Unveiling the Frailty Spatial Patterns among Chilean Older Persons: Exploring Sociodemographic and Urbanistic Influences

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Abstract

Frailty syndrome increases the vulnerability of older people. The growing proportion of older adults emphasizes the need to enhance the understanding of the factors contributing to the prevalence of frailty. The main objective of this study was to analyse the relationship between various elements of the urban physical environment and the level of frailty syndrome in older people, as assessed by the mean of the Fried Frailty Phenotype criteria tool. A cohort of 300 adults aged 65 years and above from Talca City, Chile, underwent comprehensive medical assessments and were geographically mapped within a Geographic Information Systems (GIS) database. A spatial analysis of the frailty condition was conducted in conjunction with layers depicting urban physical facilities within the city, including: vegetables and fruits shops, senior centers or communities, pharmacies, emergency health centers, main squares and parks, family or community health centers, and stadiums and sports fields. Frail individuals exhibit geospatial patterns suggesting intentional proximity to health facilities, sports venues, and urban facilities, unveiling associations with adaptive responses to frailty features and socioeconomic factors, highlighting the crucial intersection of urban environments and frailty for geriatric medicine and public health initiatives.

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ABSTRACT

Frailty syndrome increases the vulnerability of older people. The growing proportion of older adults emphasizes the need to enhance the understanding of the factors contributing to the prevalence of frailty. The main objective of this study was to analyse the relationship between various elements of the urban physical environment and the level of frailty syndrome in older people, as assessed by the mean of the Fried Frailty Phenotype criteria tool. A cohort of 300 adults aged 65 years and above from Talca City, Chile, underwent comprehensive medical assessments and were geographically mapped within a Geographic Information Systems (GIS) database. A spatial analysis of the frailty condition was conducted in conjunction with layers depicting urban physical facilities within the city, including: vegetables and fruits shops, senior centers or communities, pharmacies, emergency health centers, main squares and parks, family or community health centers, and stadiums and sports fields. Frail individuals exhibit geospatial patterns suggesting intentional proximity to health facilities, sports venues, and urban facilities, unveiling associations with adaptive responses to frailty features and socioeconomic factors, highlighting the crucial intersection of urban environments and frailty for geriatric medicine and public health initiatives.

Keywords: *Aging; Frailty; Geospatial clustering; Urban factors; Neighborhood conditions*.

INTRODUCTION

Understanding the aging process and the sociodemographic determinants related to enhance quality of life has emerged as very relevant research area in light of the rapid aging of the global population (1, 2, 3). Currently, 12% of the world's population is aged ≥60 years, and projections suggest that this proportion may rise to 21.5% by the mid-century (4). Similarly, the ≥80 years age group is expected to increase from 1.7% to 4.5% (4). In this context, Chile is experiencing a pronounced aging phenomenon (4, 5). Projections indicate that the Chilean population aged ≥60 years is set to surge from 15.7% to 32.9% by 2050, with the proportion of individuals aged ≥80 years potentially reaching 10.3% (4).

According to the Worldwide Health Organization (WHO) the frailty syndrome is a crucial determinant regarding the state of dependency, presence of chronic diseases, and quality of life in older people (6, 7). The frailty syndrome is defined as a preventable and reversible clinical state in which the capacity of older people to cope with everyday stressors is compromised by an increase in vulnerability and the physiological deterioration associated with aging (8). Recent results show a prevalence of frailty in Chile slightly higher than 20% (9, 10). Frail persons have higher risks of mortality, cognitive impairment, fractures, and hospitalization, among other adverse health events; which considering the increase in the population of older people, represents a challenge for public health and social welfare systems (11, 12).

The built environment refers to spaces altered or created by human activities, encompassing a spectrum from homes and schools to workplaces, highways, urban expanses, accessibility to amenities, recreational areas, and pollution (13). This environment can be delineated into two primary components: the micro-environment, encapsulating neighbourhood and street-level attributes, and the macro-environment, which includes the degree of urbanization and patterns of land use (14). Enhancing our understanding of how the urban physical environment impacts older adults can significantly aid in formulating effective plans and interventions to prevent the progression and onset of frailty while promoting the well-being of this population (15). Previous research conducted by our group has demonstrated that leveraging geomatic tools, which integrate geolocation as an additional dimension of analysis, can provide valuable insights for studying frailty as a syndrome and supporting the implementation of preventive measures (16, 17).

