SSM - Population Health 20 (2022) 101301

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: www.elsevier.com/locate/ssmph

Grand designs for design policy: Associations between apartment policy standards, perceptions of good design and mental wellbeing

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ABSTRACT

Comprehensive apartment design policies have been legislated by Australian state governments to address concerns about poor design in residential buildings. These policies aim to improve apartment design and promote good health. This study examined whether: (1) residents living in apartments that implemented more minimum design requirements perceived better apartment design and amenity; and (2) increased implementation of minimum requirements and better perceptions of design were associated with positive mental wellbeing. Apartment complexes (n = 114, built 2006–2016) were sampled from Sydney, Perth, and Melbourne. Building plans and elevations were used to measure and score apartments for their implementation of 96 quantifiable policy-specific requirements and residents (n = 1072) completed a self-report survey on their apartment design and health. Multi-level linear regression models were used to account for clustered data. Residents in apartments with greater implementation of requirements for solar and daylight, indoor space, private open space, communal space and parking had more positive perceptions of their apartment in terms of natural light and winter thermal comfort, indoor space and layout, private open space, communal area quality, and parking, respectively (all $p < 0.05$). Perceptions of natural ventilation, summer thermal comfort, indoor space, and communal area quality were independently associated with positive mental wellbeing (all $p < 0.05$), but the objective implementation scores had no direct association. When implemented as intended, minimum requirements had a positive impact on perceptions of design, which were associated with mental wellbeing. The study underscores the importance of planning instruments and design review processes that increase industry uptake of minimum policy standards.

1. Introduction

Globally, urban consolidation is widely promoted as the preferred development model to sustainably house a growing population (OECD, 2012), with increases in residential density primarily delivered via the construction of apartment housing. Apartments have proliferated in recent years, even in Australia where there is a longstanding preference for detached housing and cities have traditionally been characterised by sprawling low density suburbs (Kelly et al., 2011). The past decade has seen a rapid expansion in apartment development in all major Australian cities (Rosewall & Shoory, 2017; Shoory, 2016), and by 2015, building had commenced on more attached than detached dwellings for the first time (Australian Bureau of Statistics, 2020). However, the influx of new apartments in Australian cities has not been without controversy, with serious concerns raised about the quality and amenity of contemporary apartments (City of Melbourne, 2013; Randolph, 2006; The State of Victoria Department of Environment Land Water & Planning, 2021).

To improve the quality of residential apartment buildings, numerous Australian state and local government planning departments have increased their regulation of the built environment via policy instruments (Carmona, 2016; Foster et al., 2020). Until recently, planning provisions for residential housing in most Australian states focused predominantly on suburban or low-rise development, with multi-unit or apartment housing largely neglected (Western Australian Planning Commission, 2018). However, there was one exception: in 2002, the New South Wales (NSW) government enacted a comprehensive performance-based planning code to address the shortcomings in the design of new apartments. Since it was legislated, NSW's State Environmental Planning Policy 65 (SEPP65) and its accompanying design guide are generally considered to have improved the quality of apartments in the state (Moore et al., 2015; Mould, 2011). The successful NSW experience has influenced design governance in other Australian

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https://doi.org/10.1016/j.ssmph.2022.101301
Received 16 October 2022; Received in revised form 21 November 2022; Accepted 21 November 2022
Available online 24 November 2022

states (Foster et al., 2020). In recent years, Western Australia (WA) and Victoria (VIC) have drawn heavily on SEPP65 to introduce similar apartment design policies that are considerably more wide-ranging than the policies they replaced, and if implemented as intended, would help avoid poor design outcomes in new buildings (Foster et al., 2020). This appetite for increased design guidance is not unique to Australia, with numerous cities introducing similar policies (City of Vancouver, 2020; Department of; Housing Planning and Local Government, 2018; Mayor of London, 2021).

Industry opinions on design standards, referred to in Australian policies alternatively as 'design criteria', 'acceptable outcomes' or 'standards', are mixed. Quantifiable standards are regarded by some as a vital mechanism to protect affordable housing but derided by others as reducing housing affordability (Cheng, 2016) or encouraging developers to provide only a base level of amenity (Karotkin, 2014; Moore et al., 2015; Mould, 2011). However, as these design policies are performance-based, developers are not required to meet all standards if they apply innovative solutions that satisfy the 'qualitative intent' of the objectives (Karotkin, 2014). Indeed, an evaluation of the implementation of the quantifiable SEPP65 policy requirements in Sydney (NSW) buildings that were developed under the policy found that, on average, buildings were implementing just 56% of the measured requirements (Foster et al., 2022). While compliance was lower than anticipated, studies also underscored the important role that a more comprehensive policy plays in shaping the built form (Allouf et al., 2020; Foster et al., 2022). For example, a multi-city study compared Sydney buildings (built under SEPP65) against buildings in Perth (WA) and Melbourne (VIC) that pre-dated the new design legislation in those states and found Sydney buildings implemented significantly more minimum requirements than buildings in other cities (Foster et al., 2022).

