Multidimensional dependency subgroups in community-dwelling older adults: A latent class analysis

Subgrupos de dependencia multidimensional en adultos mayores que viven en la comunidad: un análisis de clase latente

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Abstract

Objectives: Use latent class analysis (LCA) to identify patterns of multidimensional dependency in a sample of older adults and assess sociodemographic, predictors of class membership. Material and methods: Longitudinal data were used from the Mexican Health and Aging Study (MHAS). 7,920 older adults, 55% women, were recruited. LCA were used to identify meaningful subgroups. LCA was conducted using MPlus version. The final class model was chosen based on the comparison of multiple fit statistics and theoretical parsimony, with models of increasing complexity analyzed sequentially until the best fitting model was identified. Covariates were incorporated to explore the association between these variables and class membership. Results: Three classes groups based on the nine indicators were identified: “Active older adults” was comprised of 64% of the sample participants, “Relatively independent” and “Physically impaired” were comprised of 26% and 10% of the sample. The “Active older adults” profile comprised the majority of respondents who exhibited high endorsement rates across all criteria. The profiles of the “Active older adults” and “Relatively independent” were comparatively more uniform. Finally, respondents belonging to the “Physically impaired” profile, the smallest subgroup, encompassed the individuals most susceptible to a poor dependency profile. Conclusions: These findings highlighted the usefulness to adopt a person-centered approach rather than a variable-centered approach, suggesting directions for future research and tailored interventions approaches to older adults with particular characteristics. Based on patterns of multidimensional dependency, this study identified a typology of dependency using data from a large, nationally representative survey.

Keywords: Multidimensional dependency; Latent class analysis; Ageing; MHAS.

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Introduction

Globally, the population is growing older and has major socioeconomic consequence of increasing importance, and pose major challenges for the health care system and other areas of social policy. The number of older adults aged 60 years or over will increase by 56% between 2015 and 2030 and the population over 80 years of age (oldest-old) will increase even faster\(^1\). Among adults in this same age group who do not perceive themselves as disabled, 3.2% are unable to perform at least one “activity of daily living” (ADL), and another 2.4 percent have difficulty performing at least one ADL\(^2\). People experience dependency transitions during the aging process\(^4,16\). The dependency status of each older adult is a synergistic combination of multiple health dimensions. In addition, older adults might experience dependency transitions differently in regards to rate (quantity) and pattern (quality) of changes; that is heterogeneity\(^17,18\). Using any single health indicator to examine dependency change is insufficient to describe the complexity and heterogeneity of dependency transition completely. We postulated that for each condition there would be considerable heterogeneity in the dependency at the end of life.

In this research, we aim to answer the question, is whether there exists a latent classification that makes substantive sense to study the dynamic of dependence status in older populations presenting with complex care needs. We hypothesize that dependency in older adults is a multidimensional concept. This research identifies subgroup of multidimensional dependency, constructed on the basis of not only functional limitations but also social, psychological and economic domain.
Material and Methods

For this study we performed a secondary data-analysis on the MHAS, a longitudinal survey with a broad socioeconomic and health perspective. MHAS is the largest and longest running study on aging in Mexico. The MHAS began in 2001 with a nationally representative sample of 15,186 people aged 50 and older (response rate: 91.8%). All persons aged at least 50 in the selected households were interviewed. Although the partners of eligible persons living in the same household were also surveyed independently of the age, we retained the sample aged 50 or above. Follow-up interviews were completed in 2003, 2012 and 2015. The third wave “2012” included a new group of individuals who participated in the survey for the first time. We use data from the third wave “2012”. Detailed information about the survey is provided elsewhere.

Inclusion criteria

The current study is a secondary data analysis of variables from wave 2012 from the MHAS. Participants were included in the study sample if they (a) were present in wave 2012 survey (n = 7,920).

The present study used four major dependency domains to measure multidimensional dependency patterns: physical, social, psychological and economic. These four variables were observed at 2012. Therefore, a total of nine indicators were used to measure multidimensional dependency.