According to reports from the World Health Organization (WHO) on aging and friendly cities, enhancing the environment through improvements in physical structures and community support is an effective approach to maintaining the health of older people (18). Recent evidence underscores the impact of neighborhood characteristics on frailty among older people. Those residing in neighborhoods with abundant green spaces exhibit a lower incidence of frailty, whereas individuals perceiving precarious conditions in their surroundings, houses and environment face a higher risk of frailty (19, 20, 21). A comprehensive multilevel (individual and community) cross-sectional analysis highlighted that older people residing in aesthetically pleasing and walkable areas with a high land use composition experience lower frailty level. In contrast, areas with high-traffic roads, for example, were associated with a higher prevalence of frailty (22, 23). These findings emphasize the critical role of physical environmental factors in shaping the health and well-being of older populations, highlighting the importance of designing age-friendly communities that promote active and healthy aging.

In this context, the present study aims to analyze the relationship between various elements of the urban physical environment and the level of frailty syndrome in older people, as assessed by the mean of the Fried Frailty Phenotype criteria tool.

MATERIALS AND METHODS

Participants and study design: The research adopted a cross-sectional case-control design, employing a representative sample of older persons (aged ≥65 years, both men and women) randomly selected from various Family Health Centers and community groups of older people in Talca city, Chile (n=300). The inclusion criterion was adults aged 65 years and older. Participants with self-reported or medically documented cancer, Parkinson's disease, or vascular accidents were excluded, as well as older individuals unable to walk or speak, and those currently on statin therapy (18). Approval for the study was obtained from the ethics committee of Universidad de Talca, and written informed consent was acquired from all participants. The calculation of the sample size (aged ≥65 years, both men and women) considered a prevalence of frailty in older adults of 24.6% (9), with a confidence level of 95%, statistical power of 80% and a loss percentage of 20%. The proportions of women and men in the sample were determined by the relative distribution of the adult population over 65 years of age, using data from the National Socioeconomic Characterization Survey (24).

Frailty diagnosis: The Fried frailty phenotype criteria were employed as the diagnostic tool for assessing frailty. This method involves evaluating the presence or absence of the following components: slowness, weakness, weight loss, exhaustion, and low physical activity. Participants meeting three or more of these components were categorized as frail, those presenting one or two components were considered pre-frail, while individuals lacking all components were classified as non-frail or robust (8, 25).

Geospatial clusters: Each participant was geographically located and represented as a point object based on the residence information provided during the medical evaluation. All data were organized into a point feature layer accompanied by its corresponding thematic table. This layer was integrated into a geodatabase for subsequent analysis within its geographical context, along with pertinent factors related to the urban physical environment. Figure 1 displays the individual residency positions of each older adult participating in the study within their respective geographical cluster. These geographical areas were delimited in the city of Talca, Maule Region, Chile, based on geospatial location and sociodemographic characteristics. Cluster 1 corresponds to the northeastern sector characterized by high socioeconomic status, cluster 2 encompasses the southeastern sector with low socioeconomic status, cluster 3 covers the northern sector with a lower-middle socioeconomic class, cluster 4 represents the "historic center" area. The southern sector of medium-high socioeconomic level is covered by cluster 5, and cluster 6 corresponds to the "industrial center" area.

Urban quality level: A georeferenced database was constructed using Geographic Information System (GIS) technology to represent pertinent geographical information concerning urban physical facilities within the city, encompassing: A) Vegetables and fruits shops, B) Senior centers or communities, C) Pharmacies, D) Emergency health centers, E) Main squares and parks, F) Family or community health centers, and G). Stadiums and sports fields. Each component within the study area was depicted as a GIS layer, either in point or polygon form, at the neighborhood scale. This representation (Figure 2) was derived from data sourced from OSM (Open Street Map https://www.openstreetmap.org), Google Maps (https://www.google.com/maps) and IDE Chile (Geospatial Infrastructure Chile https://www.ide.cl). Subsequently, each GIS layer underwent analysis using the Euclidean distance method, providing insights into the proximity of every location within the city to the considered infrastructure. The resulting distance layers were subsequently classified to delineate 3 distinct zones encircling the urban facilities, categorizing their proximity as either close, medium, or distant. Next, each proximity class for every layer was assessed on a scale ranging from 1 to 3, wherein the closest proximity received a score of 3, and the more distant areas were assigned a score of 1. The distance ranges and the corresponding values assigned to each urban facility are presented in Table 1. A raster calculator was employed to aggregate all layers, yielding a Summary Index where a higher numerical value signifies enhanced urban quality in the depicted area. Afterward, the values derived from the distance analyses and the corresponding Summary Index for each participant were integrated into the point feature layer. Management, processing and analysing data were performed using ArcGIS software, version 10 (ESRI, Redlands, CA, USA).

Statistical analysis: Statistical analyses were conducted using GraphPad Prism 9. Continuous variables were expressed as mean ± standard deviation (SD) or median with 95% confidence interval (CI). Categorical variables were expressed as percentages with a 95% CI. In the evaluation of differences between groups, the Chi-Squared test with Yate's correction was utilized to assess proportions, while ANOVA or Kruskall-Wallis test, as appropriate, were applied to assess differences in means or medians. Statistical significance was considered at p-values below 0.05.