While the primary objective of the design policies is to improve apartment design, the new WA (Western Australian Planning Commission, 2019) and Victorian policies (The State of Victoria Department of Environment Land Water & Planning, 2016) also aspire to promote health (Foster et al., 2020). The policies are peppered with references to occupant health and wellbeing, including the importance of good design in providing 'comfortable, productive and healthy' environments (Western Australian Planning Commission, 2019). There is also explicit acknowledgement that the prior lack of planning guidance for apartments 'had led to a proliferation of buildings with windowless, tiny bedrooms and unhealthy spaces' (The State of Victoria Department of Environment Land Water & Planning, 2021, p.4). The aspirations of these policies to promote health are consistent with international examples that similarly acknowledge a relationship between design quality and health (City of British Columbia, 2019; Mayor of London, 2021).

The health ambitions of these policies are supported by a body of evidence that largely confirms that, when higher density housing realises certain design objectives, it is associated with better health among residents (Foster et al., 2020). Key design objectives addressed in apartment design policy *and* associated with health outcomes include natural ventilation (Wargocki et al., 2002; Wong & Huang, 2004), thermal comfort (Howden-Chapman et al., 2007; Lloyd et al., 2008), sunlight exposure (Brown & Jacobs, 2011; Lai et al., 2013; Nagare et al., 2021), acoustic privacy (Andargie et al., 2021; Babisch et al., 2014; Jakovljevic et al., 2009; Wu et al., 2019), apartment outlook (Amerio et al., 2020; Kaplan, 2001; Wells, 2000) and space (Amerio et al., 2020; Evans et al., 1996; Kan et al., 2022; Oswald et al., 2011; Sarkar et al., 2021), including communal space (Kim & Ohara, 2010; Kimura et al., 2008). A wide variety of outcomes have been examined to date spanning physical and mental health outcomes (e.g., blood pressure, respiratory tract infections, asthma, sick building syndrome symptoms, hypertension, depression, loneliness, sleep quality) (Foster et al., 2020). However, research and practice have predominantly focused on characteristics that prevent discomfort, dissatisfaction, or disease, rather than positive outcomes that enhance the lives of occupants (Altomonte et al., 2020).

Over recent years there has been increased emphasis on the concept of positive mental health and its contribution to a satisfying, productive life (Altomonte et al., 2020). The World Health Organisation defines mental health as 'a state of wellbeing in which every individual realises his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community' (World Health Organization, 2004, p.13). Within built environment research, there is a growing acknowledgement that building design standards and practices should aspire to promote higher level needs that enhance the physical, social and emotional lives of inhabitants, such as wellbeing, rather than settle for 'reducing the negative', where the focus might be on promoting comfort, or indeed, minimising discomfort (Altomonte et al., 2020, p.3). However, the pathways linking building design and construction to wellbeing are complex and inter-related. For example, building level exposures (e.g., daylight access, natural ventilation, internal space) can impact on health and wellbeing both directly via building-induced environmental stressors (e.g., too little or too much daylight, inadequate thermal comfort, noise annoyance, crowding), or indirectly via psychosocial and behavioural impacts (e.g., social interaction, sleep quality) (Altomonte et al., 2020; Foster et al., 2019).

While many of the overarching design policy themes have been examined for their impact on health, one notable gap in the evidence base are studies measuring policy-specific exposures, where the impact of the requirements that underpinned the design of the buildings are assessed (Foster et al., 2019). For example, numerous studies identify associations between apartment size and mental health (Evans et al., 1996; Kan et al., 2022; Oswald et al., 2011; Sarkar et al., 2021) yet until recently (Amerio et al., 2020), few have sought to identify a space threshold that could inform policy standards or test the impact of existing space requirements on health and wellbeing. This highlights the generic nature of much of the evidence and its disconnection from the policy environment, practices and legislation (Allender et al., 2009; Durand et al., 2011). In contrast, several recent studies have objectively assessed apartment buildings for their adherence with design standards, but these policy-specific measures have not, to date, been assessed in relation to residents perceptions of apartment living and/or health outcomes to evaluate their impact (Abidi & Rajagopalan, 2020; Allouf et al., 2020; Foster et al., 2022).

Given the increasing reliance on design policies to improve the quality of apartment housing – and the health aspirations of these policies – there is a need for research that assesses whether apartments that implement more policy-specific requirements positively impact the experience and wellbeing of apartment dwellers. This study measured and scored apartments based on the implementation of 96 policy-specific design requirements drawn from three Australian state policies to examine associations between policy implementation, residents' experiences of apartment design and mental wellbeing (see Fig. 1 conceptual model). The study aims to assess: (1) whether residents living in apartments with increased implementation of minimum design requirements perceive better apartment design; and (2) whether objectively measured design requirements and residents' subjective perceptions of good design are associated with mental wellbeing.

