obesity. Nevertheless, higher levels of categorisation for AA and DoR appeared to provide a more nuanced view than our “base” analyses, suggesting that there is ample scope for more detailed research in the future.

Discussion and conclusion

The purpose of this study was to investigate differences in the levels of obesity among foreign-born people from English-speaking and non-English-speaking countries relative to those among native-born Australians, and how those differences changed with duration of residence and age at arrival. We were also interested in examining the mediating roles of English language proficiency, SES and health behaviour factors in the association between nativity, duration of residence and obesity. Unlike analyses that examined these research questions using cross-sectional data, we used 16 waves of longitudinal data to investigate the nature of the association between immigration and obesity in the Australian setting. Extending previous longitudinal work, including that of Setia et al. (Setia et al., 2009, 2011, 2012), we used hybrid regression models to help reduce estimation bias. With respect to our research questions, we found that:

1. The odds of being obese were patterned by nativity: foreign-born people from both English-speaking and non-English-speaking countries had lower odds of being obese than those of native-born people.
2. Relative to the native-born, foreign-born people from non-English-speaking countries had a measurable obesity advantage when they had been living in Australia for less than

10 years or 10–19 years, though they lost their obesity advantage with respect to the native-born after 20 years of residence in Australia. There was no difference in the odds of being obese between immigrants from English-speaking countries and native-born Australians by any duration of residence.

3. We found that immigrants from English-speaking and non-English-speaking countries who arrived in Australia aged 25 years or older had significantly lower odds of being obese relative to native-born people. In addition, FB people from NES countries who arrived in Australia before age 25 also had significantly lower odds of being obese relative to native-born people in Model I of Table 4, but English language proficiency may have played a mediating role.
4. We did not find any evidence of mediating roles for socio-economic status and health behaviour factors in the association between nativity, DoR and obesity for immigrants from non-English-speaking countries. While there were hints that English language proficiency and socio-economic status factors mediated the relationship between nativity/duration of residence and obesity for immigrants from English-speaking countries, the effects were marginal.

In response to our first research question, our findings are consistent with prior research showing that foreign nativity is associated with lower BMI, overweight and obesity (Antecol and Bedard, 2006; Lauderdale and Rathouz, 2000; Popkin and Udry, 1998; Sanchez-Vaznaugh et al., 2008). By adopting a longitudinal lens, our study contributes new insights into this well-documented pattern, commonly referred to as the “healthy migrant effect”. This hypothesis states that migrants are positively selected on health, either through direct mechanisms such as medical screening, or indirectly via immigration policies that favour individuals with higher education, skills and financial resources, as well as self-selection processes (Akresh, 2007; Antecol and Bedard, 2006; Biddle et al., 2007; McDonald and Kennedy, 2004). Additionally, individuals with obesity have worse health conditions and a higher prevalence of pre-existing chronic conditions, which can be a barrier to the decision to immigrate, especially among the most vulnerable socio-economic groups. For a more detailed discussion of the underlying mechanisms contributing to the healthy immigrant effect, including selection processes and structural determinants, see Jatrana et al. (2018a).

Additionally, our second research question is answered affirmatively, particularly in the case of FB individuals from NES countries. Notably, the health advantage observed among NES immigrants diminished after two decades in Australia. A key explanation for this pattern is the process of acculturation, through which prolonged residence may lead to the adoption of health-damaging behaviours and the erosion of protective cultural practices (Antecol and Bedard, 2006; Delavari et al., 2013b; Wallace, 2022). Changes in diet and physical activity are often cited as primary mechanisms (Akresh, 2007; Delavari et al., 2013a). While our data did not include dietary information, we analysed physical activity and found no strong evidence that it mediated the association between DoR and obesity. However, prior work (Joshi et al., 2017) showed that FB individuals from NES countries have persistently lower odds of engaging in physical activity, even after 20 years of residence.

Although acculturation offers a useful framework, it has limitations. It often assumes that migrants come from healthier environments and that Western societies induce negative

behavioural change. This perspective can overlook the global diffusion of unhealthy behaviours prior to migration. For instance, Martínez (2013) demonstrated that many Latino immigrants had already adopted Westernised diets before migrating to the U.S. Similarly, Australia's infrastructure and environmental conditions – such as its lower pollution, accessible green spaces and recreational facilities – may promote healthier behaviours than some migrants' countries of origin. In other cases, similarities between Australia and the country of origin may limit behaviour change post-migration.

