



Association of the built environments and health-related quality of life in community-dwelling older adults: a cross-sectional study

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Abstract

Purpose The relationship between built environments and the quality of life (QoL) of the elderly has gained great attention in recent years. However, most QoL studies have been conducted in western countries; thus, limited research was found in Asia, in which the population density, urban forms, narrow roadways, and land use patterns are more compact and highly mixed in terms of use. Therefore, the purpose of this study was an interdisciplinary analysis of two national datasets, the National Land Use Investigation and the National Health Interview Survey, to explore the relationship between built environments and the health-related quality of life of older adults in Taiwan.

Methods Eight types of built environments at the township level were calculated, and 1222 nationally representative older adults aged 65 and older were recruited. The outcome variable was health-related QoL as measured using the EQ-5D, including utility score and the EQ-VAS. Statistical methods included descriptive analysis, bivariate analysis, and mixed-effects logistic regression analysis, which were conducted using SAS 9.4 software.

Results The results showed that a significant relationship exists between cultural and historical facilities and low EQ-VAS; none of the built environments were found to be related to the EQ-5D. Individual factors are the main determinants of the EQ-5D of older adults in Taiwan. Positive relationships were found if older adults were engaging in physical activities and social participation.

Conclusions We suggest that building a supportive environment in which elderly people could consistently engage in physical activities and social participation is another potential approach that might contribute to active aging.

Keywords Built environments · Quality of life · The elderly · EQ-5D · Multi-level analysis

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Introduction

Many countries worldwide face the challenge of a growing aging population. The global population of older persons in 2015 is projected to be more than double by 2050, reaching nearly 2.1 billion [1]. At least 22% of this population will

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comprise older adults aged more than 65 [2, 3]. Aging is a necessary process in human life. However, with age, people are faced with illnesses and a decline in their physical functions, which might in turn reduce their quality of life [4, 5].

According to the World Health Organization (WHO), quality of life (QoL) refers to individuals' perceptions of their position in life in the context of the culture and value systems in which they live, and in relation to their goals, expectations, standards, and concerns [6]. This reflects that QoL is a subjective evaluation based on cultural, social, and environmental contexts. Due to the significant relationship between health and quality of life, many health-related quality of life (HRQoL) scales have been developed, such as the short-form 36 (SF-36), World Health Organization Quality of Life (WHOQOL), and the EuroQol-5 dimensions (EQ-5D). The HRQoL is a multidimensional concept that can be used to assess not only general health but also psychological, functional, and existential health [7–9]. In contrast to the large number of questions in the SF-36 and WHOQOL, the six simplified items of the EQ-5D make it a more suitable and easier measurement for the purposes of a national health survey based on the fieldwork situation, especially in the case of an older population [10–12].

Faced with the rapid growth of the aging population worldwide, the relationship between built environments and the quality of life of the elderly has gained significant attention in recent years [13]. Built environments such as parks, open spaces, recreational destinations, grocery shops, social welfare and medical services facilities, sidewalks, public transportation facilities and routes, and land use mixed are frequently discussed in the research related to the health and behavior of older adults, regardless of whether objective or subject measurements are used [14–16]. In addition, “third places” providing for unorganized social interaction such as recreation ground or restaurant or shopping mall are another type of built environment, which are different from other places where social interaction might occur in that without needing to play a “role” [17].

The theoretical hypotheses between built environment and human health and quality of life were derived from the health map model [18, 19], which reveals the complex relationships among health, environments (physical/social/economic), and the entire eco-system [20, 21]. Namely, it indicates that “built environment” affects human activity directly, such as travel patterns to destinations including working, shopping and learning. In addition, it also indirectly affects social networks, economic efficiency, and new employment opportunities. These impacts of built environment are shown to be the determinants of health and well-being. Hence, an integrated ecological model of the settlement environment was presented in the health map, which inspires comprehensive analysis and invites researchers in different fields to explore the impacts within its framework. Furthermore, WHO defined active

ageing as “the process of optimizing opportunities for health, participation, and security in order to enhance quality of life as people age”, which shows an ongoing need to explore the relationship between built environment and health or well-being for older adults [22].

However, compared to western countries, the population density is greater in Asia, and the narrow roadways and land use are more compact and highly mixed, resulting in a substantial number of places and services having little importance to older adults that do not consider other management issues such as noise and cleanliness [14]. Due to the different culture and contextual background, exploring the role of built environments and the quality of life in older adults is of interest in Asia and might provide another approach to improving the QoL of older populations in aged societies.

Most previous studies exploring the association between physical environments and QoL have been conducted in western countries and have focused more on factors at the individual level, such as demographics, psychological factors, lifestyle, social support, access to resources, and health status [7, 23–25]. Very few studies have explored this association from a multi-level perspective in countries in Asia, especially in terms of an older population [16, 26–28]. Public health and urban planning are historically linked due to the unhealthy conditions that existed in the nineteenth century. Spatial planning has been recognized as an effective approach to affect behavior, health status, and quality of life [29–31]. Therefore, an ecological approach that considers both individual and environmental factors has been suggested for the elderly in order to improve their quality of life [32–35].

Taiwan became an aged society in 2018, and by 2026, it will be categorized as a super-aged society (when the proportion of older adults aged 65 and older exceeds 14% and 20%, a country is called an aged society and a super-aged society, respectively). The older population in Taiwan has increased rapidly since 2011 and exceeded the younger generation (0–14 years old) in 2017 as a consequence of the post-war baby boomers and a very low birth-rate [36]. With the shrinking of family members and support systems, it is important to enable older adults to engage in physical activity and social activities so they can avoid becoming disabled, can live independently, and can experience a good quality of life in their later years.