2. Method

2.1. Study context

The High Life Study is a cross-sectional study of the association between apartment design policy and residents' health and wellbeing (Foster et al., 2019). Apartment buildings in three Australian cities (Sydney, Melbourne, and Perth) were stratified by area disadvantage and randomly selected. To be eligible for inclusion, buildings were required to have three or more storeys, at least 40 apartments (with no maximum size limit), be built between 2006 and 2016, and that the

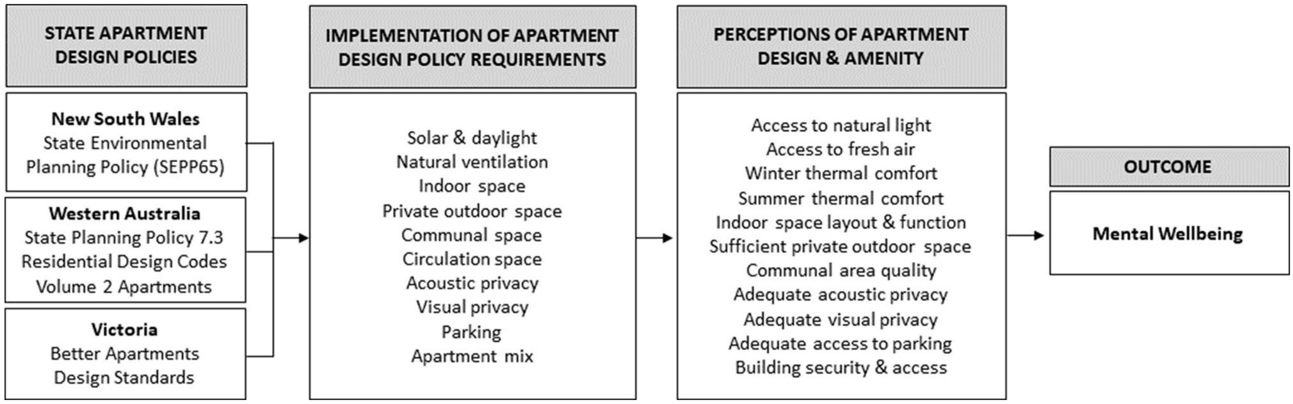

Fig. 1. Conceptual model connecting apartment design policy with positive mental wellbeing.

endorsed architectural or development plans be available. Building residents were invited to complete a self-report survey on apartment living, including questions on their apartment and building design, and mental wellbeing. Survey administration occurred over a two-year period from October 2017 to October 2019 (during spring and autumn). The study was approved by the RMIT University Design and Social Context College Human Ethics Advisory Network (CHEAN B 21146-10/17) and the University of Western Australia Human Ethics Research Committee (RA/4/1/8735). . The study is described in full elsewhere (Foster et al., 2019). After excluding participants with missing data, the analytic sample comprised 1072 participants from 114 different apartment complexes.

2.2. Study variables

2.2.1. Policy-specific design requirements

Apartment design policies and guidelines from NSW, Victoria and WA (NSW Department of Planning and Environment, 2015; The State of Victoria Department of Environment Land Water & Planning, 2016; Western Australian Planning Commission, 2019) were reviewed for the quantifiable requirements related to ten design objectives: (1) solar and daylight access; (2) natural ventilation; (3) acoustic privacy; (4) visual privacy; (5) indoor space; (6) private open space; (7) communal space; (8) circulation space; (9) parking; and (10) apartment mix. Plans and elevations for each building were systematically screened and data pertaining to each requirement were extracted by architecturally qualified research assistants. Methods included the visual inspection of layouts, measuring dimensions from scaled pdfs, measuring building separation and setbacks in Nearmap, and sun path modelling. Extracted data were then used to calculate 96 policy-specific design requirements (Supplementary Table S1). Thermal comfort was not addressed by this process because the policies included few requirements that could be measured with our methodology and any relevant requirements were embedded within the solar and daylight access and natural ventilation scores.

Most requirements were assigned a score from 0 to 1 based on the level of implementation. For example, balcony dimensions were used to calculate whether the balcony met the minimum area stipulated for that apartment type (e.g., primary balconies for 2-bedroom apartments should be at least 10 m^2 based on the NSW and WA policies). If the balcony met the standard, the apartment was allocated a point. One exception to this scoring range was the ceiling height to room depth ratio measures, where policies identified both acceptable and optimum thresholds, so the scoring was amended to reflect the two possible levels (i.e., acceptable and optimum ratios were allocated 1.0 and 1.5 points, respectively). Points assigned for the implementation of each requirement were summed to create an apartment-level sub-score for each of the ten design objectives (e.g., natural ventilation, indoor space) and a combined, total policy implementation score. The method is described in detail elsewhere (Hooper et al. 2022).

