Maturitas 161 (2022) 49–54

Contents lists available at ScienceDirect

Maturitas

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

Original Article

Longitudinal trajectories of intrinsic capacity and their association with quality of life and disability

Aarón Salinas-Rodríguez [a], Emmanuel González-Bautista [b], Ana Rivera-Almaraz [a], Betty Manrique-Espinoza [a,*]

[a] Center for Evaluation and Surveys Research, National Institute of Public Health, Av. Universidad #655. Colonia Santa María Ahuacatitlan, Cuernavaca, Morelos ZC 62100, Mexico

[b] Gerontopole of Toulouse, Institute of Aging, Toulouse University Hospital (CHU Toulouse). CERPOP, Université de Toulouse, Inserm, UPS, Toulouse, France

A R T I C L E I N F O

Keywords:
Intrinsic capacity
Quality of life
Disability
Growth mixture modeling
Longitudinal trajectories

A B S T R A C T

Objectives: Intrinsic capacity (IC) is a key concept within the World Health Organization's (WHO) healthy aging model. The systematic assessment of IC could provide a better understanding of the functional trajectories of individuals. Our aims were to identify the longitudinal trajectories of IC and estimate their association with quality of life and disability.
Study design: The study data comes from the three waves of the WHO Study on global AGEing and adult health (SAGE) in Mexico (2009, 2014, 2017). In total, 2735 adults aged 50 years or more were included. An IC score was constructed using item response theory. We used growth mixture modeling (GMM) to investigate the longitudinal trajectories of IC. Three-level linear mixed effect models were used to estimate the associations of IC with quality of life and disability.
Main outcome measures: Disability was measured using the WHO Disability Assessment Schedule (WHODAS 2.0) and quality of life using the WHOQOL (WHO Quality of Life) instrument.
Results: Three classes were identified: low baseline IC with a steeply decreasing trajectory, medium baseline IC with a slightly decreasing trajectory, and high baseline IC with a moderately increasing trajectory. The class with the better trajectory (higher baseline IC score and a moderately increasing pattern) exhibited higher quality-of-life scores and lower disability scores.
Conclusions: The findings show that older Mexican adults exhibit different IC trajectories, and that these may be associated with quality of life and disability. Results highlight the need for health policies and strategies to maintain intrinsic capacity and to promote primary prevention.

1. Introduction

Healthy aging has become a central concept for geriatric practice, clinical and epidemiological research, as well as for the implementation of public policies directed towards the older adult population [1,2]. In the most recent World Report on Aging and Health, the World Health Organization (WHO) reaffirmed the concept that healthy aging is more than just the absence of disease, defining it as the process of promoting and maintaining the functional capacity that enables well-being in old age [3].

This definition emphasizes the interaction between the individual and his/her environment. While it is recognized that each individual has their intrinsic capacity (which is the result of their genetic inheritance, personal and health characteristics), it is also emphasized that individuals live in a specific environment that can change over time and is highly dependent on the political, economic and social resources of each society. In the end, the interaction between intrinsic capacity and environmental characteristics determines functional capacity.

Intrinsic capacity (IC) is the composite of the physical and mental capacities which an individual may draw upon as they age [3]. The rationale for this construct relies on distinguishing the physiological or "intrinsic" determinants of healthy aging from those environmental or

Abbreviations: FML, Full-maximum likelihood; GMM, growth mixture modelling; GRM, graded response model; IC, intrinsic capacity; IRT, item response theory; LCGA, latent class growth analysis; SAGE, study on global AGEing and adult health; WHODAS, WHO Disability Assessment Schedule; WHOQOL, WHO Quality of Life.