RESULTS

Table 2 presents the sociodemographic characteristics of the analyzed cohort of older people. The sample comprised 74.5% women and 25.2% men, with no significant differences observed in age and BMI between the two genders. Additionally, Table 2 illustrates the distribution of the geospatial clusters established during the study. Analysis indicated no significant difference in the distribution of the six designated clusters between men and women.

Figure 3 shows the different levels of urban quality (3) obtained from the cumulative assessment of physical environmental elements considered in this study. These elements mainly encompass basic urban services and infrastructures essential for the local population, with particular importance for the cohort of older people under study. The quality level is closely related to the accessibility of the various facilities from each location within the city. Additionally, Figure 3 also shows the individual distribution of older adults, each denoted by their frailty status, which is subsequently analyzed in Table 3. This table displays the distribution of the frailty status through the different geospatial clusters. The prevalence of frailty varies between 7.3% and 34.1% among these clusters. Notably, cluster 3 exhibits a significantly high prevalence of frail people (34.1%, p=0.0059), followed by cluster 5 (21.9%, p=0.4173); however, this last prevalence is not significantly high.

Figure 4 illustrates the variation in average distance between old persons (categorized by their frailty status) and relevant urban facilities. For the facilities of vegetable and fruit shops (A), senior centers or communities (B), pharmacies (C), and family and community health centers (F), there were no significant differences in average distance across different frailty status groups ($p<0.05$). However, a clear linear trend is observed between the groups, where frail people tend to reside further from vegetable/fruit shops (F: 335,6±31,2 vs NF: 275,9±16,5) and closer to the senior centers or communities (F: 368,2±38,6 vs NF: 435,9±35,9) than the non-frail people. On the other hand, the facilities of emergency health centers (D), main squares and parks (E), and stadiums and sports fields (G) present significant differences in average distance across different frailty status groups, where frail people resided significantly closer to emergency health centers (F: 960,4±90,4 vs NF: 1352±93,6, p=0,04), main squares and parks (F: 155,0 ±13,0 vs PF: 204,8±10,5, p=0,03), and stadiums and sports fields (F: 304,0 ±23,6 vs PF: 445,7±32,2, p=0,04), than both non-frail and pre-frail people, respectively.

Finally, Figure 5 shows the variations in the Summary index and Population density between the frailty status groups. While the Summary index (A) shows no significant differences between groups (p<0.05), there is a significant difference in Population density (B) between the frail and non-frail status groups, being higher for frail people (F: 0.013±0.001 vs NF:0.01±0.0007, p=0,03).

DISCUSSION

This study explores the relationship between urban physical environment factors and frailty syndrome, with particular focus on its criteria. We utilized the Fried Frailty Phenotype as our primary diagnostic tool due to its relevance as a standard frailty assessment in various studies involving older people (11, 26, 27). Investigating the link between frailty and urban environment is innovative and can provide invaluable insights for government programs centered on enhancing the well-being of older people (28, 29). However, this emerging topic remains underdeveloped, limiting the scope for comparisons specific to frailty. The incorporation of Geomatics tools enables the inclusion of geolocation as an additional analytical dimension, offering valuable insights into the study of frailty as a syndrome. This is especially crucial when the primary focus is on understanding the impact that the urban physical environment exerts on the frail condition of older individuals (16, 17).

The data from Table 2 indicates homogeneity within the cohort, with no significant influences in the study parameters when stratified by gender. Participants had an average age range of 73-75 years and exhibited a high BMI. This trend of elevated BMI is consistent with findings from other studies focused on older Chilean people, wherein a significant prevalence of obesity (BMI>25) has been documented (8, 9, 30). Gender did not appear to influence the distribution prevalence within the identified clusters. However, it's necessary to account for gender in geospatial clustering analyses involving older people, given its potential impact on various health outcomes, as recently evidenced in COVID-19 studies (31).

The findings presented in Table 3 suggest that geospatial distribution significantly impacts the prevalence of frailty syndrome. Notably, clusters 3 and 5, which are associated with middle to low socioeconomic classes, concentrate more than a half of the frail people. This evidence is consistent with studies where low socioeconomic groups have been associated with a higher risk of developing frailty (32). Furthermore, previous research indicates that frailty condition among the older people tends to exhibit spatial clustering, wherein certain areas within and outside the city display localized concentrations of both high and low prevalence of frail people (16, 33). These clustering patterns can be attributed to the diverse urban infrastructures and socioeconomic disparities observed across different sectors within the city (16).