Latent class analysis

This study employed LCA to identify classes of dependency in Mexican older adults. LCA is widely assessed in the psychology medical, economic, and social research, where heterogeneous populations constitute the focus of analysis. In geriatric, LCA has been used heterogeneity of health of the elderly to test criterion validity of physical frailty16, measure mobility disability20 and study behavioral syndromes in Alzheimer’ patients21. We found no example of its use to model heterogeneity in older individuals’ multidependency. LCA provides an empirical method that examines the interrelationships among sociodemographic indicators and characterizes the underlying set of mutually exclusive latent classes that account for the observed indicators. To elucidate the heterogeneity within elderly people, we have explored the physical, psychological social and economic domains of dependency. We have conceptualized dependency from a broader perspective, which also includes the psychological social and economic domains22-24. Still, the distinction between the separate domains does not demonstrate the full complexity of dependency in older people. The domains might influence or reinforce each other and thus it remains unclear which specific combinations lead to adverse outcomes25. The observed variables we used in the LCA were Physical functioning (ADL, IADL, and vision impairment, difficulties flights of stairs, difficulties pushing or pulling), social functioning (marital status), psychological functioning (depressive symptoms, cognitive impairment) and economic distress Table 1.

Table 1. Sample characteristics at 2012, The Mexican Health and Aging Study (MHAS).

| Baseline | No | %  |
|----------|----|----|
| 50 - 59  | 4,136 | 52.22 |
| 60 - 69  | 2,712 | 34.24 |
| 70 - 79  | 936 | 11.82 |
| 80 and more | 136 | 1.72 |
| Gender   |     |     |
| Male     | 3,535 | 44.63 |
| Female   | 4,385 | 55.37 |
| Respondent’s yrs of education |     |     |
| 0        | 1,962 | 27.12 |
| 1 to 5   | 2,884 | 39.86 |
| 6 and more | 2,389 | 33.02 |
| Quality of health |     |     |
| Yes      | 2,860 | 38.22 |
| No       | 4,623 | 61.78 |
| Smoking  |     |     |
| Yes      | 4,577 | 57.83 |
| No       | 3,337 | 42.17 |
| Alcohol  |     |     |
| Yes      | 5,328 | 67.32 |
| rural    | 2,266 | 28.61 |
| No       | 2,587 | 32.68 |
| Residency |     |     |
| urbano   | 5,654 | 71.39 |
| Yes      | 6,939 | 93.94 |
| Exercise |     |     |
| No       | 448 | 6.06 |

Activities of daily living (ADL)

Functionally normal | 7,186 | 90.76 |
Functionally impaired | 732 | 9.24 |

Physical impairment

Instrumental activities of daily living (IADL)

Functionally normal | 5,798 | 82.23 |
Functionally impaired | 1,253 | 17.77 |

Flights of stairs

Not Difficult | 4,481 | 68.31 |
Difficult | 4,079 | 31.69 |

trouble pushing or pulling

Not Difficult | 4,639 | 68.33 |
Difficult | 2,150 | 31.67 |

Marital status

accompaniedliving alone | 5,562 | 70.23 |
| 2,358 | 29.77 |

Depression

Suggestive of depression | 4,588 | 65.06 |
| 2,464 | 34.94 |

Economic situation

Suggestive of economic distress | 6,011 | 85.32 |
| 1,034 | 14.68 |
Physical dimension

In this study, physical functioning was assessed with two commonly used measures of functional status: activities of daily living\(^26\), instrumental activities of daily living\(^27\). These scales are based on Likert-type self-reports of the difficulty involved in walking, bathing, eating, dressing, moving from bed to chair, and using the toilet (activities of daily living); cooking, shopping, doing housework, using the telephone, and managing money (independent activities of daily living). In this study, those reporting difficulty or inability to carry out two or more of the six ADL were defined as having a dependence. Participants were asked how much difficulty they had performing those activities from 0 (completely independent) to 3 (unable to do the activity at all). Sum scores of personal ADL and IADL were calculated and then averaged to obtain an overall functional limitation score.