* Corresponding author.
E-mail address: bmanrique@insp.mx (B. Manrique-Espinoza).

https://doi.org/10.1016/j.maturitas.2022.02.005
Received 10 June 2021; Received in revised form 1 February 2022; Accepted 18 February 2022
Available online 26 February 2022

"external" determinants. This duality is enrooted in the disablement model of Verbrugge and Jette who present the "intra-individual factors" as opposed to the "extra-individual factors" [4]. Later, Ustun et al. propose the capacity approach to measure health and distinguish it from external environmental factors [5].

Evidence indicates that various factors influence the health of older people [6,7]. Nonetheless, it has been assumed that a single aging profile -good health followed by a rapid decline and then death- is the expected trajectory for all older people. However, it has been suggested that aging is instead a heterogeneous process [8]. Then, there is a need to explore dynamic and non-static measurements of IC if we are to advance toward healthier aging and provide policymakers and clinicians with evidence on the potential aging trajectories and their effects on essential outcomes for older adults like disability and quality of life. The ultimate goal would be to contribute to more effective strategies that enable healthy aging.

Given that IC is a key concept within the healthy aging model proposed by the World Health Organization (WHO) [3], an assessment of IC is necessary for a better understanding of the functional trajectories and health-related outcomes of the individuals. Although some studies have estimated the trajectories of several constructs related to healthy aging [9–11], there are no specific studies about longitudinal trajectories of IC. This study aimed to identify the longitudinal trajectories of IC and estimate their association with quality of life and disability.

2. Methods

2.1. Population and sample

Data from the three waves of World Health Organization (WHO) Study on global AGEing and adult health (SAGE) in Mexico were used. A multi-country, longitudinal study, SAGE was based on nationally representative samples of individuals aged 50+ years. It has been conducted in six countries (China, Ghana, India, Mexico, Russia, and South Africa) with different geographic distributions, population sizes, income levels (low and medium) and demographic as well as epidemiological transition phases. To date, SAGE has three longitudinal measurements in Mexico, Wave 1 in 2009, Wave 2 in 2014, and Wave 3 in 2017. Details of the study design have been published elsewhere [12].

2.2. Mexican sample

For the SAGE Mexican sample, data for Wave 1 (baseline) was collected between July and September 2009, with a total sample of 2404 respondents. Wave 2 data was collected in July-October 2014, with a refreshed sample of 618 individuals, and Wave 3 in August-November 2017 with 2937 participants (including 255 new interviews). In total, 3277 individuals were interviewed in the three waves. Participants were included in the study if they were 50 years or older and had at least two IC measurements, given that we aimed to identify longitudinal trajectories of intrinsic capacity. Individuals with severe memory problems (measured through self-report) or bedridden due to serious illness were excluded from the study. Hence, the final analytical sample had 2735 subjects, with an overall response rate of 83%. Baseline differences between the final sample and excluded participants occurred in several analytical variables; the latter were older, had higher prevalence of frailty and a greater prevalence of multimorbidity ($p < 0.05$).

2.3. Measurements

Height and weight (measured through stadiometers and calibrated electronic weighting scales) were used to create the body mass index (kg/m^2). Grip strength was measured twice for both hands using the hand dynamometer (Baseline Electronic Smedley Hand Dynamometer, Fabrication Enterprises, White Plains, NY, USA). Four meters time walk was used to measure the gait speed. Participants were asked to walk at a normal pace. Walking aids (like a cane) were allowed to guarantee the security of the individuals.

2.4. Definition of variables

2.4.1. Outcomes

Quality of life (QoL). It was assessed using the WHOQOL (WHO Quality of Life) instrument. This eight-item questionnaire covers the following core domains (two items per domain): physical, psychological, social, and environmental. The results of the eight items were summed for an overall score ranging from 0 to 100. The higher the score, the higher quality of life [13].

Disability. The cross-culturally validated 12-item version of the WHO Disability Assessment Schedule Version 2.0 (WHODAS 2.0) was used. The WHODAS 2.0 scale measures limitations in activity and daily-life participation from the last month. It covers six domains explored through a total of 12 items (two per domain): (1) cognition and communication, (2) self-care, (3) mobility, (4) interpersonal relations, (5) life activities, and (6) participation. The results of the 12 items are summed to obtain a global score expressed on a continuous scale from 0 (no disability) to 100 (complete disability) [14].