Levels of implementation were calculated as the percentage of all policy requirements implemented (i.e., apartments with higher scores implemented more policy requirements). Scores were divided by 10 for ease of interpretation (i.e., scores are interpreted for every 10% increase in policy implementation). The total possible scores attainable for each apartment varied depending on the design of the apartment and building. That is, apartments were only scored on the requirements that were relevant, so apartments without multiple bedrooms, single aspects, or courtyards and balconies were not scored for the implementation of requirements specific to these features. When calculating sub-scores, requirements could be counted in multiple design objective scores (e.g., 'every habitable room must have a window in an external wall' was included in 'solar and daylight access' and 'ventilation') but were only counted once in the overall policy implementation score.

In this study, implementation scores were based on the pooled requirements drawn from the state policies, rather than focus on a single policy, as the buildings were drawn from three cities with different operational policies. Further, the sampled buildings in Perth and Melbourne pre-dated the introduction of the apartment design policies in WA (effective 2019) and Victoria (effective 2017). Thus, the scores are not intended to represent the on-ground delivery (and potential impact) of one specific policy, but rather to capture the holistic delivery of minimum standards in an apartment as a proxy for achieving a base level of design quality.

2.2.2. Perceptions of apartment design and amenity

Survey questions on apartment and building design were developed to assess residents' perceptions of good design. Participants were asked about their agreement with a series of statements based on a five-point Likert scale (1 = strongly disagree; 5 = strongly agree). Examples include 'I can easily move furniture around or change how I use the rooms in my apartment' and 'my apartment gets direct sunlight all year round'. Factor analysis using principal axis factoring and varimax rotation was used to identify a series of latent underlying constructs, with factor loadings higher than ≥0.40 interpreted as measuring the same construct (Ford et al., 1986). Constructs included: access to natural light (4 items, Cronbach's α = 0.805), access to fresh air (5 items, Cronbach's α = 0.753), summer thermal comfort (3 items, Cronbach's α = 804), winter thermal comfort (4 items, Cronbach's α = 0.669), indoor space and layout (7 items, Cronbach's α = 0.855), sufficient private outdoor space (2 items, Cronbach's α = 0.845), acoustic privacy (4 items, Cronbach's α = 0.679), visual privacy (3 items, Cronbach's α = 0.694), communal area quality (4 items, Cronbach's α = 0.738), building security and access (3 items, Cronbach's α = 0.624) and adequate parking (2 items, Cronbach's α = 0.550). Items are listed in Supplementary Table S2. All scales were continuous (range 1–5), except for communal area quality which was also used as a categorical variable as some participants did not have a communal area in their building (i.e., no communal area; scores of ≤3.25 = low quality area; scores of >3.25 = high quality area).

2.2.3. Adjustment variables

Demographic information included age (years), sex (male; female), education (secondary or less; trade, apprenticeship or certificate; bachelor degree or higher), household income (<$60,000; $60,001-$100,000; >$100,000; not reported), living arrangement (partner; no partner); and children in the household (no children; children).

2.2.4. Outcome variable

Positive mental health was measured using the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) (Tennant et al., 2007). Participants responded to 14 items relating to their state of mental wellbeing (thoughts and feelings) in the previous two weeks. Items include optimism, perception of usefulness, confidence, social interaction, energy, and interest in new activities. The complete list of items is documented elsewhere (Tennant et al., 2007). The scale was scored by summing the responses to each item answered (range: 14–70, Cronbach's α = 0.927).

2.3. Statistical analysis

Multi-level linear regression analyses were conducted using STATA to account for the three-level hierarchical data structure (i.e., individuals nested within buildings nested within neighbourhoods) (Stata Corporation, 2016). All models adjusted for age, sex, living arrangement, children at home, education, and household income. Initially, policy implementation sub-scores were examined for associations with residents' perceptions of apartment design and amenity. Each implementation sub-score (i.e., natural ventilation, indoor space, etc.) was examined against the most appropriate/aligned perception scale. For example, the indoor space implementation score was paired with perceptions of indoor space and layout; whereas the solar and daylight implementation score was assessed against perceptions of natural light, summer thermal comfort and winter thermal comfort, as these design requirements could plausibly relate to all three constructs. Next, models examined the associations between: (1) Residents' perceptions of apartment design and amenity and mental wellbeing; and (2) policy implementation scores, including total policy implementation and each of the sub-scores (e.g., indoor space, daylight and solar access) and mental wellbeing. Models initially examined associations between each exposure variable (i.e., subjective perception or objective policy implementation score) and wellbeing individually. Any statistically significant variables ($p < 0.05$) were included together in a subsequent multivariable model.