In our study, the outcomes depicted in Figure 3 reveal a show a geospatial clustering concentrated in the southern part of the city, primarily associated with clusters 3 and 5. However, when considering the general condition of the urban physical environment, characterized by the summary index, the group of frail people does not show significant differences compared to the other groups (Figure 5 A). This suggest that, despite various groups of adults residing in environments characterized by comparable habitability conditions, distinctions in certain factors, as evidenced in Figure 4, can exert relevant positive or negative influences. Thus, the urban physical environment is likely connected with concurrent factors associated with the frailty syndrome, serving either as causal factors or as responses to such influences.

Acknowledged as a critical factor influencing the health and well-being of older people (11-18), frailty stands out as the primary risk factor and indicator for the initiation of dependency, as well as the occurrence of chronic diseases, hospitalizations, falls, fractures, and mortality. The extensive array of health-related challenges observed in frail people may be associated with their close proximity to emergency health centers, as well as family or community health centers (15-20). Likewise, frailty has exhibited strong associations with obesity, sarcopenia, and low physical activity. Consequently, the proximity identified between the frail group and stadiums and sports fields may suggest a purposeful endeavor to improve body composition and address underlying clinical conditions (34, 35).

Simultaneously, the frail group exhibited greater proximity to main squares and parks, and to senior centers or communities, renowned for fostering social activities among older people (36). Given the well-established associations between frailty and social isolation, depression, and loneliness (37), the observed significant trend might signify a proactive response to enhance community engagement. This trend could also be indicative of the city government's concerted efforts to provide these facilities to a population in need.

Conversely, the robust association between frailty and obesity might elucidate the trend observed trend of increased distance from the frail group to fruit/vegetable shops. Nevertheless, validation of this hypothesis necessitates examination within a more extensive cohort. While elevated intake of fruits and vegetables has been linked to a diminished frailty risk, the impact of the proximity of these food supply points on frailty remains ambiguous (38). Furthermore, greater distances to pharmacies may indicate challenges in accessing essential drugs and medications, a factor that should be taken into account in health programs tailored to support the frailty group.

The findings depicted in Figure 5 (B) indicate that the frail group tends to inhabit regions characterized by elevated population density. This circumstance poses an increased risk to this group, as current scientific understanding suggests a positive correlation between population density in a given neighborhood and an increased susceptibility of middle-aged and older adults to overweight conditions (39). This association can be ascribed to the proclivity of individuals residing in densely populated areas to adopt a sedentary lifestyle, marked by limited physical activity and diminished energy expenditure (20, 39). Notably, low physical activity and sedentarism are integral components of the frailty phenotype, observed across diverse cohorts of older adults (11, 12, 26). Furthermore, elevated population density has been lined to increased mortality rates across all causes in older people (11, 12, 40, 41).

Initiatives aimed at preventing frailty underscore the imperative to advocate for physical activity, nutrition, and social engagement as primary and efficacious interventions. These interventions can be effectively implemented through a health education program tailored to inspire and engage older people (42, 43). Our findings underscore the importance of taking urban factors into account when examining frailty condition of older people. This aligns with prior research emphasizing the importance of these factors in the well-being and social engagement of older adults, as well as their association with frailty (16, 44). These results emphasize the imperative to further investigate and enhance our comprehension of the role played by urban factors in shaping frailty among the older people. Regardless, it is imperative to consider the complex interrelationship between the urban physical environment and frailty condition when devising structural preventive measures aimed at improving the well-being of older people (16, 40).

CONCLUSIONS

Contemporary evidence underscores the relevance of urban factors in influencing the onset of frailty and the diverse health factors linked to this syndrome. Frailty stands as a highly prevalent geriatric syndrome in the elderly, elevating the susceptibility to a range of adverse health and social outcomes. Addressing this challenge necessitates the development of age-friendly cities tailored to the needs of older populations. Our findings suggest that individuals classified as frail tend to reside in closer proximity to emergency health centers, as well as family or community health centers, which may be indicative of adaptive responses to the features associated with frailty syndrome such as elevated mortality risk and diminished levels of physical activity. Likewise, frail people tend to reside closer to stadiums and sports fields, which may imply a deliberate endeavor to enhance body composition and address underlying clinical conditions. On its part, the closer proximity of frail people to urban infrastructures such as main squares and parks, and senior centers or communities, may be indicative of the concerted effort by the municipal government to provide these facilities to a population in need. However, it is important to highlight that the frail group predominantly inhabits areas characterized by elevated population density, aligning with earlier research associating higher mortality rates with increased population density among older adults. Likewise, the geospatial clustering highlights the relevance of both socioeconomic status and geographic location in relation to frailty prevalence, unveiling an elevated occurrence of this syndrome in sectors characterized by a lower-middle socioeconomic class. This finding aligns with and reinforces previously established evidence. Ultimately, the existing body of evidence, coupled with our study findings, underscores the significance of investigating frailty and its associations with the urban environment and related factors. This emerging field of research holds groundbreaking potential, offering substantial implications for geriatric medicine. Moreover, it provides invaluable insights that can inform the development of governmental initiatives aimed at promoting healthy aging and proactively preventing frailty.