The limitations in physical functioning were similarly measured for the following activities: climbing a flight of stairs without pausing, and pushing or hauling large objects such as living room furniture.

Vision impairment

Vision quality was assessed by two self-reported indicators: distance eyesight and reading eyesight with the usual use of glasses or contact lenses. Subjects who considered that their eyesight was fair or poor and not excellent, very good, or good, were categorized as visually impaired.

Social dimension

Widowhood is a situation that may coexist with economic, social, and psychological problems, as well as changes in health behaviors and functional disability due to health problems derived from widowhood and emotional stress\(^28\), which in turn can lead to depression\(^29,30\). Widowhood was assessed with the question “What is your current marital status?” Response options were dichotomized: single, married, civil union, divorced, or separated were coded as “0” and widowed as “1”.

Psychological dimension

Depression symptoms is assessed with the Centers for Epidemiologic Studies Depression (CES-D) scale\(^31\). The CES-D scale was developed by the Center for Epidemiologic Studies at the National Institute of Mental Health for use in studies of depression in community samples. The CES-D have 8 items and has been used in studies of elderly population. The scale contains eight dichotomous items “yes/no responses” reflecting a respondent’s feelings much of the time over the week prior to the interview (a) depressed, (b) that everything they did was an effort, (c) their sleep was restless, (d) unhappy, (e) lonely, (f) they did not enjoy life, or (g) sad. We reverse-coded the positive items to construct a summary score (range 0-7), with higher scores indicating more pronounced depressive symptoms. A response with a value of 1 is considered positive for depressive symptoms.

Cognitive impairment

Global cognitive function was assessed by the modified version of the short version of the Cross-Cultural Cognitive Examination (CCCE), which focuses on the epidemiological and cross-cultural evaluation of cognitive functioning status. The domains of executive functioning, visual learning and memory, verbal learning and memory, working memory, expressive language, visual spatial functioning, and information processing speed were assessed using a variety of measures with adequate reliability and validity, as outlined below. The individual measures were scored based on available age-matched normative data, with the resulting scaled scores for each test utilized as the units of analysis to better assess patterns across tasks and within domains.

Memory problems have two subdimensions, namely immediate memory and delayed memory. We evaluated verbal memory (learning and recall, scores from 0 to 8), visuo-constructive skills (copying a figure and recalling that figure, scores from 0 to 8), and visual scanning (scores from 0 to 60). The maximum score for the cognitive scales used is 88 points.

The participants’ cognitive functioning status was estimated using five cognitive domains, each including five items: verbal learning (immediate recall of an 8-word list), verbal memory (delayed recall of an 8-word list), visual–constructive skills (drawing of two figures in 90 seconds), visual memory (delayed recall of the figures previously drawn), and attention (visual scanning). Immediate memory was evaluated by asking respondents to recall a list of 10 words. After performing this and other cognitive performance tests, the subjects were asked to recall all the words they could from the initial word list, this time to assess delayed memory. Based on the results of the cognitive assessments we divided subjects into two groups, those (a) with normal cognitive abilities and (b) those with impaired cognitive
abilities. We evaluated verbal memory (learning and recall, scores from 0 to 8), visuo-constructive skills (copying a figure and recalling that figure, scores from 0 to 8), and visual scanning (scores from 0 to 60). The maximum score for the cognitive scales used is 88 points. Standardized normative scores for each measure were calculated. Raw scores for all measures were converted to standardized scores (Z scores) and then assigned to their corresponding raw scores with a mean of 0 and a standard deviation of 1. We made a total score variable that included all components. This scale was reverse scored to construct a scale for memory issues (the higher the score, the greater the memory problems).

Economic dimension

The question was asked: “How is the economic situation of your family?” and answers included the following categories: excellent, very good, good, fair, or poor. The answer “poor” was indicative of economic distress. The categories were combined and coded as follows: 1 = (poor), 0 = (fair, good, very good, or excellent).