2.4.2. Main exposure: intrinsic capacity

The five domains proposed by Cesari et al. were used: cognition, psychological (mood), sensory, vitality, and locomotion [15], according to available information in the SAGE survey, to construct an IC score through Item Response Theory (IRT). Specifically, a graded response model (GRM) was adjusted given that variables used for each domain of IC have ordered responses [16,17]. The final extracted IC score was transformed to a 0–100 scale with higher scores indicating higher IC. Description of the five domains, their operationalization, and details about GRM are presented in Appendix 1 of the Supplemental Material.

2.4.3. Covariates

The following health and socioeconomic variables were used as potential confounders: sex (female = 1), age, marital status (with couple = 1), paid job (yes = 1), years of formal education, and dwelling area (rural = 1). We included the following lifestyle-related behaviors: physical activity, tobacco use, alcohol consumption, and daily vegetable and fruit intake. Four variables related to geriatric syndromes were also included: mild cognitive impairment (MCI), sarcopenia, frailty status (frail, pre-frail and not frail or robust), and falls. A list of 12 chronic diseases contained in the SAGE study was also included. The following conditions were measured according to self-reported medical diagnoses: diabetes, stroke, hypercholesterolemia, hypertriglyceridemia, osteoporosis, cataracts, asthma, chronic obstructive pulmonary disease (COPD), and angina pectoris. Depression and arthritis were estimated based on symptomatology and self-reported treatment. Hypertension was determined by either blood pressure measurement and/or self-reported treatment. Regarding functionality, we included the limitations in activities of daily living (ADL) and instrumental activities of daily living (IADL). A complete description of the covariates and their operationalization can be found in Appendix 2 of the Supplemental Material.

2.5. Statistical analysis

Baseline characteristics are presented in percentages and means (standard deviation) as appropriate. Health and socioeconomic profiles related to longitudinal trajectories of IC were determined by comparing the mean or proportion of each covariate using Chi-square or ANOVA tests.

Growth mixture modeling (GMM) was used to investigate the longitudinal trajectories of the intrinsic capacity [18]. GMM is useful since it provides information about the growth factors (intercept and slope) of each trajectory. The growth factors are interpreted as usual in longitudinal modeling: the level of outcome variable when time is equal to zero (intercept) and the rate of change in the outcome over time (slope).

According to current recommendations [19], a single-class latent growth curve model to determine the pattern of change over time was initially specified. Given the number of available measurements in the SAGE study (three waves) a linear and a quadratic pattern of change were examined. Then three different GMM specifications were applied: (1) Latent Class Growth Analysis (LCGA), a specific type of GMM where it is assumed that the estimated variance and covariance of the growth factors within each class are fixed to zero, i.e., fixed intercept and slope, (2) Growth Mixture Modeling with class-specific random intercepts (GMM-1), and (3) Growth Mixture Modeling with class-specific random intercepts and slopes (GMM-2). An exploratory approach was applied fitting models with an increasing number of classes to identify the optimal latent class model.

The selection of the best model (the one with the optimal number of classes) was based upon a combination of statistical criteria, parsimony, and interpretability [19]. Specifically, the following were considered: (1) the lowest values of the goodness of fit measures Bayes Information Criteria (BIC), Akaike Information Criteria (AIC) and the sample-size adjusted BIC (aBIC), (2) the next versions of the likelihood ratio tests (LRT): Vuong-Lo-Mendell-Rubin, Lo-Mendell-Rubin adjusted, and Bootstrapped, (3) the way to which the trajectory classes captured distinct and important patterns in the data, and (4) the quality of the model in terms of posterior probability diagnostics, namely the entropy and average posterior probability for each trajectory class.

