Impacts of Physical Environment Perception on the Frailty Condition in Older People

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Abstract

Frailty increases the vulnerability of older people who commonly develop a syndrome leading to growing dependence and finally often death. Physical environment conditions may affect the severity of the syndrome positive or negatively. The main objective of this study was to analyse the conditions of different urban physical environments and their relationship with the frailty syndrome in older people. Geographic Information Systems (GIS) analyses were performed to detect global and local geographic clustering. Investigating 284 adults with ages from 60 to 74 years old from Talca City, Chile, we found spatial clustering of frailty conditions registered for older people, with hotspots of high and low values associated with areas of different urban infrastructures and socioeconomic levels into the city. The spatial identifications found should facilitate exploring the impact of mental health programmes in communities exposed to disasters like earthquakes, thereby improving their quality of life as well as reducing overall costs. Spatial correlation has a great potential for studying frailty conditions in older people with regard to better understanding the impact of environmental conditions on health.

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Introduction

Human populations are aging as expressed by the ongoing global decrease in mortality rates and fertility rates (Lutz *et al.*, 2008; Feigin *et al*., 2010). By 2050, the number of older people in the world is expected to double from 11% to 22% (Bloom *et al*., 2011; Clegg *et al*., 2013). Chile has the same tendency (Szot Meza, 2003; Pérez and Sierra, 2009). According to the Latin American and Caribbean Demographic Centre (CELADE) and the National Service of the Elderly, Ministry of Health, Chile (SENAMA), seniors will by 2050 form 28% of the population, more than doubling the number recorded in 2010 (approximately 13%) (CELADE, 2007; SENAMA, 2009). According to the Economic Commission for Latin America and the Caribbean (ECLAC), published by the World Health Organization (WHO), Chile is one of the countries considered to be at the stage of "advanced aging" and expected to have the highest rate of aging in Latin America by 2025 (WHO, 2009).These expectations constitute a challenge for the health system since the age acceleration increases the risk of disability (and loss of autonomy), which also involves significant loss of quality of life and social role (Chen *et al*., 2018). This situation poses a major threat to their welfare and health management due to the economic impact associated with the complex clinical interventions required, and the low probability of reversal once a condition has been established (Fairhall *et al*., 2015; Yang *et al*., 2016).

The frailty syndrome is defined as a clinical picture with multiple causes, characterized by decreased strength, stiffness and reduced physiological functions, which increase the vulnerability of older people to a growing dependence or death. Frail patients drift towards events such as fall, bone fracture, disability, hospitalization, postoperative complications, institutionalization, social isolation and finally death. In a broad term, frailty is seen as a continuum between normal aging and the final state of disability and death (Morley, 2013). These facts shift the focus from treatment and interventions towards prevention (Fairhall *et al*., 2015). From an economic perspective, prevention of frailty is highly positive for a country since with an intervention rate of, say 2.6 (which means that for every 2.6 prevented expressions of frailty, one new disability can be avoided), significant savings for the health system would result (Fairhall *et al*., 2015; Alzheimer's Association, 2015). If nothing is done, the expenditures for disability treatment might reach around 40% of the public health budget by 2040. The use of geomatic tools, which incorporates geolocation as an additional dimension of analysis, can help to generate useful knowledge for the study of frailty as a syndrome as well as support implementation of prevention activities (Bhunia *et al*., 2010). This is the reason why, in recent studies, methodologies based on

Global Positioning Systems (GPS) technology are being incorporated for recording the spatio-temporal characteristics associated with different elements and activities of patients. Use of GPS is thus a good example of modern tools contributing to the improvement of policies and public health systems (Wen *et al*., 2010; Keddem *et al*., 2015).

It has been demonstrated that a relationship exists between the geographical location of the older people and the conditions of the environment around them (Oliveira *et al*., 2015; Aytur *et al*., 2015). Espinoza and Hazuda (2015) found that residence in a low-income neighbourhood (Mexican American families) versus a high-income, suburban neighbourhoods (European American families) in southern United States is associated with higher odds of old-age frailty. Silva and Almeida (2018) identified socio-demographic and sedentary lifestyle as risk factors, while Kwan *et al*. (2019) found that life-space and social participation are associated with a reduced risk of frailty. In this context, Cramm and Nieboer (2013) highlight the importance of feeling safe, social cohesion and a sense of belonging within the neighbourhood, while Ye *et al*. (2018) argue that construction of aesthetic, walkable and cohesive neighbourhoods may decrease frailty among older people.

The work presented here aims to analyse the conditions of different urban physical environments and their relationship with the frailty syndrome in older people in Talca City, Chile. The physical environmental conditions were surveyed with the aim of finding potential associations with the frailty syndrome.