Explanatory Variables

We tested the relation between sociodemographic covariates and class membership profile\textsuperscript{32,33}. Three groups of covariates were used to predict multidimensional dependency patterns, including demographic, social and health-related behavioral factors\textsuperscript{34}. The demographic factors were age (50 - 59, 60 - 69, 70 - 79, 80 - more), sex (male, female), and education (0, 1 to 5, 6 and more) level. The social factors included quality of life (excellent or very good, very poor), place of residence (urban, rural), and exercise (health improve with exercise, no). The variables constituting health-related behavioral factors included alcohol use and tobacco use. All of the covariates were time-independent.

Data analysis

We used LCA classify individuals into distinctive and theoretically meaningful subgroups/classes that represent particular response patterns of multiple categorical indicators in the complex array of data\textsuperscript{35,36}. We assume that individuals weigh aspects of dependency differently and attempts to analyze empirical patterns based on similarities in dependency items via person-centered analysis\textsuperscript{33-37}. This approach formulates categorical latent variables that represent underlying concepts of dependency based on observable multiple indicators\textsuperscript{38}.

Five statistical obtained with LCA, Akaike Information Criteria AIC, Bayesian Information Criterion (BIC), Entropy, Lo-Mendell-Rubin (LMR) and Lo-Mendell-Rubin likelihood ratio test (aLMLR) which combine goodness of fit and parsimony\textsuperscript{35,39}. The adjusted Lo-Mendell-Rubin likelihood ratio test (aLMLR) used to decide on the number of classes\textsuperscript{40}; it compares improvement in fit (p < 0.001) between sequential class models through an approximation of the LRT distribution. The Entropy is used to assess how well the model predicts class membership; values range from 0 to 1 and high values are preferred\textsuperscript{41,42}.

Results

The total study population consisted of 7,920 older people. Of the respondents, who ranged in age from 51 to 105 years old at the baseline, about 52% were between 50 and 59 years old, 34% were between 60 and 69 years old, and 2% were 80 year old or older. The sample was nearly evenly split by gender (55% female). While 27% of the respondents had zero years of education and about 40% have between 1 to 5 years of education, around 33% or 6 and more year of education. Overall, the sample reported higher levels of ADL (90%) and IADL (82%) respectively. In contrast, relatively low economic independence was found (15%). The descriptive statistics of each variable at both waves are presented in Table 1.

The models were fit with an increasing number of class sizes until the best sample adjusted value was reached. Four statistics obtained with LCA, the AIC, BIC, entropy and the BLRT, have been found to be the most effective at identifying the number of latent classes that should be extracted from the indicator variables, and fourth criteria were considered in selecting from among the four different LCA solutions for each of these constructs. With the AIC, BIC, the solution with the smallest value is identified as the optimal model, whereas the BLRT tests the statistical significance of the improvement in the model when an additional class is extracted.

The lowest AIC and BIC value reached for the 4-class model but larger LMR-LR test p-value was statistically significant for the 4-class model (p <0.053) indicated that the 3-class model should not be rejected in favor of the 4-class model. Classification quality, based upon the average conditional probabilities for most likely class membership, indicated that the three classes were reasonably well defined: 0.93 for latent class one, and 0.94 for latent class three. The entropy measure (0.65)
similarly suggested that the data was adequately defined by a three-class solution. The bottom panel in Table 2 reports the structure matrix for the three-class LCA solution for the dependency items.

**Table 2. Model fit values and statistical test results for the fitted mixture models.**

| Class | AIC   | BIC   | Entropy | Class count and proportion | Probability | LMR test | LMR adjusted |
|-------|-------|-------|---------|---------------------------|-------------|----------|--------------|
| 1     | 57154 | 57184 | 0.72    | 0.28 - 0.72               | 0.90 - 0.93 | p < 0.000 | 4354.        |
| 2     | 52763 | 52828 | 0.72    | 0.10 - 0.64               | 0.67 - 0.94 | p < 0.000 | 393          |
| 3     | 52384 | 52482 | 0.65    | 0.11 - 0.64               | 0.66 - 0.85 | p < 0.053 | 135          |
| 4     | 52265 | 52398 | 0.64    |                           |             |          |              |

Note: AIC = Akaike Information Criteria; LMR = Lo-Mendell-Rubin (LMR) likelihood ratio test, BIC = Bayesian Information Criterion. A smaller BIC value suggests a better model fit. Entropy values range from zero to one, with values closer to one indicating clearer delineation of latent classes. Reported p-values are for LMR-adjusted log ratio test.