3. Results

The mean age of participants was 42 years (Table 1). The sample comprised more females than males, was generally well educated (67% had a bachelor's degree), and about half had household incomes over $100,000. Almost 52% of participants lived with a partner, but just 12% had children living at home. The mean mental wellbeing score was 50.6. Participants living with a partner, with a bachelor degree or higher and those on higher incomes had higher mental wellbeing scores.

Associations between the policy implementation sub-scores and the most appropriate perceptions of apartment design and amenity are presented in Table 2. The implementation of solar and daylight requirements was positively associated with perceptions of natural light and winter thermal comfort, but negatively associated with summer thermal comfort. Implementation scores for indoor space, private open space, communal space and parking were all significantly and positively associated with their most comparable perception scale. For example, for every 10% increase in the implementation of design requirements related to the provision and design of private open space (i.e., balconies and courtyards), participants perceptions of the amenity of this space increased by 0.13 ($p = 0.000$).

All perceptions of apartment and building amenity were positively and significantly associated with mental wellbeing, except for natural light which was only marginally non-significant (Table 3). When all

Table 1
Characteristics of the sample.

		Positive mental wellbeing	
	% (n)	Mean (SE)	p
Sex			
Male	38.7 (415)	50.2 (0.4)	0.276
Female	61.3 (657)	50.8 (0.3)	
Living with partner			
Partner	51.7 (554)	52.0 (0.3)	**0.000**
No partner	48.3 (518)	49.1 (0.4)	
Children at home			
Yes	11.8 (126)	51.5 (0.3)	0.209
No	88.2 (946)	50.5 (0.8)	
Education			
Secondary or less	14.0 (150)	49.8 (0.8)	**0.005**
Trade/certificate	18.8 (202)	49.1 (0.6)	
Bachelor or higher	67.2 (720)	51.2 (0.3)	
Household income			
$0 - $60,000	22.9 (246)	49.2 (0.6)	**0.011**
$60,001 - $100,000	24.7 (265)	50.3 (0.5)	
>$100,001	48.5 (520)	51.3 (0.4)	
Not reported	3.8 (41)	52.0 (1.3)	
Age (years)[a]	41.7 (15.4)	–	–

Bold denotes $p < 0.05$.
[a] Mean and standard deviation presented for continuous variables.

Table 2
Associations between the implementation of apartment design policy requirements and residents' perceptions of design and amenity.

Policy requirement implementation scores	Perceptions of design & amenity	β	95% CI	P
Solar & daylight	Natural light	0.84	0.04, 0.12	**0.000**
	Winter thermal comfort	0.38	0.00, 0.07	**0.039**
	Summer thermal comfort	−0.06	−0.10, −0.01	**0.014**
Natural ventilation	Natural ventilation	0.02	−0.02, 0.05	0.282
	Winter thermal comfort	−0.02	−0.05, −0.02	0.336
	Summer thermal comfort	0.02	−0.02, 0.06	0.377
Indoor space	Indoor space and layout	0.07	0.02, 0.12	**0.007**
Private open space	Private outdoor space	0.13	0.09, 0.16	**0.000**
Communal space	Communal area quality[1]	0.18	0.14, 0.22	**0.000**
Circulation space	Communal area quality[1]	0.03	−0.00, 0.06	0.078
Acoustic privacy	Acoustic privacy	−0.03	−0.08, 0.02	0.218
Visual privacy	Visual privacy	0.04	−0.01, 0.09	0.101
Parking	Parking	0.10	0.03, 0.02	**0.007**

Apartment mix implementation score was not included as there was no aligned perception scale.
Models adjust for age, sex, living arrangement, children at home, education, and household income, and for the clustering of apartments within buildings and buildings within neighbourhoods.
Perceptions of communal area quality sample n = 907.
Bold denotes $p < 0.05$.

Table 3
Associations between residents' perceptions of design and amenity and mental wellbeing.

		Single factor models			Multivariable models		
Design perceptions	Mean (SD)	β	95% CI	P	β	95% CI	P
Natural light	3.99 (0.82)	0.58	−0.02, 1.19	0.059	–	–	–
Natural ventilation	3.72 (0.79)	2.32	1.68, 2.97	**0.000**	1.08	0.29, 1.88	**0.008**
Winter thermal comfort	3.53 (0.78)	1.22	0.56, 1.87	**0.000**	0.28	−0.38, 0.94	0.411
Summer thermal comfort	2.96 (1.03)	1.34	0.83, 1.85	**0.000**	0.79	0.27, 1.31	**0.003**
Indoor space & layout	3.54 (0.76)	2.38	1.72, 3.03	**0.000**	1.26	0.49, 2.02	**0.001**
Private outdoor space	3.74 (1.02)	1.14	0.64, 1.65	**0.000**	0.24	−0.31, 0.78	0.395
Acoustic privacy	3.29 (0.85)	1.35	0.75, 1.94	**0.000**	−0.21	−0.90, 0.49	0.560
Visual privacy	3.38 (0.98)	0.96	0.42, 1.50	**0.000**	0.34	−0.22, 0.90	0.236
Parking	3.09 (1.08)	0.88	0.41, 1.36	**0.000**	−0.15	−0.65, 0.35	0.559
Building security	4.20 (0.60)	2.10	1.27, 2.94	**0.000**	0.80	−0.90, 1.69	0.079
Communal Area[a]							
No area provided	15.4 (165)						
Low quality area	39.7 (426)	−0.81	−2.33, 0.71	0.298	0.16	−1.326, 1.635	0.838
High quality area	44.9 (481)	2.19	0.66, 3.72	**0.005**	1.94	0.469, 3.406	**0.010**