Materials and Methods

Study subjects and design

The participants in this study, 284 adults aged between 60 and 74 years, were asked about age, income, address and the physical environment in their immediate neighbourhood. The study was conducted between September 2016 and October 2017 in health care centres located in the Maule Region, in central Chile (Palomo *et al*., 2019). The frailty condition (FRA_CONDI) was evaluated according to Palomo *et al*. (2019) and based on criteria defined by Fried *et al*. (2001) that consider the presence or absence of the following five measurable, clinical manifestations: slowness, weakness, weight loss, exhaustion and low physical activity. An assessment of each component is shown in Table 1. The subjects were classified as frail when they met three or more of these symptoms, as pre-frail when they met one or two symptoms and not frail when none of these symptoms was present (Garcia-Garcia *et al*., 2011).

Assessment of the physical environment

Physical environmental conditions were evaluated considering the participants' perceptions of their close environment with respect to a set of variables related to: i) Recreation (REC): 4 variables regarding quantity and quality of green areas; ii) Transportation (TRA): 2 variables indicating availability and facilities of public transportation; iii) Neighbourhood (NEI): 6 variables regarding to neighbourhood's habitability; iv) Services (SER): 5 variables indicating availability of various public services; v) General Environment (GEN): 4 variables regarding to environment's conditions; and vi) Community (COM): 2 variables related to social living.

The list of variables and their rating scale are shown in Table 2. A final score regarding the physical environment (PHY_ENVIR) for each patient was calculated by summing the values corresponding to the alternatives chosen for each variable according to the table. Variables related to close physical environment (REC, TRA and NEI) were weighted by 0.7, while variables related to general physical environment were weighted by 0.3.

Geographical Information System (GIS) and database

A geo-referenced database was built in a GIS to contain relevant geo-information of the city with regard to streets, urban blocks, green areas (obtained from cartography of the Military Geographic Institute of Chile) and satellite images from Spot and Worldview (https://www.maxar.com). This information was organized as feature and image layers on top of a base map of the geographic study area at the neighbourhood scale. Every participant was geo-located and spatially represented as point data according to residency informed during the medical evaluation which also included consultations about the physical environment at the address. All data were structured as point feature layers (with its respective thematic table) in the database and later used as main input for the spatial autocorrelation analysis. Management, processing and analyzing data were performed as done by Mitchell (2005) using ArcGIS software, version 10 (ESRI, Redlands, CA, USA).

Table 1. Methods used for evaluating frailty syndrome symptoms.

Manifestation	Method	Reference
Slowness	Defined according to after walking three m at usual pace (cut-off at 0.8 m/s), adjusted for sex and height according to the 'Short Physical Performance Battery*' standards	Cabrero-García *et al.*, 2012
Weakness	Measured with an electronic handgrip dynamometer (Camry, City Industry, USA), according to a sex-specific cut-off (male at 27 kg, female at 15 kg)	Arroyo *et al*., 2007
Weight loss	Defined as self-reported unintentional weight loss of at least 5 kg in the previous 6 months	Albala *et al*., 2017
Exhaustion	Defined as when participants agreed to any of the following two declarations: a) "I felt that anything I did was a big effort"; b) "I felt that I could not keep on doing things at least 3 to 4 days a week"	Garcia-Garcia *et al.*, 2011
Low physical activity	Defined as a manifestation recognized by a positive reply two questions: a) "Do you have difficulty walking a block?"; b) "Do you have difficulty climbing several flights of stairs without resting?"	Santos-Eggimann *et al.*, 2009; Albala *et al*., 2017

* Guralnik *et al*., 1994.

Spatial autocorrelation analysis

Moran's *I* global statistic was used to analyze the correlation among observations of neighbouring participants in order to detect whether the spatial distribution was clustered, dispersed or random (Chen *et al*., 2015). This allows identification of those variables that have a particular zoning in place making it possible to contextualize the scenario studied with the information collected. Moran's *I* ranges between −1 to +1 where a value near 0 indicates lack of spatial clustering, values near +1 that values tend to cluster and values near -1 that higher and lower values are interspersed in the area under analysis (Zhao *et al*., 2013). Considering study area size and neighbourhood conditions, the threshold distance used as search radio for the analyses was 1,000 m.