The item-response probabilities together provide a sense of what characterizes the three different dependency profiles these older adults. Unconditional item probabilities of class-1 and class-2 trended consistent, the class-1 was labeled “Active older adults” because individuals in this status had the highest probability of independence in all observed indicators. Individuals in the class-2 labeled “Relatively independent” had a high probability of independence in all observed indicators. Finally, participants in Class III had a distinct dependency profile compared to the Class I and II participants. Members of the Class III had probability of independence in all observed indicators. We labeled this class the “Physically impaired”.

The estimated unconditional probability of each class of endorsing or reporting each item was shown in Table 3. The unconditional probability of “active older adults” was 0.64. This means that “Active older adults” was comprised of 64% of the sample participants. The “Relatively independent” and “Physically impaired” were comprised of 26% and 10% of the sample.

**Table 3. Average Posterior Probabilities for a three-class model.**

| Probability   | Active older adults (n= 5,034, 64%) | Relatively independent (n= 2,059, 26%) | Physically impaired (n= 827, 10%) |
|---------------|-----------------------------------|--------------------------------------|----------------------------------|
| Independence in ADL | 0.996                             | 0.96                                 | 0.312                            |
| Independence in IADL | 0.951                             | 0.771                                | 0.1                               |
| Without vision impairment | 0.954                             | 0.855                                | 0.738                            |
| Without difficulties flights of stairs | 0.918                             | 0.376                                | 0.053                            |
| Without difficulties pushing or pulling | 0.923                             | 0.363                                | 0.104                            |
| Marital status | 0.777                             | 0.646                                | 0.475                            |
| Without depressive symptoms | 0.82                              | 0.414                                | 0.333                            |
| Without cognitive impairment | 0.948                             | 0.928                                | 0.91                             |
| Economic independence | 0.917                             | 0.77                                 | 0.714                            |

**Multinomial Logistic regression**

We performed multinomial logistic regression tests to compare each pair of classes (based on pseudo-class draws from posterior probability-based class membership) in terms of differences in each demographic characteristic. Participants in “Relatively independent” were significantly more likely to be older (OR=1.04; p = .001), have Excellent or very good OoL (OR=2.17; p = .001), were significantly less likely to be male (OR=.53; p = .001) compared with participants in the “Active older adults” profile.

“Physically impaired” differed from class “Active older adults” profile in that “Physically impaired” participants were significantly more likely to be older (OR=1.15; p =.001) and less likely to be male (OR=.39; p =.001). (Table 4)
Table 4. Odds ratios (95% Confidence intervals) of the association between predictors and latent class membership (Reference “Active older adults” group).

|                                | Relatively independent | Physically impaired |
|--------------------------------|------------------------|---------------------|
|                                | OR         | P>|z| | IC 95%               | OR         | P>|z| | IC 95%               |
| Age in years                   | 1.04       | 0.000 | (1.03  1.05) | 1.15       | 0.000 | (1.13  1.16) |
| Sex [Male]                     | 0.53       | 0.000 | (0.47  0.61) | 0.39       | 0.000 | (0.32  0.48) |
| Education in years [0 year education] | 0.93 | 0.000 | (0.92  0.95) | 0.96       | 0.002 | (0.94  0.98) |
| Quality of life [Excellent or very good] | 2.17 | 0.000 | (1.92  2.45) | 3.05       | 0.000 | (2.49  3.75) |
| Cigarette smoking [Not regularly] | 1.10 | 0.124 | (0.97  1.25) | 1.16       | 0.131 | (0.96  1.40) |
| Alcohol use [Not regularly]    | 0.91       | 0.154 | (0.80  1.04) | 0.76       | 0.013 | (0.61  0.94) |
| County rurality [Rural]        | 1.02       | 0.727 | (0.90  1.16) | 1.07       | 0.484 | (0.88  1.30) |
| Exercise [Health improve exercise] | 1.27 | 0.032 | (1.02  1.59) | 0.96       | 0.824 | (0.69  1.35) |