However, the population density, the urban fabric, the land use patterns, and the overall lifestyle in Asian countries are very different from those in western countries. For example, there were 58.4 scooters for every one hundred persons in Taiwan, which was 1.7 times higher than the 33.7 cars per one hundred person in 2017. If using populations of more than 20,000 as the definition of urban districts, as suggested by the United Nations, 94.6% of the population of Taiwan lives in urban areas [37]. Thus, urban areas have

been re-defined as populations of more than 50,000 at the township level in Taiwan, which is higher than that in western countries [38].

Facing the coming of a super-aged society in 2026, it is worth focusing on how to maintain and enhance the quality of life of the older population by improving the existing built environments. Hence, this study is based on a multi-level perspective to develop an interdisciplinary analysis by which to examine the association between the built environments in townships and the health-related quality of life among the older population in Taiwan.

Methods

Data source

A multi-level design and two national datasets were used in this study to examine the relationship between built environments and the health-related quality of life in older adults. These two national datasets included (1) the 2009 National Health Interview Survey (NHIS) (data at individual level), and (2) the 2006 National Land Use Investigation (data at the township level). The National Land Use Investigation is conducted every ten years, and the last wave was taken in 1995. We used the data from the 2006 National Land Use Investigation, which is the closest to the data from the 2009 National Health Interview Survey, to analyze the relationship.

Participants

The individual data in this study was from the 2009 Taiwan National Health Interview Survey (NHIS), which is a multi-stage stratified systematic sampling design and is a national and city/county representative sample of the entire population of Taiwan. Detail sampling procedure was described in online supplement: Methods.

Figure 1 shows the sample enrollment procedure. Initially, of the total of 2,904 adults aged 65 and over in the 2009 NHIS survey, about half of the participants were randomly selected to answer the optional questionnaires (including the EQ-5D). Thus, 1457 samples were obtained in this study. After excluding those living in institutions, outlying islands (Kinmen, Matsu, and Penghu), those with no living area data, and fewer than three samples in each area, only 1222 adults aged 65 years and above were included in the analysis.

Measurements- outcome variable

In this study, we used the EQ-5D as the outcome variable for measuring health-related quality of life for older adults [39]. The EQ-5D includes two parts, EQ-5D utility

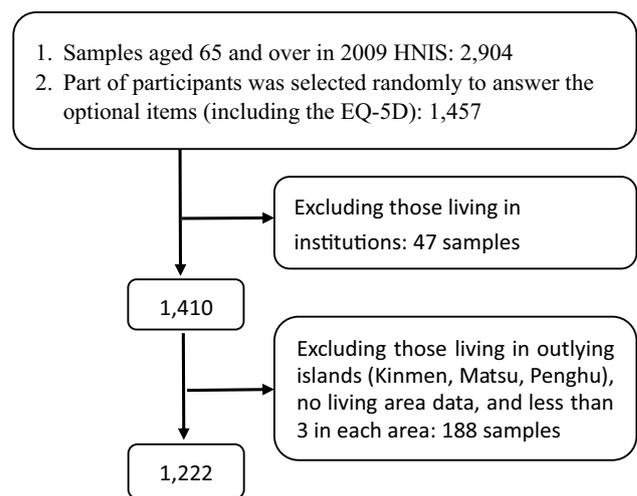


Fig. 1 Participant enrollment procedure

and EQ-VAS. The first part (EQ-5D utility) contains five domains: mobility, self-care, usual activity, pain/discomfort, and anxiety/depression, for which three levels of severity can be expressed in each domain: having no problems, having some or moderate problems, and being unable to do/having extreme problems. The results of these five questions were then weighted to produce a single summary EQ-5D utility score by using a time trade-off valuation technique [39–41]. The EQ-5D utility score usually ranges from less than 0 (where 0 is equal to death; negative scores are considered to be worse than death) to 1 (full health) [39, 40]. After calculating the EQ-5D by the tariff of Taiwanese version, the EQ-5D utility score ranges from -0.674 to 1 [41].

The second part, the EQ-VAS, comprises a 20-cm vertical, visual analog scale, for which values range from 0 (the worst health you can imagine) to 100 (the best health you can imagine). The validity and weighted utility score for the EQ-5D have been examined previously in Taiwan [12, 41, 42].

Measurements- explanatory variables

Individual level

Other factors at the individual level included gender (male/female), age (< 70 years, 70–79 years, ≥ 80 years), educational level (illiterate, literate, ≤ 6 years, ≥ 7 years), spouse (yes/no), smoking (yes/no), alcohol consumption (yes/no), and number of diseases, including hypertension, diabetes, stroke, kidney disease, heart disease, and cancer. Physical activity (yes/no): This analysis used 150 min/week as the cutoff point to define whether these older adults engaged in physical activity. Social participation (yes/no): If older adults did not participate in any one of the four activities,

including caring for children, volunteering, neighborhood activities, and religious activities, this was defined as a lack of social participation.

Ecological level

The independent variables in this study were built environments. The built environments were obtained from the National Land Use Investigation which is conducted every 10 years and for which the most recent year is 2006. In this study, eight types of the built environments from two categories of land use related to living environments including public use and recreational use were examined. Detail description of built environments please refer to online supplement: Methods.

All data was obtained from the 2006 National Land Use Investigation conducted by the National Geographic Information System. Arc GIS 10.3.2 (Esri Corporation, Redlands, CA, USA) was used to intersect and calculate the built environment data, and the unit of each township was calculated as per capita area (m²). In the analysis, the built environment data was divided into quartiles because of the skewness (with the lowest per capita area serving as the reference category), which has been done in other studies [43–45], and its relationship to the outcome variable was examined.