Linear mixed-effects regression models were used to analyze the association between IC trajectories and two distal outcomes: QoL and disability. Given that all individuals aged 50 years or older within the same household were included in the SAGE-Mexico study, and the repeated measurements of QoL and disability, data had a three-level hierarchical structure: measurement occasions at level 1, individuals at level 2, and households at level 3. In particular, random intercept models with subject and household IDs, as random effects, were adjusted. Regression coefficients and 95% confidence intervals were reported.

Models for the GMM were estimated in Mplus v8.5 by full maximum likelihood (FML) and robust standard errors to non-normality [20]. To avoid local maxima for the EM (expectation-maximization) algorithm, models with 200 random starting values and 100 iterations per set of start values were estimated According to the guidelines for reporting on latent trajectory studies [21], the syntax code is provided in Appendix 3 of the Supplemental Material. The Models to estimate the association of IC trajectories and distal outcomes were adjusted in Stata 16.1. The power of this study was based on two-tailed tests, significance level 0.05, intraclass correlation coefficient 0.70 (for repeated measures), and a significant slope (β‡0). A power of 0.88 was estimated for the observed sample size with these input data.

2.6. Ethics approval and consent to participate

All procedures performed involving human participants were in accordance with the ethical standards of the Ethics Committee, National Institute of Public Health, Cuernavaca, Mexico, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

3. Results

3.1. Trajectories of intrinsic capacity

The results of the single-class latent growth curve model, comparing linear versus quadratic patterns of change over time, showed favorable evidence for the linear model ($p < 0.01$) over the quadratic model ($p = 0.99$). Models from one to four trajectories were adjusted for each of three different GMM specifications: LCGA, GMM-1, and GMM-2. Table 1 provides the information of the Model Selection Criteria for all the models tested. In all the three GMM specifications, the three-class model was the best model according to the fit indices in combination with the entropy and the *p*-values associated with the three LRT used (Vuong-Lo-Mendell-Rubin, Lo-Mendell-Rubin adjusted, and Bootstrapped). Then, the three-class model with random intercept (GMM-1) was selected

Table 1
Model Selection Criteria of the Growth Mixture Model (GMM) analysis.

		Latent class growth analysis (LCGA)							Likelihood Ratio Test *p*-value		
		Free parameters	LL	AIC	BIC	aBIC	Classes-size	Entropy	Bootstrapped	Vuong-Lo-Mendell-Rubin	Lo-Mendell-Rubin
	1-class	13	−47,404.08	94,834.16	94,911.05	94,869.75	100				
	2-classes	12	−24,610.94	49,245.88	49,316.86	49,278.73	51, 49	0.76	<0.01	<0.01	<0.01
	3-classes	19	−24,245.24	48,528.49	48,640.86	48,580.50	50, 27 ,23	0.74	<0.01	<0.01	<0.01
	4-classes	26	−24,245.24	48,542.49	48,696.27	48,613.66	50, 27, 23, 0	0.79	0.49	0.49	1
		Growth mixture model (GMM)							Likelihood Ratio Test *p*-value		
		Free parameters	LL	AIC	BIC	aBIC	Classes-size	Entropy	Bootstrapped	Vuong-Lo-Mendell-Rubin	Lo-Mendell-Rubin
Random intercept (GMM-1)	1-class	14	−46,551.05	93,130.09	93,212.90	93,168.41	100				
	2-classes	13	−24,380.96	48,787.92	48,864.81	48,823.51	52, 48	0.71	<0.01	<0.01	<0.01
	3-classes	20	−24,176.72	48,393.44	48,511.73	48,448.18	50, 26, 24	0.70	<0.01	<0.01	<0.01
	4-classes	27	−24,176.72	48,407.44	48,567.13	48,481.35	50, 26, 24, 0	0.76	0.5	0.5	1
Random intercept and slope (GMM-2)	1-class	16	−46,524.01	93,080.01	93,174.65	93,123.81	100				
	2-classes	15	−24,379.72	48,789.45	48,878.17	48,830.51	52, 48	0.71	<0.01	<0.01	<0.01
	3-classes	22	−24,176.71	48,397.41	48,527.53	48,457.63	50, 26, 24	0.70	<0.01	<0.01	<0.01
	4-classes	29	−24,176.71	48,411.41	48,582.94	48,490.79	50, 26, 24, 0	0.76	0.49	0.49	1