**Discussion**

This study not only examines the multidimensional dependency profile using a longitudinal panel in a Mexican older adult. We identified the characteristics of elderly people by exploring their multidimensional dependency profiles and the sociodemographic characteristics of these profiles. Three classes groups based on the nine indicators were identified: “Active older adults”, “Relatively independent” and “Physically impaired”. The “Active older adults” profile comprised the majority of respondents who exhibited high endorsement rates across all criteria. The profiles of the “Active older adults” and “Relatively independent” were comparatively more uniform. Finally, respondents belonging to the “Physically impaired” profile, the smallest subgroup, encompassed the individuals most susceptible to a poor dependency profile. We found that older age, being female, and lower socioeconomic status increased the risk of membership of the “Physically impaired” group as compared to the “Active older adult” group. Being in the older age groups increased the risk of being in the “Physically impaired” group. The participants in these groups have a greater probability of being physically impaired, having more psychological impairment, and possessing fewer assets. Also, they were older, were predominantly female, had less schooling, and had poorer QOL compared with the participants in the other groups. This dependency pattern was generally related to physical dependency, which agrees with the finding that managing medical conditions was the prevalent task engaged in by this group.

It has been well documented that the heterogeneous group of older adults actually consumes a large and sometimes inappropriate share of health care services.32 The results of this research illustrates that elderly persons in the “Physically impaired” profile report more functional and economic problems than “Active older adults” and “Relatively independent” profile. Results of this study expresses obviously that the prevalence of dependency is very high in this groups. The explanation behind this phenomenon is the late age and weakening body in the final segment of life. Older persons with sufficient economic/financial resources can fulfill their needs of daily life appropriately.32 From this perspective, the approach of assessing the effects of heterogeneity and exploring their sociodemographic characteristics could be used by decision makers to understand health characteristics of older adults, to project their subsequent care needs and adjust the distribution of health care resources.

To our knowledge, this is the first investigation to examine the multidimensional dependency, specific domains of dependency physical, social, psychological and economic using latent class statistical methods. The underlying principle of latent class analysis is to search for an unobserved latent categorical variable that explains the association among a set of observed variables. The latent class model has two advantages. First, the model does not demand that we assign older adults to a specific class, as each elderly receives an estimated probability of class membership. In other words, misclassification error is minimized. Second, the latent class model also lets us, simultaneously, take into account baseline covariates other than the key variables under study in assessing their independent relationship to dependency membership class.

**Strengths and Limitations**

The current study has a number of strengths. It used LCA to identify individual subgroups of multidimensional dependency and to delineate inter-group differences that were based on dependency alone rather than mixing them with other health
condition indices. Then, it (independently) explored the association of multidimensional dependency profiles with sociodemographic covariates.

Multidimensional dependency is a very complex approach. The use of LCA to group older adults into a limited number of subgroups with similar combinations of latent dependency variable is much more practical than analysis of every possible variable combination. Therefore, we performed LCA based on the hypothesis that the dependency is a multidimensional construct. In this study, we used a LCA to identify probabilistic rather than deterministic subgroups based on responses to a set of observed variables, and assumes that the pattern is explained by unobserved categorical latent variables of K classes.

Conclusions

This study identified three qualitatively separate, broad multidimensional dependency using LCA in a Mexican nationally representative sample of older adults with distinct Physical, social, psychological, economic and sociodemographic characteristics. The latent classes identified presented relatively low misclassification errors, and demonstrated predictive and external validity. Multidimensional dependency has been consistently related to greater burden and increased use of health services. The single-indicator paradigm does not seem to fit the majority of persons with more than one dependency condition. Future efforts should focus on the underlying mechanisms of these multidimensional dependency clusters (Physical, social, psychological, economic) and determine targets for prevention and intervention.

Conflict of interests

The authors declare that they have no Financial and Non-financial competing interests.

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