Also, studies have found that urbanization [46–48] and neighborhood income [49, 50] are related to both behavior and health. Accordingly, urbanization and median township income were considered as control variables at the ecological level. The urbanization level of townships was divided into 5 levels [44], and the median township income was obtained from the 2006 tax statistics provided by the Ministry of Finance. The unit for each township was calculated as per capita thousand dollars (NT\$), and the median township income was also divided into quartiles in this study. Figure 2 describes the study framework.

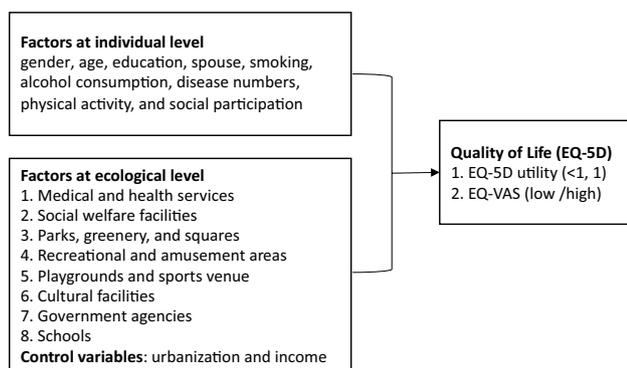


Fig. 2 Study framework

Statistical methods

The study methodology included three stages: Firstly, the built environment data were obtained by using a GIS overlay analysis. Secondly, the ecological data and individual data were merged to analyze the relationship between the built environments and the EQ-5D scores of the older adults under consideration. Due to the skewness of the EQ-5D utility and the EQ-VAS score (Kolmogorov–Smirnov test, $p < 0.05$), both EQ-5D utility and EQ-VAS were divided into low (0) and high (1) based on the median score. Mixed-effects models using PROC GLIMMIX procedure for categorical data [51] were performed using a multilevel logistic regression. All analyses were carried out using SAS 9.4 software (SAS Institute, Cary, NC, USA).

Six models were conducted to examine the association between ecological and individual factors and the EQ-5D using a multi-level logistic regression. Models 1–3 showed the influence of built environments on full health (EQ-5D utility = 1); models 4–6 examined the relationship between the built environments and the EQ-VAS. A two-level analysis was conducted, where Level 1 examined the association between the EQ-5D and factors at the ecological level, and Level 2 examined the association between the EQ-5D scores and factors at the individual level.

Correlations among variables were assessed, and multicollinearity diagnostics were performed before modeling. Multicollinearity was assessed by calculating values for tolerance and the variance inflation factor (VIF). Although a common cutoff point is a tolerance value of 0.10, which corresponds to a VIF value of 10 [52], a more stringent approach is to use values as low as 5 [53–55]. In this study, the VIF value for all factors in every model was less than 2. Thus, multicollinearity was not considered to be an issue in this study.

Results

Table 1 shows the characteristics of the participants. The mean age of the participants was 74.13 ± 6.34 years. The majority of the 1222 participants were female, aged 70–79 years old, with no more than 6 years of education, with a spouse, non-smoker, no alcohol consumption, having one disease, and engaging in physical activity and social participation. The mean \pm SD and median of EQ-5D utility score and EQ-VAS were 0.765 ± 0.314 , 1, 67.0 ± 18.3 , and 70, respectively. When the EQ-5D utility score and EQ-VAS were divided into two groups as (< 1, 1) or low/high based on the median score, more than half (52.4%) of the older adults were categorized as full health (EQ-5D utility = 1) and 52.3% older adults were categorized as high EQ-VAS group (EQ-VAS \geq 70). The factors at individual

Table 1 Characteristics of participants and factors related to the EQ-5D utility and EQ-VAS of older adults (*n* = 1222)

Variables	Total		EQ-5D utility			EQ- VAS		
	<i>n</i>	%	<i>n</i>	M ±SD	<i>p</i>	<i>n</i>	M±SD	<i>p</i>
Gender					< .0001			.0866
Male	556	45.5	556	.823 ± .276		537	67.9 ± 18.0	
Female	666	54.5	666	.715 ± .335		601	66.2 ± 18.6	
Age (years)					< .0001			.2140
< 70	396	32.4	396	.836 ± .252		380	67.9 ± 17.1	
70–79	593	48.5	593	.753 ± .315		553	66.4 ± 18.2	
80+	233	19.1	233	.673 ± .375		205	67.0 ± 20.7	
Level of education					< .0001			.0016
Illiterate	340	28.0	340	.692 ± .346		288	64.5 ± 20.5	
literate	204	16.8	204	.740 ± .348		191	65.8 ± 18.6	
≤ 6 years	357	29.4	357	.796 ± .289		343	67.2 ± 16.7	
≥ 7 years	314	25.8	314	.824 ± .263		309	69.7 ± 17.3	
Spouse					< .0001			.0210
Yes	799	65.4	799	.805 ± .281		756	67.9 ± 17.6	
No	423	34.6	423	.689 ± .357		382	65.3 ± 19.6	
Smoking					.0108			.8211
Yes	285	23.3	285	.807 ± .285		275	67.3 ± 18.4	
No	937	76.7	937	.752 ± .321		863	66.9 ± 18.3	
Alcohol consumption					< .0001			.0190
Yes	454	37.2	454	.824 ± .264		439	68.7 ± 17.3	
No	768	62.8	768	.732 ± .336		699	66.0 ± 18.9	
No. of diseases ^a					< .0001			< .0001
0	419	34.3	419	.828 ± .266		394	71.8 ± 16.0	
1	472	38.6	472	.792 ± .295		437	67.6 ± 17.9	
≥ 2	331	27.1	331	.646 ± .362		307	60.0 ± 19.4	
Regular physical activity ^b					< .0001			< .0001
Yes	616	51.0	616	.845 ± .219		591	69.6 ± 16.9	
No	592	49.0	592	.697 ± .353		536	64.5 ± 19.1	
Social participation					< .0001			< .0001
Yes	626	51.2	626	.832 ± .233		586	69.6 ± 17.3	
No	596	48.8	596	.694 ± .368		552	64.3 ± 19.0	
EQ-5D ^c (<i>n</i> , %)								
Low (< 1)			582	47.6		583	47.7	
High (1)			640	52.4		639	52.3	