It is possible that changes in the composition of immigrants might influence the obesity trend over time. To investigate this, we conducted additional sensitivity analysis (results not shown but available from the lead author upon request) to assess how the composition of immigrants evolved over time. The data did not reveal a significant change in immigrant composition. Given the lack of substantial changes in the makeup of immigrants from regions with notably different obesity rates and dietary habits – such as those from Asia, the Middle East or non-English-speaking countries compared to those from traditional source countries in Europe and North America – it appears unlikely that shifts in immigrant composition are affecting obesity trends.

Our findings regarding the impact of AA differ from those of prior studies (Kaushal, 2009; Oza-Frank and Narayan, 2010a; Roshania et al., 2008) that showed a potential interaction between DoR and the age at which individuals arrived. However, due to wide confidence intervals, our analysis may have lacked sufficient statistical power to detect significant differences across AA groups, and the results should be interpreted with caution pending further validation. As noted in prior research (Kinra, 2004), disentangling the effects of AA from DoR remains a methodological challenge especially in observational studies. In the field of migration studies, the interdependence of age, AA and DoR poses a challenge when attempting to disentangle the individual impacts of age at migration and the overall duration of exposure to a new environment (Kinra, 2004). Consequently, in an individual-level analysis, it becomes difficult to incorporate age, AA and DoR as continuous variables simultaneously. However, this challenge is not insurmountable when these variables are grouped together, even though correlations between the categories may complicate the detection of significant differences. Nonetheless, in our specific study, this issue did not appear to be a significant concern, except for the youngest and the most recently arrived immigrant groups.

Acknowledging the interdependence of age, period and cohort (APC) is essential, as their correlation can introduce multicollinearity problems in longitudinal analyses. However, omitting these factors risks misinterpreting effects, for instance mistaking age effects for period or cohort influences. In this study, we used age at arrival, which is an inherently fixed characteristic and thus enables a clear assessment of its impact on obesity. However, both age and duration of residence increase linearly with each HILDA wave. To address this, we fixed both DoR and age at wave 1 to prevent conflation of effects. Given the overlapping influences of age at arrival, temporal trends and year of arrival, further analyses (see Supplementary material Figures S.2 and S.3) are provided to illustrate respectively the distribution of duration of residence and age at arrival among foreign-born respondents at wave 6, and general trends in obesity by age, period (year), duration of residence and age at arrival. Additionally, Table S.6 provides regression model results for foreign-born people

in Australia with obesity as the dependent variable and (i) CoB, DoR and their interaction and (ii) CoB, AA and their interaction as the main exposure variables with DoR and AA as continuous covariates.

We did not find any compelling evidence to suggest that health behaviours played a mediating role in the relationship between nativity, DoR and obesity. However, for immigrants from ES countries, English language proficiency and SES emerged as potential mediators in the relationship between DoR and obesity. After accounting for English language proficiency (Table 3, Model II) and SES factors (Table 3, Model III), previously non-significant findings for immigrants from ES countries relative to NB Australians became statistically significant. While marginal, this significance was evident for English language proficiency (DoR > 20 years) and SES (DoR 10–20 years). We also gained some insight into the role of English language proficiency in mediating the relationship between DoR and obesity when we did a sensitivity analysis by removing the so-called “Western countries” (e.g. France, Germany) from the NES category and adding them to the ES category, i.e. making this a “European” national grouping that ignored language differences. Specifically, the odds ratio estimates for those with a DoR of less than 20 years became statistically significant, while the estimate for those with a DoR exceeding 20 years lost its statistical significance (results not shown but available on request).

There are two plausible mechanisms through which English language proficiency might act as a mediator affecting weight gain among immigrants from ES countries. First, a stronger command of the English language might motivate immigrants to make better use of available information, such as that from mass media, and encourage participation in recreational physical activities (Caperchione et al., 2013). Second, because English proficiency and success in the labour market are closely linked, individuals with higher English proficiency are more likely to belong to higher income quartiles. This finding is consistent with the earlier research evidence suggesting that the ability to speak English influences the obesity levels of immigrants (Gee et al., 2008, 2010). However, the effect of language proficiency on health is complex and may operate through several mechanisms (Gee et al., 2010). The study by Gee et al. (2010) even challenges the presumption that use of the English language represents acculturation, and suggests new avenues of research focused on bilingualism (Schachter et al., 2012).