Authors contribution.
Conceptualisation, DA, YO, JCC; data curation, formal analysis, DA, YO; funding acquisition, CM, IP, EF; investigation, DA, YO, JCC; methodology, DA, YO, JCC; project administration, CM, IP, EF; resources, CM, IP; software, YO; supervision, CM, IP; validation, CM, IP; writing-original draft and writing-review&editing, DA, YO.

Conflicts of interest.
The authors declare no conflicts of interest.

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Highlights.

What are the main findings?

- Frail individuals tend to live closer to emergency health centers, stadiums, sports fields, and senior centers, suggesting efforts to improve their health and social engagement.
- Frail individuals mostly reside in densely populated areas, which is associated with limited physical activity and higher mortality rates.

What are the main implications of these findings?

- In the urban planning area, prioritize accessibility to health facilities, sports venues, and social centers to improve the health and well-being of older adults by promoting physical activity and social engagement.
- In the public health policies area, create supportive environments in densely populated areas with community-based programs, better access to nutritious foods, and tailored health services for frail individuals.

FIGURES AND TABLES

Table 1. Distances ranges and values considered for each urban physical facility.

Facility	Distance Ranges (m)	Value
Vegetables and fruits shops	< 300; 300 – 600; > 600	3; 2; 1
Senior centers or communities	< 500; 500 – 1000; > 1000	3; 2; 1
Pharmacies	< 500; 500 – 1000; > 1000	3; 2; 1
Emergency health centers	< 1000; 1000 – 2000; > 2000	3; 2; 1
Main squares and parks	< 200; 200 – 400; > 400	3; 2; 1
Family or community health centers	< 700; 700 – 1400; > 1400	3; 2; 1
Stadiums and sports fields	< 400; 400 – 600; > 600	3; 2; 1

Table 2. Sociodemographic description and geospatial distribution of the studied sample of older people.

		Women (n=187)	Men (n=64)	P-value
Variable	Gender % (95% CI)	74.5 (68.7-79.4)	25.5 (20.5-31.2)	-
	Age (mean ± SD)	73.8 ± 5.9	75.0 ± 5.0	0.1515
	BMI (mean ± SD)	33.6 ± 33.5	28.4 ± 6.5	0.2431
Spatial Cluster	Cluster 1 (95% CI)	10.2 (6.6-15.3)	15.6 (8.7-26.4)	0.2596
	Cluster 2 (95% CI)	18.7 (13.7-24.9)	14.1 (7.6-24.6)	0.4515
	Cluster 3 (95% CI)	16.6 (11.9-22.5)	25.0 (16.0-36.8)	0.1415
	Cluster 4 (95% CI)	11.2 (7.5-16.6)	9.4 (4.4-18.9)	0.8171
	Cluster 5 (95% CI)	26.2 (20.4-32.9)	17.2 (9.8-28.2)	0.1752
	Cluster 6 (95% CI)	17.1 (12.4-23.2)	18.8 (11.1-29.9)	0.8491

Table 3. Distribution of older people by frailty status and geospatial clustering.

		Frailty status			P-value
		Non-Frail (%)	Pre-Frail (%)	Frail (%)	
Spatial Cluster	Cluster 1	14.3 (8.5-22.9)	11.7 (6.9-19.0)	7.3 (2.5-19.4)	0.6196
	Cluster 2	14.3 (8.5-22.9)	21.6 (14.9-30.2)	17.7 (8.5-31.3)	0.2703
	Cluster 3	12.1 (6.8-20.4)	19.8 (13.5-28.2)	34.1 (21.5-49.5)	0.0059
	Cluster 4	14.3 (8.5-22.9)	8.1 (4.3-14.6)	12.2 (5.3-25.5)	0.4769
	Cluster 5	30.7 (22.2-40.9)	20.7 (14.2-29.2)	21.9 (12.0-36.7)	0.4173
	Cluster 6	14.3 (8.5-22.9)	18.0 (11.9-26.2)	7.3 (2.5-19.4)	0.2247
	Total	100.0	100.0	100.0	