The bold number means statistically significant (*p* < .05)

^aAccording to the number of diseases, including hypertension, diabetes, stroke, kidney disease, heart disease, and cancer

^bUsing 150 min/week as the cutoff point to define whether older adults engage in physical activity

^cEQ-5D utility was categorized into two groups (< 1,1) and EQ-VAS as low/high (< 70, ≥ 70)

and township levels related to full health (EQ-5D utility = 1) and low/high EQ-VAS are provided in online supplementary Table (Table S1 and Table S2).

Table 1 also shows the factors at the individual level associated with EQ-5D utility and the EQ-VAS. The high EQ-5D utility group included being male, younger (less than 70 years old), more than 6 years of education, with a spouse, employed, smoking, consuming alcohol, no disease, CESD < 10, no disability problem, engaging in

physical activity and social participation. The high EQ-VAS group was similar to that in terms of EQ-5D utility, including more than 6 years of education, with a spouse, employed, smoking, consuming alcohol, no disease, CESD < 10, no disability problem, engaging in physical activity and social participation. However, gender, age, and smoking were not significantly associated with the EQ-VAS scores.

The built environments

Table 2 presents the descriptive statistics of the built environments in the 144 townships from the 2009 NHIS. The distribution of the built environments in these townships is highly skewed. The median of the per capita area for “medical and health services,” “social welfare facilities,” “parks, greenery, and squares,” “recreational and amusement areas,” “playgrounds and sports venue,” “cultural facilities,” “government agencies,” and “schools” at the township level was 0.17, 0.54, 2.83, 0.69, 0.38, 0.13, 0.67, and 6.21, respectively. The mean of the medium income of township is 539.4 ± 73.2 per capita thousand dollars (NTD).

The relationship between the built environments and EQ-5D utility/EQ-VAS in older adults is shown in Table 3. Different types of built environments were not found to be significantly related to EQ-5D utility. However, social welfare facilities, recreational/amusement areas, medium income of township, and level of urbanization were significantly related to EQ-VAS ($p \leq .0001, .0365, .0019, < .0001$, respectively). The lowest EQ-VAS appeared in the Q4 groups of social welfare facilities and recreational/amusement areas, the level 3 of urbanization, and the Q1 group of the medium income of township ($62.3 \pm 22.6, 64.6 \pm 19.4, 63.7 \pm 17.7, 64.1 \pm 20.7$, respectively).

Multi-level analysis

Table 4 summarizes the full health (EQ-5D utility = 1) results of the multi-level logistic regression at the ecological and individual levels. Model 1 shows no relationship between the eight built environments (level 1: township level) and full health. Model 2 contains only the individual variables (level 2: individual level) related to full health. Those who were older (OR 0.70, 0.62, 95% CI 0.52–0.94, 0.42–0.91, respectively) and had more than one disease (OR 0.37, 95% CI 0.26–0.52) were less likely to report full health, compared to those aged less than 70 years and

without disease. However, those who were male, with a spouse, and engaged in physical activity and social participation had 1.92, 1.37, 1.80, and 1.42 times as much likelihood of reporting full health, respectively, compared with those were female who did not engage in physical activity. Model 3 presents the full model containing all variables related to full health (EQ-5D utility = 1) at the individual and ecological levels. None of the eight types of built environments were found to be significant; only variables at the individual level as discussed above were significantly correlated with full health. The fit statistic ($-2LL$) of Model 3 was lower than that for Model 1 and Model 2, which indicated a better model fit (Change rate of $-2LL$: 14.5%).

The results for the EQ-VAS of the multi-level logistic regression at the ecological and individual levels are outlined in Table 5. Model 4 illustrates a negative dose–response relationship between social welfare facilities and EQ-VAS scores, indicating that living in a higher amount of social welfare facilities was associated with worse self-rated health. Compared with the Q1 group, those living in the townships with cultural and historical facilities in Q2 group had significantly higher risk of low EQ-VAS (OR 0.57, 95% CI 0.33–0.98).

Model 5 shows the association between individual factors and the EQ-VAS. Among them, three factors were significantly positive (education ≥ 7 years, physical activity, and social participation, OR 1.92, 1.82, 1.57, respectively), and number of diseases was negatively related to a high EQ-VAS score (OR 0.53, 0.30, 95% CI 0.39–0.72, 0.21–0.43). Model 6 was the full EQ-VAS model. After controlling for variables at the individual level, the negative relationship between social welfare facilities in the Q4 group and EQ-VAS disappeared. However, the significantly negative relationship between cultural and historical facilities in the Q1 group and EQ-VAS still existed (OR 0.50, 95% CI 0.28–0.89).