Notes: LL: Log Likelihood; AIC: Akaike's information criteria; BIC: Bayes Information criteria; aBIC: sample-size adjusted BIC.

based on the lower values of AIC, BIC, and aBIC.

Fig. 1 shows the trajectories for the three classes estimated with the random intercept model. Based on the growth factors (intercepts and slopes), the first class (Group 1) was identified as "steeply declining" (low baseline IC with a steeply decreasing trajectory). There were 475 individuals (17% of the sample) with an average baseline IC of 36.92 (SE:0.99, p-value < 0.01) and a steep average decline rate of −4.38 (SE:0.38, p-value < 0.01). The second class (Group 2) "slightly declining" (medium baseline IC with a slightly decreasing trajectory) had 1366 individuals (50.0%) with moderate IC at baseline (intercept:49.28, SE:0.62, p-value < 0.01) and slight decline (slope: −1.47, SE:1.36, p-value < 0.01). The third class (Group 3) "moderately increasing" (high baseline IC with a moderately increasing trajectory) had 894 participants (33%). This group had the higher average baseline IC score (intercept:61.20, SE:0.79, p-value < 0.01) and a moderately increasing average rate of 1.12 (SE:0.44, p-value < 0.01) (Table 2). Tables S2 and S3, in Appendix 4 of the Supplemental Material, shows the baseline socio-demographic and health characteristics of participants by trajectories of IC.

3.2. Associations of IC trajectories with QoL and disability

The associations of IC trajectories with the distal outcomes QoL (WHOQoL score) and disability (WHODAS 2.0 score) are depicted in Table 3. Regarding QoL, the class with better trajectory (higher baseline IC score with a moderately increasing pattern) was associated with a higher QoL score ($\beta = 2.65$; 95% CI: 1.14;4.15). There were no significant differences in QoL between the two groups with decreasing trajectories of IC. For disability, the group with low baseline IC and a steeply decreasing trajectory (class 1) had the highest scores in the WHODAS 2.0, and therefore higher levels of disability compared to the groups with a slightly decreasing trajectory ($\beta = -6.86$; 95% CI: −8.21;−5.52) and a moderately increasing trajectory ($\beta = -11.58$; 95% CI: −13.27;−9.90), respectively.

Table 2
Parameter estimates for the three-class model.

Sample size	Group 1Steep declining $n = 475$ (17%)	Group 2Moderate declining $n = 1366$ (50%)	Group 3Slight increasing $n = 894$ (33%)
Average probability of class membership	0.843	0.820	0.872
Latent variables means			
Intercept	36.92 (SE = 0.99)	49.28 (SE = 0.62)	61.20 (SE = 0.79)
Slope	−4.38 (SE = 0.38)	−1.47 (SE = 1.36)	1.12 (SE = 0.44)
Latent variables variance			
Intercept variance	8.88 (SE = 25.37)	67.38 (SE = 21.13)	55.77 (SE = 8.36)
Residual variance	70.60 (SE = 3.77)	86.09 (4.55)	110.96 (SE = 8.26)

Notes: SE: standard error. Group 1: Low baseline IC with a steeply decreasing trajectory; Group 2: Medium baseline IC with a slightly decreasing trajectory; Group 3: High baseline IC with a moderately increasing trajectory.