Models adjust for age, sex, living arrangement, children at home, education, and household income, and for the clustering of apartments within buildings and buildings within neighbourhoods.
Bold denotes $p < 0.05$.
[a] %(n) presented for categorical variable.

significant perceptions were modelled together (i.e., multivariable model), four perceptions remained independently associated with wellbeing: natural ventilation, summer thermal comfort, indoor space and layout and communal area quality. For example, for every unit increase in perceptions of indoor space and layout, mental wellbeing increased by 1.26 points ($p = 0.001$).

The implementation of design policy requirements varied across the design objectives (see Table 4). On average, apartments were implementing about 60% of the requirements, however this ranged from 83% for the private open space requirements down to 43% for circulation space requirements. Neither the total implementation score, nor the sub-scores focusing on specific design objectives, were directly associated with mental wellbeing.

4. Discussion

This study appears to be the first to comprehensively examine whether the implementation of policy-specific minimum design requirements impacts on residents' experiences of apartment living and mental wellbeing. Each participant's apartment was scored for the execution of up to 96 policy-specific requirements, summarised as an overall implementation score, and individual sub-scores for different policy objectives (e.g., indoor space, natural ventilation). While other studies have examined the impact of indoor environments, as assessed for their green or WELL building credentials (Allen et al., 2015; Altomonte et al., 2020), our focus on a broad range of design requirements is unique and tailored to providing policy-makers with an empirical evaluation of how these policy instruments impact the lives of residents.

Table 4
Associations between the implementation of apartment design policy requirements and mental wellbeing.

Implementation scores	Mean (SD)	β	95% CI	P
Total implementation	59.85 (7.51)	0.36	−0.39, 1.10	0.346
Solar & daylight	55.66 (13.61)	−0.33	−0.71, 0.06	0.094
Natural ventilation	53.69 (13.91)	−0.10	−0.48, 0.27	0.583
Indoor space	61.94 (10.53)	0.15	−0.36, 0.66	0.564
Private open space	83.20 (16.44)	0.18	−0.14, 0.50	0.269
Communal space	46.29 (22.87)	0.15	−0.10, 0.41	0.237
Circulation space	43.54 (23.03)	0.05	−0.19, 0.29	0.680
Acoustic privacy	72.22 (10.89)	0.28	−0.20, 0.75	0.256
Visual privacy	58.31 (14.33)	−0.04	−0.42, 0.34	0.834
Parking	74.46 (14.86)	0.11	−0.28, 0.49	0.586
Apartment mix	66.07 (11.88)	−0.02	−0.48, 0.44	0.929

Models adjust for age, sex, living arrangement, children at home, education, and household income, and for the clustering of apartments within buildings and buildings within neighbourhoods.

We anticipated that increased implementation of minimum requirements would equate to higher mental wellbeing, however there were no significant associations. In part, this may be due to our focus on mental wellbeing, which is impacted by numerous individual, social and built environment factors (World Health Organization and Calouste Gulbenkian Foundation, 2014), and the complex and indirect pathways that link our policy exposure measures and wellbeing (Foster et al., 2019; Wierzbicka et al., 2018). However, while there was no direct relationship between the implementation scores and wellbeing, the implementation of minimum requirements was significantly associated with residents' perceptions of apartment design and amenity. Residents' living in apartments with greater implementation of requirements for solar and daylight, indoor space, private open space, communal space, and parking had more positive perceptions of their apartment in terms of its natural light and winter thermal comfort, indoor space and layout, private open space, communal area quality, and parking, respectively. These findings indicate that, when implemented as intended, the minimum requirements included in Australian design policies have a positive impact on apartment residents. That is, they perceive their homes to be light and bright, warm in winter, spacious, versatile, and functional. The study vindicates the decisions of the government agencies who advocated for comprehensive design policies, including minimum standards, to improve the design of residential apartment buildings.