Table 2 Descriptive statistics of the built environments in the study townships ($n = 144$)

Built environments	Mean	SD	Min	Max	Q1	Median	Q3
Medical and health services ^a	0.43	1.18	0.01	12.35	0.07	0.17	0.42
Social welfare facilities ^a	0.75	1.13	0.01	9.20	0.26	0.54	0.80
Parks, greenery, and squares ^a	3.68	4.00	0.16	30.26	1.54	2.83	4.18
Recreational/amusement areas ^a	4.78	13.56	0.00	135.05	0.26	0.69	2.89
Playgrounds and sports venue ^a	0.72	1.17	0.00	11.85	0.22	0.38	0.80
Cultural facilities ^a	0.72	1.79	0.00	13.58	0.04	0.13	0.48
Government agencies ^a	1.46	2.35	0.05	21.44	0.33	0.67	1.71
Schools ^a	7.69	6.78	1.27	54.76	3.94	6.21	8.71
Medium income of township ^b	539.4	73.2	421.0	829.0	487.0	523.0	575.5

^aUnit: Per capita area (m²)

^bUnit: Per capita thousand dollars (NTD)

Table 3 The relationship between built environments and EQ-5D utility and EQ-VAS

	n	EQ-5D utility		EQ-VAS	
		M ± SD	p	M ± SD	p
Medical and health services ^a			.8585		.5200
Q1	259	.767 ± .304		69.1 ± 16.3	
Q2	312	.757 ± .318		66.3 ± 18.9	
Q3	306	.776 ± .302		65.9 ± 20.7	
Q4	345	.760 ± .329		67.2 ± 16.6	
Social welfare facilities ^a			.0520		< .0001
Q1	292	.771 ± .298		71.3 ± 14.6	
Q2	277	.803 ± .300		69.1 ± 16.2	
Q3	338	.747 ± .322		65.9 ± 17.3	
Q4	315	.744 ± .330		62.3 ± 22.6	
Parks, greenery, and squares ^a			.5389		.9993
Q1	306	.777 ± .281		67.7 ± 16.6	
Q2	288	.747 ± .342		67.2 ± 17.5	
Q3	321	.779 ± .322		66.9 ± 18.6	
Q4	307	.753 ± .310		66.2 ± 20.5	
Recreational/amusement areas ^a			.3321		.0365
Q1	253	.779 ± .308		69.8 ± 15.8	
Q2	337	.758 ± .315		67.6 ± 17.6	
Q3	319	.740 ± .339		66.5 ± 19.5	
Q4	313	.785 ± .290		64.6 ± 19.4	
Playgrounds and sports venue ^a			.6330		.4468
Q1	301	.779 ± .313		66.5 ± 20.1	
Q2	299	.761 ± .300		68.6 ± 16.2	
Q3	300	.766 ± .307		66.3 ± 19.5	
Q4	322	.754 ± .335		66.6 ± 17.0	
Cultural and historical facilities ^a			.9270		.4420
Q1	268	.773 ± .301		68.7 ± 16.7	
Q2	306	.773 ± .296		65.5 ± 20.5	
Q3	331	.763 ± .327		66.7 ± 18.0	
Q4	317	.751 ± .330		67.2 ± 17.6	
Government agencies ^a			.4193		.0585
Q1	280	.795 ± .285		68.1 ± 18.5	
Q2	267	.759 ± .309		67.5 ± 18.9	
Q3	324	.755 ± .315		67.5 ± 16.9	
Q4	351	.754 ± .339		65.2 ± 18.9	
Schools ^a			.7017		.2279
Q1	248	.775 ± .296		68.7 ± 16.9	
Q2	272	.774 ± .320		66.7 ± 18.1	
Q3	329	.740 ± .336		67.6 ± 17.8	
Q4	373	.772 ± .301		65.5 ± 19.7	
Medium income of township ^b			.7934		.0019
Q1	316	.754 ± .321		64.1 ± 20.7	
Q2	298	.754 ± .330		65.3 ± 19.8	
Q3	313	.768 ± .321		69.4 ± 15.7	
Q4	295	.782 ± .286		69.4 ± 15.6	
Level of urbanization			.6566		< .0001
Level 1: lowest	204	.769 ± .327		69.9 ± 21.7	
Level 2	198	.753 ± .300		65.5 ± 20.7	
Level 3	260	.762 ± .299		63.7 ± 17.7	
Level 4	384	.756 ± .342		68.4 ± 16.9	
Level 5: highest	176	.793 ± .270		71.9 ± 13.4	

The bold number means statistically significant ($p < .05$)

^aPer capita area (m²)

^bPer capita thousand dollars (NTD)

Table 4 Factors associated with whether the respondent had the full health (EQ-5D utility = 1): Multi-level analysis