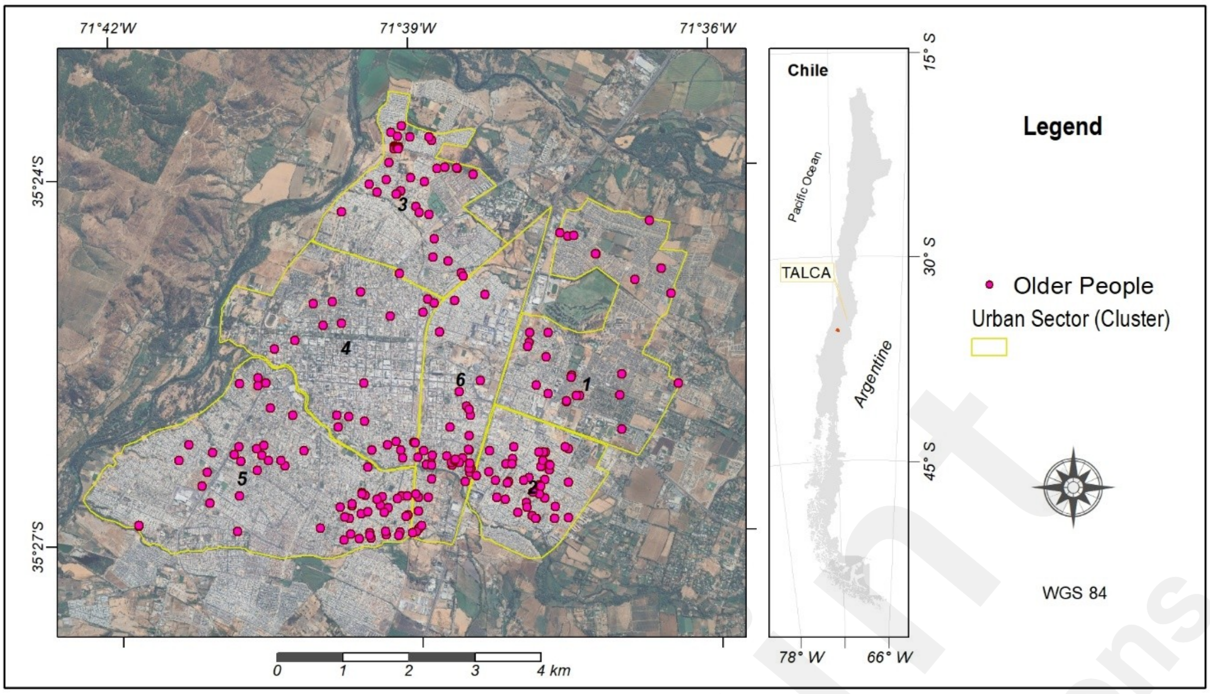

Figure 1. Location of older individuals within the six urban sectors.

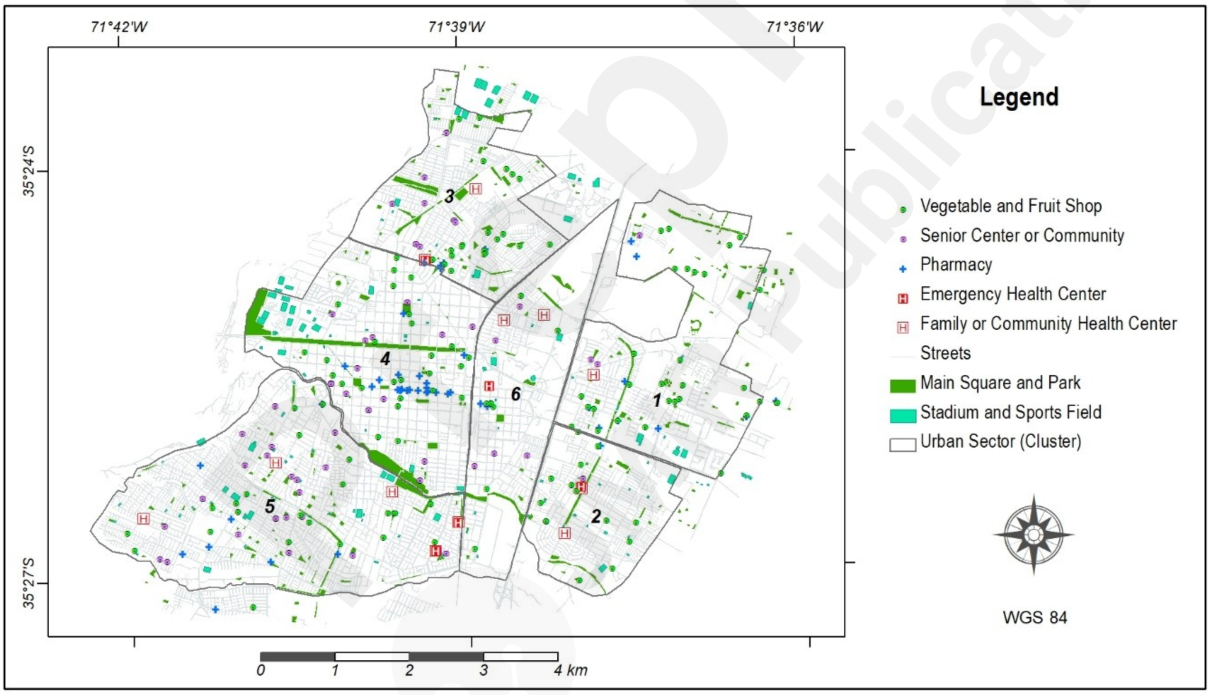

Figure 2. Geographical distribution of urban physical facilities within Talca city.