4. Discussion

This study identified three longitudinal trajectories of IC in a nationally representative sample of older Mexican adults after eight years of follow-up: "steeply declining", "moderately declining", and "slightly increasing". People in the declining trajectories had low or medium levels of IC at baseline, exhibited declining IC over time, and ended with the worst levels of QoL and disability. The older adults in the increasing group started with a higher IC level and concluded with slightly higher IC. They also exhibited the lowest levels of disability and the highest levels of QoL. These results contribute to the current body of evidence in at least two ways. First, and to the best of our knowledge, this is the first study that analyzes the specific longitudinal trajectories of IC. Other studies have analyzed potential healthy aging trajectories (a construct that includes three elements: functional ability, intrinsic capacity, and

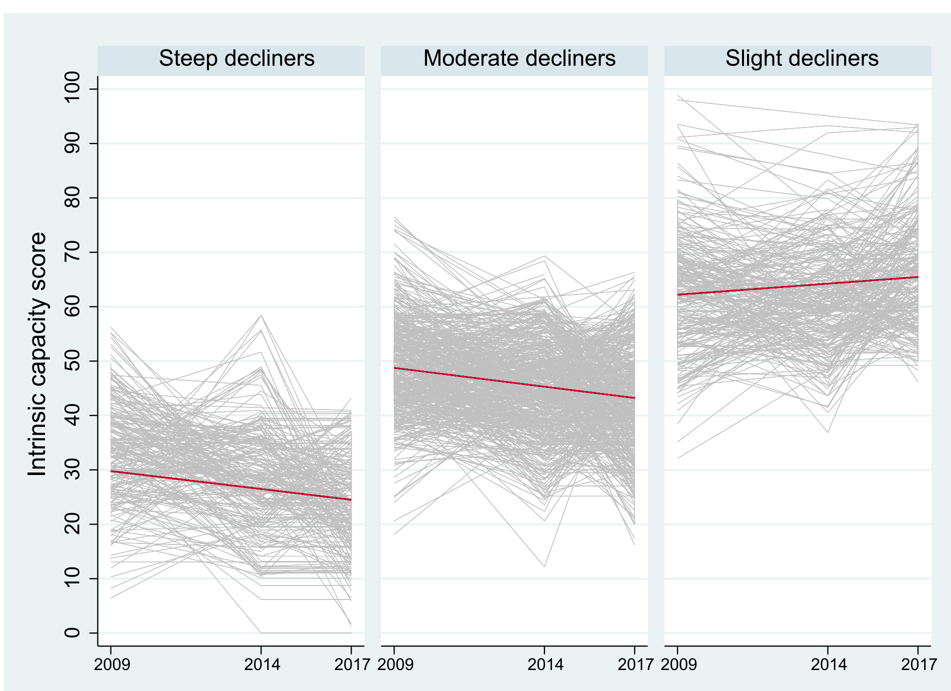

Fig. 1. Trajectories of intrinsic capacity (IC) for the 3-class model. Notes: Steep declining: Low baseline IC with steeply decreasing trajectory ($n = 475$, 17%). Moderate declining: Medium baseline IC with slightly decreasing trajectory ($n = 1366$, 50%). Slight increasing: High baseline IC with moderately increasing trajectory ($n = 894$, 33%).

Table 3
Estimated associations between trajectories of intrinsic capacity (IC) and distal outcomes: QoL and disability.

	Quality of life (WHOQoL score)		Disability(WHODAS 2.0 score)	
	Coefficient	95% CI	Coefficient	95% CI
Group 1	Ref.		Ref.	
Group 2	0.47	(−0.72 ; 1.66)	−6.86	(−8.21 ; −5.52)
Group 3	2.65	(1.14 ; 4.15)	−11.58	(−13.27 ; −9.90)
Variance components				
Subject	11.16	(4.85 ; 25.68)	43.88	(32.45 ; 59.33)
Household	19.04	(12.15 ; 29.82)	7.72	(1.78 ; 33.46)
Intraclass correlation				
Subject	0.20	(0.16 ; 0.24)	0.28	(0.24 ; 0.32)
Household	0.12	(0.08 ; 0.19)	0.04	(0.01 ; 0.17)