	Model 1			Model 2			Model 3 ^a		
	OR	95% CI	CI	OR	95% CI	CI	OR	95% CI	CI
Level 1: township level									
Health and medical services ^b (ref: Q1)									
Q2	0.87	0.58	1.31				0.93	0.59	1.47
Q3	1.04	0.69	1.57				0.87	0.54	1.40
Q4: highest	1.01	0.67	1.53				1.05	0.65	1.71
Social welfare facilities ^b (ref: Q1)									
Q2	1.24	0.82	1.87				1.57	0.89	2.76
Q3	0.82	0.53	1.26				0.95	0.52	1.75
Q4: highest	0.94	0.59	1.50				1.19	0.60	2.34
Parks, greenery, and squares ^b (ref: Q1)									
Q2	0.95	0.65	1.39				0.92	0.58	1.45
Q3	1.41	0.94	2.11				1.46	0.93	2.30
Q4: highest	0.96	0.65	1.44				0.92	0.58	1.47
Recreational and amusement areas ^b (ref: Q1)									
Q2	0.93	0.62	1.38				0.91	0.57	1.46
Q3	0.89	0.58	1.38				0.97	0.58	1.63
Q4: highest	1.08	0.71	1.64				1.42	0.83	2.40
Playgrounds and sports venues ^b (ref: Q1)									
Q2	0.76	0.52	1.12				0.77	0.49	1.22
Q3	0.72	0.49	1.07				0.66	0.41	1.04
Q4: highest	0.90	0.60	1.35				1.03	0.63	1.67
Cultural and historical facilities ^b (ref: Q1)									
Q2	1.16	0.77	1.75				1.06	0.67	1.69
Q3	1.18	0.79	1.78				1.14	0.71	1.81
Q4: highest	1.08	0.70	1.64				1.11	0.68	1.82
Government agencies ^b (ref: Q1)									
Q2	0.78	0.52	1.17				0.84	0.52	1.36
Q3	0.71	0.47	1.09				0.69	0.42	1.13
Q4: highest	0.71	0.45	1.11				0.69	0.41	1.16
Schools ^b (ref: Q1)									
Q2	1.20	0.78	1.85				1.14	0.70	1.86
Q3	1.29	0.83	1.99				1.43	0.86	2.36
Q4: highest	1.24	0.77	2.00				1.14	0.65	1.99
Medium income of township ^c (ref: Q1)									
Q2							1.08	0.68	1.74
Q3							1.13	0.68	1.89
Q4: highest							1.31	0.71	2.42
Level of urbanization (ref: level 1-lowest)									
Level 2							0.67	0.38	1.18
Level 3							0.77	0.46	1.28
Level 4							0.96	0.51	1.80
Level 5: highest							0.88	0.36	2.14
Level 2: individual level									
Gender (ref: Female)									
Male				1.92	1.32	2.79	1.99	1.39	2.85
Age (ref: <70 years old)									
70–79				0.70	0.52	0.94	0.69	0.51	0.93
80+				0.62	0.42	0.91	0.62	0.42	0.92

Table 4 (continued)

	Model 1			Model 2			Model 3 ^a		
	OR	95% CI	CI	OR	95% CI	CI	OR	95% CI	CI
Education (ref: Illiterate)									
Literate				1.27	0.85	1.90	1.30	0.87	1.96
≤ 6 years				1.29	0.91	1.85	1.26	0.87	1.81
≥ 7 years				1.46	0.99	2.16	1.36	0.90	2.06
Spouse(ref: No)									
Yes				1.37	1.03	1.81	1.43	1.08	1.91
Smoking (ref: No)									
Yes				0.86	0.60	1.24	0.86	0.60	1.25
Alcohol consumption (ref: No)									
Yes				1.03	0.76	1.39	1.04	0.76	1.43
No. of diseases (ref: No) ^d									
1				0.88	0.65	1.18	0.86	0.64	1.16
≥ 2				0.37	0.26	0.52	0.35	0.25	0.50
Regular physical activity (ref: No) ^e									
Yes				1.80	1.38	2.34	1.81	1.39	2.37
Social participation (ref: No)									
Yes				1.42	1.10	1.84	1.42	1.09	1.85
Intercept (β, SE): (0.09, 0.07) ^f	-0.34	0.85		0.22	0.47		-0.02	1.72	
Covariance parameter estimates: (β, SE)									
Intercept: (0.14, 0.08) ^f	0.05	0.06		0.22	0.10		0.09	0.08	
Fit statistic									
AIC (1689.7 ^f)	1672.6			1539.0			1533.9		
BIC (1695.9 ^f)	1749.8			1585.2			1670.6		
-2LL (-2Log Likelihood:1685.7 ^f)	1620.6			1509.0			1441.9		
Change of -2LL = 1685.7 - value of -2LL	65.1			176.7			243.8		
Change rate of -2LL (%) ^g	3.9			10.5			14.5		

Dependent variable EQ-5D utility score was divided into two groups (< 1,1) in the logistic regression

The bold number means statistically significant ($p < .05$)

OR odds ratio, CI confidence interval

^aFull model

^bPer capita area (m²)

^cPer capita thousand dollars (NTD)

^dAccording to the number of diseases, including hypertension, diabetes, stroke, kidney disease, heart disease, and cancer

^eUsing 150 min/week as the cutoff point to define whether older adults engage in regular physical activity

^fModel-0: no predictors, just random effect for the intercept

^gChange rate of -2LL = (1685.7 - value of -2LL) ÷ 1685.7 × 100%

Discussion

This study revealed two important findings: First, the full health (EQ-5D utility = 1) was not associated with the built environments but was mainly related to individual factors. Second, two built environments, social welfare facilities and cultural facilities, in townships were demonstrated to be related to the EQ-VAS. However, after adjusting for all factors, only cultural facilities and some individual factors were associated with EQ-VAS in the full model. These findings

suggest that some significant relationships exist between older adults' quality of life and factors at both the individual and ecological levels.

Types of built environments

Different results were found in this study for the built environments and their relationship with EQ-5D utility and the EQ-VAS. This may be explained by the fact that health status will tend to be modified by the environment,

Table 5 Factors associated with whether the respondent had high EQ-VAS (≥ 70): Multi-level analysis