Later, for the main variables (FRA_CONDI and PHY_ENVI), the Getis-Ord G_i* local statistic (1995) was applied to analyze the spatial correlation among observations of neighbouring participants in order to identify statistically significant spatial clusters of high values (hotspots) and low values (coldspots) of frailty condition in older people. In this way, it was possible to analyse spatial concurrence between the values corresponding to frailty and physical environment. Z-score and *p*-value determined where there were statistically significant, spatial participant clusters identified, *i.e.* when a participant had a high (or low) value and was surrounded by other participants with equally high (or low) values. Participants with high z-scores and low *p*-values conformed a spatial clustering of high values, while participants with low, negative z-score and low *p*-value conformed a spatial clustering of low values. Z-score close to zero indicate that there is no apparent spatial clustering (Getis and Aldstadt, 2004).

Table 2. Rating of the physical environment.

Variable	Acronym	Value alternative 100	80	60	40	20
Various walking areas easily accessible	REC_VWAEA	Many	Sufficient	Some	None	Don't know
Parks or safe walking areas available	REC_PSWAA	Many	Sufficient	Some	None	Don't know
Places to sit and rest available	REC_PSARA	Many	Sufficient	Some	None	Don't know
Sidewalks or walking paths available	REC_SOWPA	Many	Sufficient	Some	None	Don't know
Public transport available nearby	TRA_PTANE	Many	Sufficient	Some	None	Don't know
Public transport with adaptations available	TRA_PTWAA	Many	Sufficient	Some	None	Don't know
Assessment of neighbourhood safety	NEI_AONES	Very safe	Secure	Fairly safe	Insecure	Dangerous
Assessment of the condition of the streets	NEI_AOCOS	Excellent	Good	Acceptable	Poor	Poor
Assessment of neighbourhood noise	NEI_AONEN	Very silent	Silent	Fairly silent	Noisy	Very noisy
Assessment of green areas in neighbourhood	NEI_AOGAN	Excellent	Very good	Regular	Poor	None
Population density	NEI_PODEN	Very low	Low	Suitable	Very high	Excessive
Sense of integration	NEI_SEOIN	Very high	Good	Fairly	Low	No integration
Availability of health services	SER_AOHSE	Excellent	Good	Sufficient	Poor	No
Availability of safe drinking water	SER_AOSDW	Excellent	Good	Enough	Poor	No
Electricity services	SER_ELESE	Excellent	Good	Sufficient	Poor	No
Commercial services	SER_COMSE	Excellent	Good	Sufficient	Poor	No
Religious services	SER_RELSE	Excellent	Good	Sufficient	Poor	No
Air quality	GEN_AIRQU	Excellent	Good	Normal	Bad	Terrible
Winter weather	GEN_WINWE	Excellent	Good	Normal	Bad	Terrible
Surrounding noise	GEN_SURNO	Very silent	Silent	A bit noisy	Noisy	Very noisy
Landscape and vegetation	GEN_LANVE	Very beautiful	Attractive	Normal	Ugly	Very ugly
Sense of identity	COM_SEOID	High	Sufficient	Sometimes	Low	Never
Membership of social groups	COM_MEOSG	Always	Regularly	Sometimes	Occasionally	Never

Table 3. Characteristics of the frailty classes.

Level of frailty	Men (n)	Women (n)	Total (n, %)	Avg. age	Avg. years of education	Avg. family income (USD)	Avg. calculated physical environment value
Frail	29	68	97, 34.1	74.8	7.9	373.8	920.7
Pre-Frail	44	61	105, 37.0	74.1	8.9	415.7	940.9
Healthy	31	51	82, 28.9	71.0	10.1	470.2	937.2
Total	104	180	284, 100.0	73.4	8.9	417.1	932.9

1 USD = 712 Chilean Pesos (CLP).

Results

According to Table 3 there were clear differences between the frailty condition groups. Participants diagnosed as frail constituted 34.2% of the sample, pre-fail 37.0%, while only 28.9% were healthy. The Table 3 further shows that the higher the age, the greater the condition of frailty and the lower the number of years, the greater the condition of frailty. In terms of family income, the lower the income, the higher the condition of frailty, while assessment of the average values of the variables (clustered) of the physical environment shows great differences in the conditions of the environment inhabited by the groups, where frail patients reside in poor or undervalued environments as opposed to the healthier group of patients.

Table 4 shows the results of Moran's *I* statistic, which indicated that the variables of the physical environment with a significant positive spatial autocorrelation (clustered) at the global level were: FRA_CONDI, REC_VWAEA, REC_PSWAA, REC_PSARA, REC_SOWPA, TRA_PTANE, NEI_AOCOS, GEN_LANVE, PHY_ENVIR (abbreviations explained in Table 3), while the results of Getis-Ord G_i* statistic applied to the frailty condition in older people is shown in Figure 1 where the city has hotspots and also low values clearly located in different sectors or neighbourhoods. Meanwhile, the Getis-Ord Gi* result for the physical environment conditions is shown in Figure 2, where the city also has hotspots with interspersed low values in distinct places.