However, consistent with other studies of the built environment that identify a mismatch between perceived and objective measures (Koohsari et al., 2015), some associations between the implementation scores and perceptions of design were non-significant. Indeed, one association was in the opposite direction, with increased implementation of solar and daylight requirements negatively associated with summer thermal comfort. This likely relates to the measurement of solar and daylight requirements and perceived summer thermal comfort, and the Australian climate. The implementation score comprised requirements on the size and presence of windows, apartment aspects, room/apartment depths and hours of direct sunlight that, in combination, would optimise the number of apartments receiving sunlight (NSW Department of Planning and Environment, 2015; Western Australian Planning Commission, 2019). This was assessed against perceived summer thermal comfort, which combined items on feeling hot in the apartment, the use of an air conditioner in summer, and direct sunlight to the apartment in summer. As our study cities are located in warm or mild temperate climactic zones, where summers can exceed the human comfort range (Australian Bureau of Statistics, 2013, p. 4671), it is unsurprising that requirements intended to increase daylight to apartments negatively impacted summer thermal comfort. However, this is not only a challenge for hotter climates – a study of high-rise apartments in London found that the attributes that increased sunlight exposure (i.e., orientation, higher floor level, high glazing ratios) exceeded sunlight requirements and increased vulnerability to overheating in summer (Nebia & Tabet Aoul, 2017). This embodies the challenge of designing apartments that promote access to sunlight and thermal comfort in both summer and winter, as the design requirements intended to improve sunlight access undermined summer thermal comfort but promoted winter thermal comfort.

While objective policy implementation did not impact wellbeing directly, its affects are likely to be indirect. All the perceptions of design and amenity were significantly and positively associated with wellbeing, except for natural light which was marginally significant. This is consistent with other studies that have tested both objective and subjective measures of the built environment and found the more immediate, proximate perceptions are typically more powerful predictors of behaviour than distal objective measures (Foster et al., 2016; Orstad et al., 2017). Furthermore, natural ventilation, summer thermal comfort, indoor space and layout, and communal area quality were independently associated with wellbeing in the multivariable model. This aligns with previous studies on the indoor environment that emphasise the importance of natural ventilation (Wargocki et al., 2002; Wong & Huang, 2004) and thermal comfort (Howden-Chapman et al., 2007; Lloyd et al., 2008) to health. Indeed, natural ventilation and summer thermal comfort are interrelated, as apartments that promote air flow help mitigate the summer heat and reduce reliance on air-conditioning for cooling (Wong & Huang, 2004), which has co-benefits for reducing apartments' greenhouse gas emissions (Giles-Corti et al., 2022). Further, for lower income residents, the financial burden of heating or cooling the apartment can be an additional source of stress that diminishes wellbeing (Howden-Chapman et al., 2012). In our study, the (objective) implementation of sunlight requirements detracted from summer thermal comfort, yet summer thermal comfort was a predictor of mental wellbeing. It reinforces the need to implement additional measures that mitigate direct sunlight in summer (e.g., shading, shutters, high performance glazing, insulation on external walls). Such measures are stipulated in Australian design policies but could not be assessed using our methodology. Further research is required to assess whether sunlight mitigation measures are being implemented as intended and evaluate their capacity to improve summer thermal comfort. Indeed, international evidence suggests that passive cooling devices are often not installed as intended by developers in colder climates where summer overheating is underestimated (Lomas & Porritt, 2017).

Consistent with other studies (Amerio et al., 2020; Kan et al., 2022; Peters & Halleran, 2021; Sarkar et al., 2021), perceptions of indoor space and layout and communal area quality were also independently associated with wellbeing, and together highlight the importance of both private and semi-private spaces. Internal private space typically impacts wellbeing via the mechanism of crowding (Evans et al., 1996; Guite et al., 2006), but quality outdoor communal areas (i.e., well-maintained areas with greenery and sufficient space and facilities to enable flexible use) may help to minimise crowding by providing respite from the indoor environment, exposure to nature, and the opportunity to interact with neighbours (Bandara et al., 2020) Alarmingly, internal apartment space has been reducing – recent data reveals the average floor area of Australian apartments shrunk by almost 15% over the past 15 years (i.e., 2005–2020), with Sydney decreases worse than other cities at 19% (ABS, 2020). In part, this may be symptomatic of the increased supply of one and two-bedroom apartments to cater to the investment market (City of Melbourne, 2013), however in the context of COVID lockdowns and increased time at home, the apparent falls in apartment size are concerning (D'Alessandro et al., 2020; Peters & Halleran, 2021). Our positive association between perceptions of indoor space and wellbeing underscores the need for design policies and approval processes that ensure apartments have sufficient floor areas and functional layouts. Indeed, a recent study found that, on average, 83% of apartments in buildings developed under SEPP65 in Sydney met minimum space standards, whereas rates were far lower in Perth and Melbourne (i.e., 64% and 32% respectively), where policy guidance at the time of building approval was comparatively weak (Foster et al., 2022).