	Model 4			Model 5			Model 6 ^a		
	OR	95% CI	CI	OR	95% CI	CI	OR	95% CI	CI
Level 1: township level									
Health and medical services ^b (ref: Q1)									
Q2	0.96	0.56	1.64				0.98	0.56	1.74
Q3	0.94	0.55	1.60				0.79	0.44	1.41
Q4: highest	0.96	0.56	1.67				1.00	0.55	1.82
Social welfare facilities ^b (ref: Q1)									
Q2	0.74	0.43	1.27				1.15	0.56	2.36
Q3	0.62	0.35	1.11				0.99	0.46	2.13
Q4: highest	0.40	0.21	0.75				0.65	0.28	1.55
Parks, greenery, and squares ^b (ref: Q1)									
Q2	0.78	0.47	1.29				0.71	0.40	1.26
Q3	0.82	0.48	1.39				0.84	0.48	1.49
Q4: highest	0.92	0.55	1.57				0.92	0.51	1.64
Recreational and amusement areas ^b (ref: Q1)									
Q2	0.99	0.58	1.67				1.08	0.60	1.94
Q3	1.21	0.68	2.16				1.57	0.83	2.97
Q4: highest	1.08	0.62	1.89				1.51	0.78	2.90
Playgrounds and sports venues ^b (ref: Q1)									
Q2	1.05	0.63	1.75				1.08	0.61	1.92
Q3	0.80	0.47	1.36				0.70	0.39	1.26
Q4: highest	0.90	0.53	1.54				0.97	0.53	1.79
Cultural and historical facilities ^b (ref: Q1)									
Q2	0.57	0.33	0.98				0.50	0.28	0.89
Q3	0.62	0.36	1.06				0.56	0.32	1.00
Q4: highest	0.80	0.46	1.40				0.80	0.44	1.47
Government agencies ^b (ref: Q1)									
Q2	1.04	0.61	1.77				1.30	0.71	2.38
Q3	1.03	0.59	1.82				1.15	0.62	2.14
Q4: highest	0.77	0.42	1.41				0.77	0.40	1.48
Schools ^b (ref: Q1)									
Q2	0.78	0.44	1.37				0.72	0.39	1.32
Q3	0.93	0.52	1.67				1.03	0.55	1.93
Q4: highest	1.03	0.53	1.98				0.93	0.46	1.89
Medium income of township ^c (ref: Q1)									
Q2							1.07	0.60	1.92
Q3							1.09	0.57	2.08
Q4: highest							1.35	0.63	2.89
Level of urbanization (ref: level 1-lowest)									
Level 2							0.69	0.34	1.40
Level 3							0.68	0.36	1.29
Level 4							0.98	0.45	2.17
Level 5: highest							1.36	0.45	4.11
Level 2: individual level									
Gender (ref: Female)									
Male				1.00	0.70	1.43	1.01	0.70	1.46
Age (ref: <70 years old)									
70–79				0.93	0.68	1.26	0.91	0.66	1.24
80+				1.07	0.71	1.60	1.07	0.71	1.62

Table 5 (continued)

	Model 4			Model 5			Model 6 ^a		
	OR	95% CI	CI	OR	95% CI	CI	OR	95% CI	CI
Education (ref: Illiterate)									
Literate				1.19	0.79	1.82	1.19	0.78	1.82
≤ 6 years				1.32	0.91	1.91	1.30	0.89	1.90
≥ 7 years				1.92	1.27	2.90	1.90	1.23	2.93
Spouse(ref: No)									
Yes				1.13	0.85	1.52	1.19	0.88	1.61
Smoking (ref: No)									
Yes				0.93	0.64	1.36	0.96	0.65	1.41
Alcohol drinking (ref: No)									
Yes				1.34	0.97	1.84	1.35	0.97	1.87
No. of diseases (ref: No) ^d									
1				0.53	0.39	0.72	0.52	0.38	0.72
≥ 2				0.30	0.21	0.43	0.29	0.20	0.42
Regular physical activity (ref: No) ^e									
Yes				1.82	1.38	2.40	1.75	1.32	2.32
Social participation (ref: No)									
Yes				1.57	1.19	2.06	1.51	1.14	2.00
Intercept (β, SE): (0.06, 0.09) ^f	-3.04	1.12		0.34	0.50		-1.39	2.14	
Covariance parameter estimates									
Intercept: (0.57, 0.16) ^f	0.42	0.14		0.65	0.18		0.44	0.15	
Fit statistic									
AIC (1655.2 ^f)	1633.8			1543.2			1535.5		
BIC (1661.3 ^f)	1711.0			1589.4			1672.1		
-2LL (-2Log Likelihood:1651.2 ^f)	1581.8			1513.2			1443.5		
Change of -2LL (1651.2 - value of -2LL)	69.4			138.0			207.7		
Change rate of -2LL (%) ^g	4.2			8.4			12.6		

Dependent variable EQ-VAS was categorized into two groups as low/high (<70, ≥ 70) in the logistic regression

The bold number means statistically significant ($p < .05$)

OR odds ratio, CI confidence interval

^aFull model

^bPer capita area (m²)

^cPer capita thousand dollars (NTD)

^dAccording to the number of diseases, including hypertension, diabetes, stroke, kidney disease, heart disease, and cancer

^eUsing 150 min/week as the cutoff point to define whether older adults engage in regular physical activity

^fModel-0: no predictors, just random effect for the intercept

^gChange rate of -2LL = (1651.2 - value of -2LL) ÷ 1651.2 × 100%

so residents will appear to have different self-perceived health. The EQ-VAS is an overall rating of participants' health that contains not only the five EQ-5D dimensions but also any aspects of health that matter to respondents [56, 57]. Due to these extra-dimensional considerations, EQ-5D utility and EQ-VAS will have different results [57]. In addition, more variance on the EQ-VAS variable than the dummy coded variable in the full health according to the EQ-5D classification system may also lead to different results.

Past research has showed the influences of environment on the level of engagement in outdoor activities and well-being; however, equivocal results and the magnitude of that influence are yet to be identified [16, 33, 58]. Although built environments such as parks, green spaces, and open spaces showed no relationship with the EQ-5D in this study, these environments are still important for daily living and social activities. Some studies have indicated that environmental perceptions are stronger predictors than objective measures and capture different constructs [16,

59]. However, this is a limitation of this study because the information on environmental perceptions was not taken into consideration.