Table 4. Results of the application of Global Moran's *I* statistic on the environmental variables

Variable	Index	Z-score	P-value	Pattern
FRA_CONDI	0.166	3.918	0.000*	Clustered
REC_VWAEA	0.118	2.812	0.005*	Clustered
REC_PSWAA	0.102	2.440	0.015*	Clustered
REC_PSARA	0.148	3.493	0.000*	Clustered
REC_SOWPA	0.142	3.363	0.001*	Clustered
TRA_PTANE	0.104	2.507	0.012*	Clustered
TRA_PTWAA	0.067	1.689	0.091	Random
NEI_AONES	0.044	1.124	0.261	Random
NEI_AOCOS	0.086	2.091	0.037*	Clustered
NEI_AONEN	0.050	1.259	0.208	Random
NEI_AOGAN	0.053	1.312	0.189	Random
NEI_PODEN	0.041	1.082	0.279	Random
NEI_SEOIN	0.014	0.398	0.691	Random
SER_AOHSE	0.039	1.011	0.312	Random
SER_AOSDW	0.025	0.693	0.488	Random
SER_ELESE	0.046	1.208	0.227	Random
SER_COMSE	0.027	0.740	0.459	Random
SER_RELSE	0.009	0.310	0.757	Random
GEN_AIRQU	0.030	0.794	0.427	Random
GEN_WINWE	-0.049	-1.070	0.285	Random
GEN_SURNO	0.016	0.459	0.646	Random
GEN_LANVE	0.224	5.392	0.000*	Clustered
COM_SEOID	0.005	0.198	0.843	Random
COM_MEOSG	0.070	1.708	0.088	Random
PHY_ENVIR	0.091	2.187	0.028*	Clustered

*Statistically significant at the P<0.05 level.

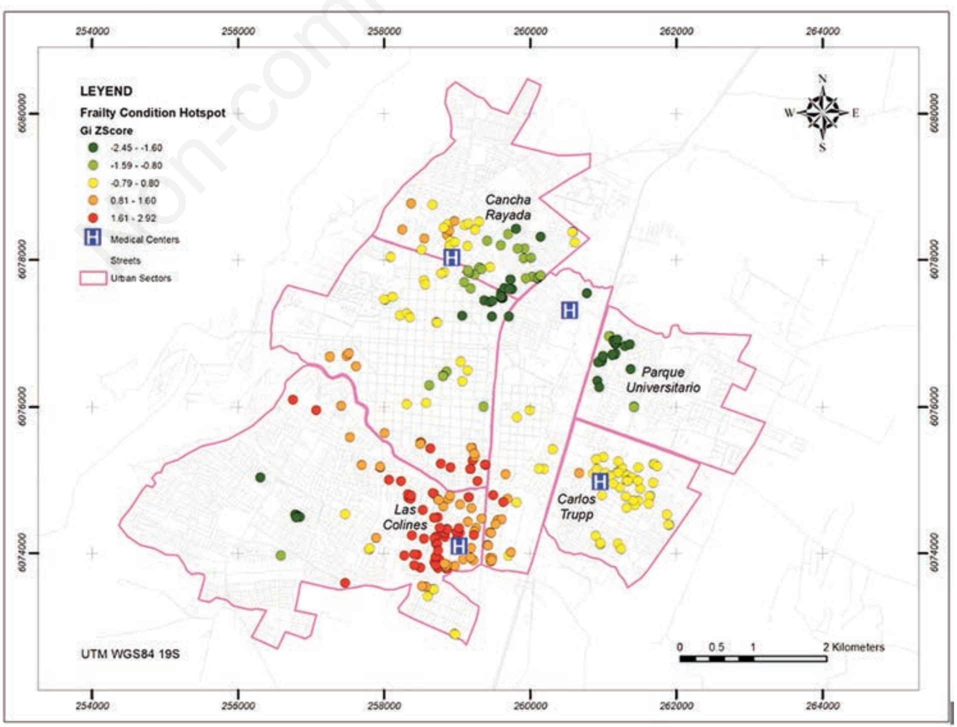

Figure 1. Spatial clustering of the frailty condition.

Discussion

The finding that increasing age leads to frailty is in line with previously reported results (Cramm and Nieboer, 2013; Ye *et al*., 2018), while the level of education lowers the risk for frailty, which is coincident with results found by Palomo *et al*. (2019). The results with respect to family income confirm the impact of the socio-economic component on the frailty syndrome (Silva and Almeida, 2018) that also influences the physical environment where people live. Thus, we found that most of the frail patients reside in poor or undervalued environments, while the healthier group of patients reside in more highly valued environments, which is corroborated by Cramm and Nieboer (2014).