This study has several strengths, including: (1) the detailed measurement of the implementation of policy-specific design requirements derived from Australian apartment design policies; (2) a holistic approach that combines these objective metrics with residents' perceptions of design and amenity, and self-reported mental wellbeing; (3) a study design that sampled apartment buildings and participants from three Australian cities, different socio-economic areas (i.e., low, mid and relatively high disadvantage) and different distances from the city centre to maximise variability in apartment design and resident demographics; and (4) our modelling approach that accounted for the clustering of participants within buildings and neighbourhoods.

While our study makes a unique contribution to the evidence base, it also has several limitations: (1) the cross-sectional study design means causality cannot be inferred; (2) participants were relatively well educated, with good incomes and few had children, which could limit the generalisability of our findings to other populations; and (3) as the spatial layouts of apartments have changed considerably over the decades (Yang et al., 2022) and we were interested in the role of contemporary requirements, we focused on apartment buildings developed in the past 20 years. While this again limits generalisability, it ensures our results are specific to the current influx of apartment development, and thus more relevant to current policy and practice.

Other limitations relate to our methodology for scoring minimum design standards, which could affect the findings. We scored apartments based on their implementation of quantifiable minimum requirements from three state policies. While a higher score reflects an apartment that meets more of the requirements, in practice these are performance-based policies and, as such, architects/developers might achieve the policy objectives via other (unmeasured) innovations (Mould, 2011). Further, many design standards are based on industry practice and intuition, rather than empirical evidence (Foster et al., 2020), and there has been little evaluation of whether the requirement thresholds are appropriate. For example, the National Construction Code, WA and NSW policies all state that the size of windows in habitable rooms must be $\geq$ 10% of the floor area, however a recent study of 12 Melbourne apartments found this threshold needed to be closer to 30% to deliver acceptable daylight to south-facing rooms (Abidi & Rajagopalan, 2020). The appropriateness of policy cut points for different minimum requirements was outside the scope of this study but remains an important area for future research. Finally, we used a simple scoring system whereby all requirements were weighted equally and combined into scores for overarching policy themes (e.g., communal space). Undoubtedly some requirements will be more important for wellbeing than others, however the intention of this study was to test the impact of the holistic delivery of minimum policy requirements, rather than identify the most important individual requirements. Future work could unpack the role of specific requirements or explore data driven solutions that group apartments/buildings based on their similarities and differences (i.e., cluster analysis), rather than policy-derived themed scores. Despite these limitations, our implementation scores were generally well aligned with their paired subjective measures of design quality, which validates the approach adopted in this study.

5. Conclusion

Our study responded to calls for more holistic explorations of living environments (Ucci & Godefroy, 2020; Wierzbicka et al., 2018), including how the architectural design of apartments impacts on inhabitants (Barros et al., 2019), and addressed the lack of research exploring the impact of policy-specific measures of apartment building design (Foster et al., 2020). We examined the associations between apartment design and residents' mental wellbeing by exploring: (1) the implementation of requirements derived from Australian apartment design policies; (2) residents' perceptions of apartment design and amenity; and (3) the inter-relationships between these variables. While the objective policy implementation scores did not directly impact mental wellbeing, residents' perceptions of the apartment were related to its design. Numerous implementation scores were associated with residents' subjective experience of design, and several design perceptions (namely natural ventilation, summer thermal comfort, indoor space and layout, and communal area quality) were independently associated with positive mental wellbeing. The findings emphasise the importance of planning instruments and design review and approval processes that ensure the implementation minimum policy standards.

CRediT statement

Sarah Foster: Conceptualisation, Methodology, Writing – Original Draft, Supervision; Funding Acquisition. **Paula Hooper**: Investigation; Writing - Review & Editing. **Gavin Turrell**: Formal analysis; Writing - Review & Editing. **Clover Maitland**: Investigation; Data Curation; Writing - Review & Editing. **Billie Giles-Corti:** Writing - Review & Editing. **Alexandra Kleeman**: Data Curation; Writing - Review & Editing.

Declaration of competing interest

There are no potential conflicts of interest to disclose and all individuals contributing to the paper have been acknowledged. All authors contributed to the research design, analysis and interpretation of data, and content of the article. The paper has not been published or submitted elsewhere for publication.

Data availability

Data will be made available on request.

Acknowledgements

The High Life Study is funded by an ARC, DECRA (DE160100140) and the Western Australian (WA) Health Promotion Foundation (Healthway; #31986). SF is supported by an ARC Future Fellowship (FT210100899). Study collaborators providing in-kind support include the Department of Planning Lands and Heritage (WA), Office of the Government Architect (WA), Planning Institute of Australia (PIA), Development WA and Heart Foundation. The assistance of apartment residents, resident associations, architects, developers and local government is gratefully acknowledged.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2022.101301.

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