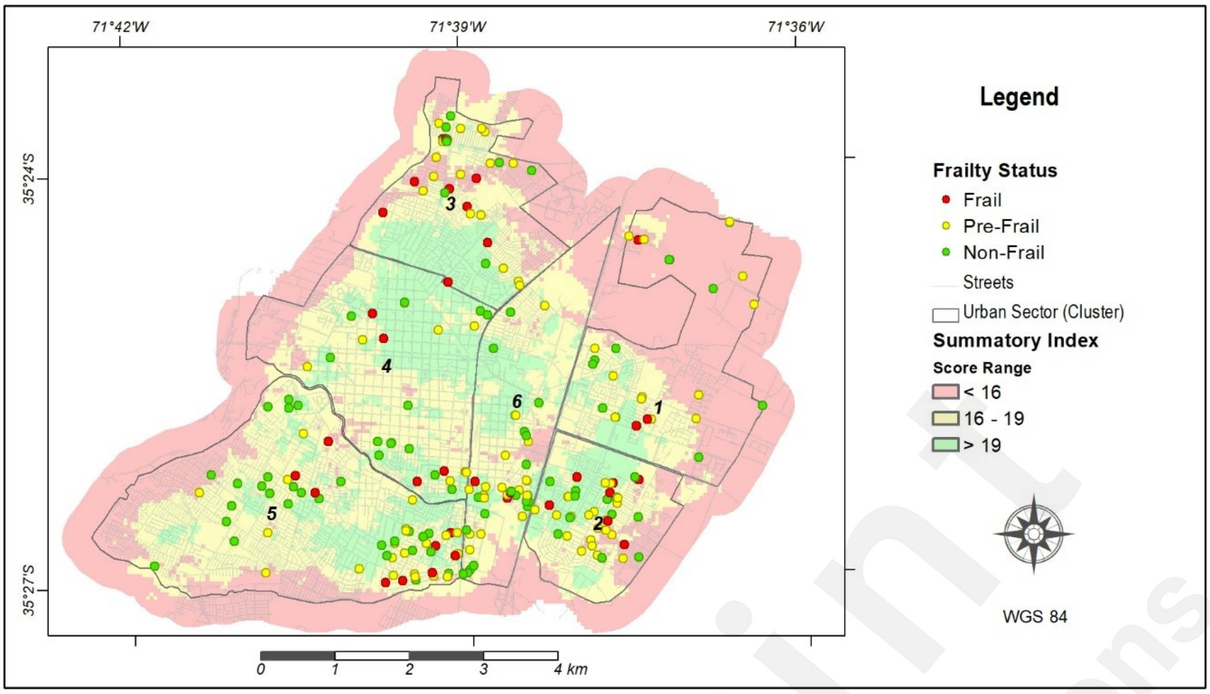

Figure 3. Frailty status of older individuals over summary index within the geospatial clusters defined for Talca city.