Spatial clustering with respect to the physical environment was mainly related to recreation and technology; while only a few variables associated with transport, neighbourhood and environment were clustered. This means that there are different conditions inside the city, creating diverse scenarios (better or worst) that influence the frailty condition (also clustered) registered in these areas. According to Table 3, frail patients live in poorly valued neighbourhoods; while healthy patients reside in neighbourhoods with better conditions. In this context, variables related to urban environment and infrastructure at a general level could affect the frailty index in older people, as for example fear of falling can moderate physical activity of older people (Harada *et al*., 2017). Variables specifically related to services or neighbourhoods, like environment-related variables, seem not to be clustered, which could be due to their heterogeneous or homogeneous nature. This particular situation could contribute to an increase of the frailty condition as explained by Cramm and Nieboer (2014), who found that neighbourhoods with high levels of security and community life are particularly beneficial for the well-being of older people.

Figure 1 clearly shows a hotspot of high values of the frailty condition located in the south-western part of the city (Las Colines), which is associated with a medium-low income level and the physical environment also shows a hotspot of low conditions (Figure 2). A hotspot of low values of frailty condition is depicted to the Northeast where some locations (Cancha Rayada and Parque Universitario) are associated with medium- and high-income levels, respectively, that coincide with hotspots of medium and high physical environment conditions, respectively (Figure 2). The rest of the city shows non-clustered values for frailty condition. This situation reinforces the idea that different physical environment conditions could affect the frailty condition in older people across the city, where a better urban infrastructure can be positively impact over the frailty condition in older people, which coincides with findings by Cramm and Nieboer (2013) and Espinoza and Hazuda (2015).

Conclusions

The results show a great potential for studying frailty in older people and to better understand the impact of the physical environment on health. The distribution of older people registered as frail was found to be associated with certain areas characterized by poor urban infrastructures and socioeconomic levels where high-frailty conditions are commonly present. It would be highly important to

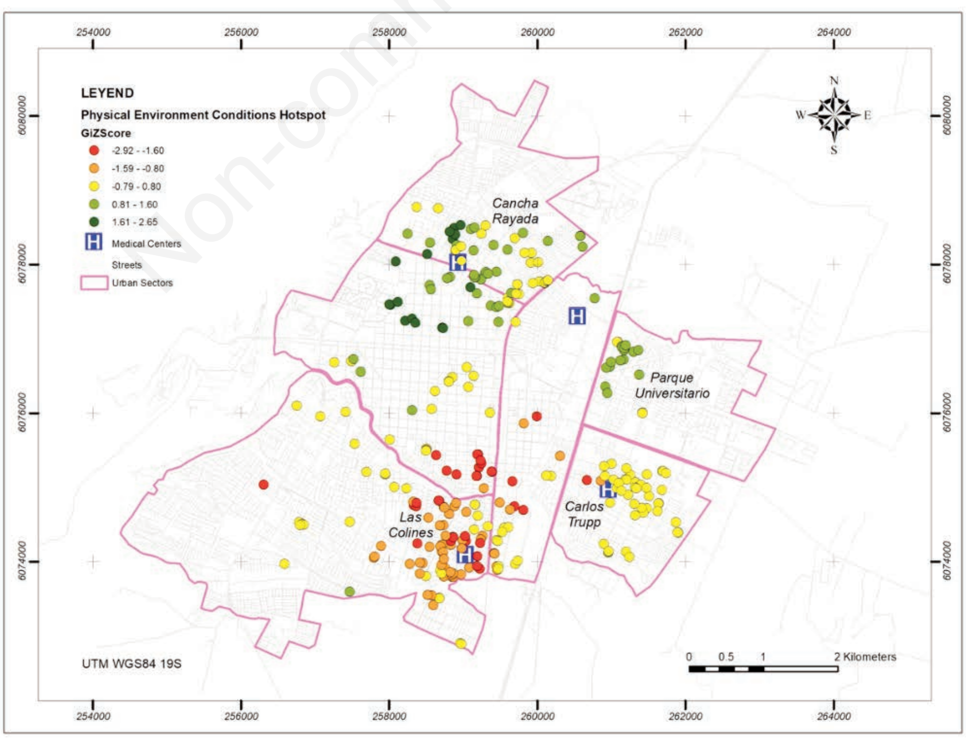

Figure 2. Spatial clustering of the physical environment conditions.

create local-level (even micro-level) geo-databases describing precisely the spatial distribution of older people with frailty conditions that could contribute to actions to improve their neighbourhoods and/or their medical conditions.

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