Social welfare facilities

In this study, older adults living in townships with social welfare facilities in the Q4 group were demonstrated to having low EQ-VAS. However, this relationship disappeared after adjusting for individual factors. This result may partly be explained by the individual factors. Previous studies have reported that some social welfare facilities exhibit the “Not-in-My-Back-Yard (NIMBY) syndrome.” Older adults do not like to go to institutional care facilities, which may be highly related to the Chinese virtue of filial piety.

However, institutional care is becoming more accepted due to the weakening of the family structure related to taking care of older people [60]. Willingness to use institutional care has improved and is related to education and self-care ability [61]. A possible explanation for this might be policy advocacy and improvements in the quality of the long-term care services system [62].

According to the 2013 Senior Citizen Condition Survey, nearly 30% of the older adults aged 65 years and over in Taiwan expressed interest in living in institutional care centers if they have friends living there. This may illustrate that self-care ability and social connections will modify the effect of environment in this population. These results may reflect those of Fu et al., who also found that those with high levels of education are more likely to choose institutional care under the core culture of Confucianism and intergenerational reciprocity in China [60]. In addition, amendment of Article 42, 46 of the Urban Planning Law in 2015 requires that social welfare facilities must be installed according to the number of households and spread of residents in an area [63]. An amendment to this law would help a lot in terms of considering services, equipment, spaces, and land acquisition related to the health of the older population.

Cultural and historical facilities

One unanticipated finding in our study was that those living in townships with cultural and historical facilities in the Q2 group had significantly lower odds of being high EQ-VAS in the full model, as compared with the Q1 group. A study in New Zealand rating expectations and satisfaction indicated that community assets (parks and gardens, historic buildings, museums, universities) are more important than the cultural, arts, and creative scene (galleries, theatres, live bands, festivals) [64]. However, the relationship between cultural and historical facilities and QOL has seldom been examined in previous research in Taiwan.

Cultural and historical facilities are usually areas used for sightseeing or tourism. Different levels of tourism development have caused a variety of impacts for the quality of life of local residents [65]. These impacts could be categorized as three types of benefits and costs: (1) economic, such as living costs, income, job opportunities, taxes, and inflation, (2) socio-cultural, such as noise, crime, crowding, cultural pride and heritage, and improvement of cultural facilities, and (3) environment, such as pollution, natural destruction, parking space or transportation, and improvement of local infrastructure [66, 67].

In addition, many temples or religious building in Taiwan were assigned as cultural heritage according to the Cultural Heritage Preservation Act. Temples are important places for spiritual sustenance, social interaction, and community activities for older adults, such as chess playing, dancing, and local markets. Thus, the impacts of cultural and historical facilities for older population are hard to distinguish between strong and weak. Why only Q2 group of the cultural and historical facilities was found to be significantly different from Q1, while Q3&Q4 were all insignificant? One possible noticeable observation reveals that these districts might have been facing a city shrinking or declining issue, which affect the resources and related-activities for older residents. Consequently, to discriminate the detailed types and functions of the “cultural and historical facilities” such as historic buildings, religious building, museums, galleries, theatres, and so on is currently beyond this study and needs further quantitative or qualitative research to clarify the impacts of cultural and historical facilities on HRQQL for the older population.

More discussions about factors at the individual level and HQOL instruments were provided in online supplement: Discussion.

Contributions and limitations

There are some research advantages and disadvantages in this study. First, this study was an interdisciplinary analysis to connect two national datasets in order to explore the relationship between built environments and HRQoL in older adults. Accordingly, this could provide a nationally representative sample and better quality information by which to explore the correlation of interest. Second, to the best of our knowledge, this study may be the first to use a multi-level analysis while considering factors at the individual and ecological level at the same time to examine the HRQoL of older adults in Taiwan. Since built environments patterns, health behavior, and the lifestyles of older adults in Asia are different from those in western countries, city planners and designers in Taiwan may want to consider how to redesign and plan a favorable environment for older adults and could even deliberate on how to redesign or modify land use

patterns in neighborhoods to make them more beneficial for older adults.

Due to the fact that this was a cross-sectional study, some inherent limitations must be taken into account, including a restricted explanation of the causality of related factors. This study shows the availability of built environments and facilities but lacks information about their accessibility and the quality. Therefore, future spatial studies are suggested to classify what, how, and why these types of built environments, such as social welfare facilities and cultural facilities, are related to the HRQOL in older adults. In addition, it is also a limitation that the scale of environment in this study is not at the smallest possible scale. A smaller scale of living areas at the individual data level is suggested to obtain and connect more precise information. Since more than half of the older adults responded a full health of EQ-5D, this study divided EQ-5D utility score into two groups (0, 1) to analyze the models. Future studies are suggested using the mixed-effects tobit model for getting a better estimation.

Conclusions

A significant relationship exists between the health-related quality of life of older adults and factors at the individual and environmental levels; however, only cultural and historical facilities and individual factors were found significantly associated with the HRQoL in the full model. Positive relationships were found if older adults were engaged in both physical activities and were active socially. It is concluded that building a supportive environment in which elderly people could consistently engage in physical activities and social participation is another potential approach that might contribute to active aging. In addition, more studies to examine the impacts of cultural and historical facilities on HRQQL for the older population are encouraged.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Ethical approval This analysis was based on a dataset from the National Health Interview Survey. However, the interpretation and conclusions contained herein do not represent those of the Health Promotion Administration, Ministry of Health and Welfare, Taiwan. All

procedures performed in this study were in accordance with the ethical standards of Institutional Review Board of National Cheng Kung University Hospital, by Human Study Approval (IRB No: B-ER-104-087).

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