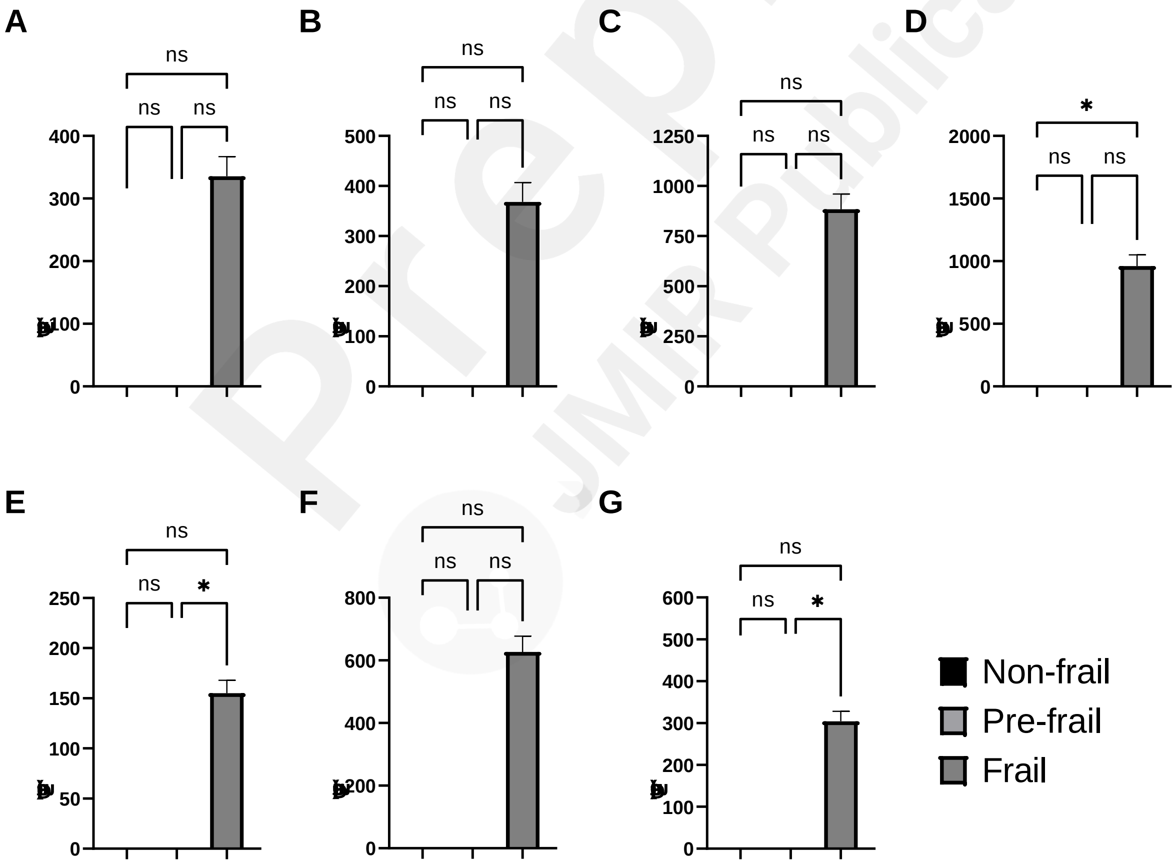

Figure 4. Comparison of mean distance for different frailty status diagnosed by Fried Phenotype respect to relevant urban facilities of: A) Vegetables and fruits shops; B) Senior centers or communities; C) Pharmacies; D) Emergency health centers; E) Main squares and parks; F) Family or community health centers; G) Stadiums and sports fields. The data presented is mean±SEM. Statistical analysis was performed by ANOVA test with Tukey pos-hoc test. *

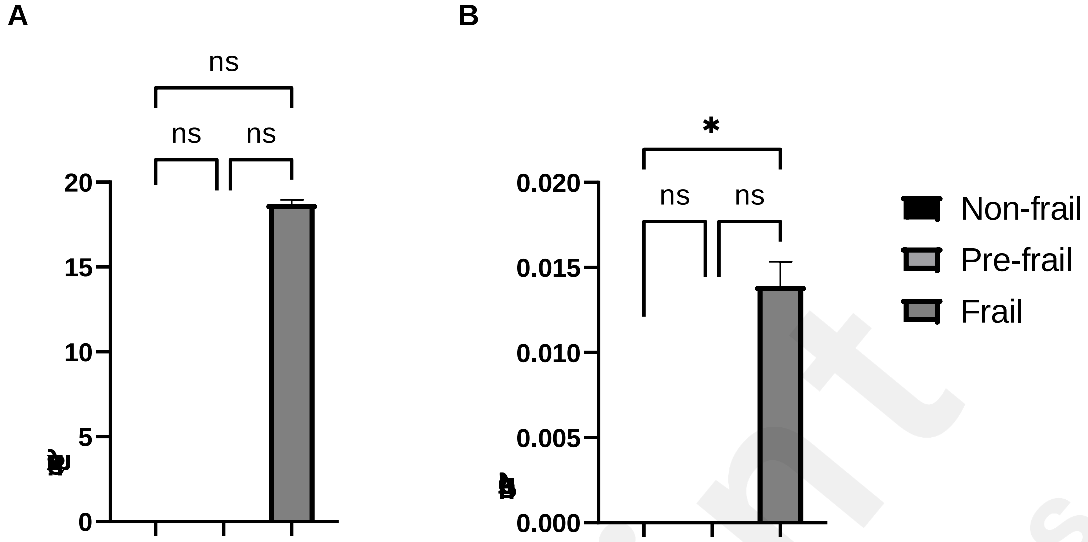

Figure 5. Comparison of mean values for different frailty status diagnosed by Fried Phenotype respect to: A) Summary Index; B) Population density. The data presented is mean±SEM. Statistical analysis was performed by ANOVA test with Tukey post-hoc test. *

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