Our study makes a substantial contribution by addressing certain limitations of prior research by using longitudinal data and a combination of both conventional mixed and hybrid models. Theoretically, our results challenge the oversimplification embedded in traditional acculturation models. Future research should investigate how the immigrant health advantage erodes over time, potentially due to factors like acculturative stress and discrimination, which may influence diet and physical activity through their effects on mental health and identity (Berry et al., 1987; Rudmin, 2009). Evidence from studies on Latino and Iranian immigrants, as well as on Asian Americans, supports the link between stress, unhealthy coping behaviours and obesity (Agne et al., 2012; Delavari et al., 2013a; Gee et al., 2008). Further work should also explore pre- and post-migration dietary patterns and compare immigrants with non-migrant cohorts in their countries of origin (Gibson et al., 2011; McKenzie et al., 2007; Stillman et al., 2009), particularly given the rising obesity rates in developing countries.

From a policy perspective, our findings highlight the need for targeted obesity prevention strategies. Although FB individuals often arrive in better health than NB Australians, this advantage declines over time. As obesity levels among immigrants from NES countries converge with those of NB Australians, the burden of related conditions, such as diabetes, heart disease and cancer, may rise, placing further strain on healthcare systems (Bray, 2004). Tailored interventions are essential, particularly those designed to prevent or delay obesity onset in immigrant communities, recognising the unique challenges they face.

Several limitations in our study warrant attention. First, height and weight data were self-reported, which may introduce bias due to tendencies to underestimate weight and overestimate height (Gorber et al., 2007), though prior studies report strong concordance with measured values (Willett, 2012). We are not aware of evidence suggesting differential reporting by nativity, though response bias remains a possibility. To mitigate this, we controlled for variables commonly associated with reporting bias, including age, gender and education.

Second, our focus on time since immigration meant that we did not distinguish between immigrant generations. First-generation immigrants were categorised as FB, while second-generation migrants were included in the NB group, as they were born in Australia.

Third, analyses by age at arrival were limited to broad categories due to sample size constraints, which also prevented us from exploring the heterogeneity within ES and NES migrant groups. Future studies with larger samples should disaggregate data more finely by nativity, country of birth and age at arrival to uncover important subgroup differences.

Fourth, due to multicollinearity between duration of residence, year of arrival and year of survey, we were unable to separate DoR effects from period or cohort effects. As noted in Jatrana et al. (2018a), this is a common challenge in immigration research, compounded by age-related health changes and external contextual factors over time. Furthermore, the interdependence of age, AA and DoR limited our ability to disentangle their individual effects.

Fifth, while we examined the mediating roles of SES, English proficiency and health behaviours, we could not assess the role of dietary factors in obesity trends. Future research should explore the contribution of diet and nutrition in shaping the obesity trajectories among immigrants compared to those among non-immigrants.

Sixth, we have assumed that the direction of causal effect in Figure 1 goes from ELP to SES. It is plausible that the causal arrow might also go in the other direction at times, e.g. being employed in a predominantly English-speaking environment could improve an immigrant's proficiency in the English language. This would be an example of reverse causation, an effect that is not amenable to detection with the approach used in this paper (Wooldridge, 2010), and would require more complex methods of causal analysis to identify (Pearl, 2009; Robins and Hernán, 2009). Of course, such methods have their own limitations, one being that rich datasets are required for estimation. Given the limitations of the HILDA dataset, there is still a place for the simpler analyses performed here, provided that the underlying assumptions are borne in mind.

Ours is one of the first studies to investigate the longitudinal association between obesity and nativity, duration of residence and age at arrival, and to do so from a causal perspective. As suggested by the limitations noted above, there is plenty of scope for confirming and strengthening our findings, for example by using more formal causal models, particularly

when larger longitudinal studies become available. In addition, these findings are highly relevant for understanding the health trajectories of migrant populations and underscore the need to consider migration-related factors in public health interventions targeting obesity. Future research should explore the role of life course exposures, acculturation pathways and structural determinants in shaping obesity outcomes across different migrant subgroups.

Supplementary material

Available online at <https://doi.org/10.1553/p-7gcp-6eab>

Supplementary file 1. Figures S.1–S.3, Tables S.1–S.6



Data availability

We used and analysed datasets from the Household, Income and Labour Dynamics in Australia (HILDA) survey, which are subject to approval by the permission from Australian Government Department of Social Service and can be requested from DSS Longitudinal Studies Dataverse (<https://dataverse.ada.edu.au/dataset.xhtml?persistentId=doi:10.26193/R4IN30>). The code used for the analysis of the data is also available upon request.

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