Notes: Group 1 “steep declining”: Low baseline IC with a steeply decreasing trajectory.
Group 2 “moderate declining”: Medium baseline IC with a slightly decreasing trajectory.
Group 3 “slight increasing”: High baseline IC with a moderately increasing trajectory.

environments), but none focused on the IC. Second, it was shown that the increasing trajectory (related to higher levels of quality of life and lower disability) could be identified as the ideal healthy aging trajectory.

The findings on distinct trajectories of IC are consistent with previous research indicating that aging is a rather heterogeneous process [22–24]. It is difficult to benchmark the results regarding evidence about IC trajectories because no other study had a similar scope. Even so, some studies that analyzed the healthy aging trajectories have been chosen, given their relevance. Several studies in high-income countries have identified trajectories of similar constructs such as successful or healthy aging. In a cohort study of English and Welsh older adults, three trajectories were identified using a successful aging index: highest functioning, moderate functioning, and low functioning [24]. Although they found similar trajectories, their three groups exhibited descending trajectories, while our study identified a group of individuals with an increasing trajectory. One potential explanation for this difference is that the successful aging index included some indicators related to the perception of older adults about their health, whereas our study used the five domains that have been proposed to assess IC objectively. Another study based on the English Longitudinal Study of Aging (ELSA) used the healthy aging construct, through which three trajectories were identified: high stable, low stable, and rapid decline [25]. Although the authors defined two trajectories as stable, overall, all three showed a downward trend. The healthy aging construct is broader than IC (in fact, IC is one of the components of healthy aging), so its trajectories could be a summary measure of a global trend that does not necessarily reflect what happens to its components (physical, cognitive, emotional). A further study with a cohort of Australian older adults, using the construct of aging-well (good self-rated health, independent capacities in instrumental ADLs, and good psychological wellbeing) identified the following trajectories: stable-good aging well, initially aging well then deteriorating; and stable-poor [22]. Although the metric used in this study is more limited in terms of the number of indicators analyzed, the observed trajectories also showed a descending pattern. A further study, with a cohort of 534 Belgian older adults, examined the transitions of four of the IC components (cognition, nutrition, mobility, and psychosocial) and their association with all-cause mortality during a 5-year follow-up [26]. Three possible transitions (stable, deteriorated, improved) were analyzed. Their findings showed that individuals with the worst transition (deteriorated) had a higher mortality risk. Two major differences should be highlighted concerning our study. First, this was not a study about trajectories but transitions. Although they are related concepts, transitions refer to changes in discrete states, while trajectories occur on a continuous line of time. Second, the analyzed outcome (mortality) is different from Qol and disability. The last two could be intermediate outcomes since a lower QoL, and greater disability would point to higher mortality. Subsequent studies could analyze this potential sequence (CI → QoL & disability → mortality) with improved designs and statistical methods. Finally, using the Mexican Health and Aging Study, one study with older Mexican adults reported the following four healthy aging trajectories: decliners, moderate-stable, high-stable, and low-stable [27]. As in the previous comparisons, no upward sloping trajectory was reported. Both studies agree that the class with the best trajectory has a higher proportion of individuals. However, one critical difference is that they designed their healthy aging score based on functional ability rather than intrinsic capacity.

Regarding the associations between IC, QoL, and disability, most studies have focused on the predictors of healthy aging trajectories rather than the potential effects on the outcomes analyzed here. Two studies that looked at such outcomes were identified. First, one study with a cohort of older women in the United States identified three trajectories of physical functioning (maintaining, slowly declining, and rapidly declining) and evaluated their association with quality of life using the 36-Item Short Form Health Survey (SF- 36). Its results showed that women with the best trajectory (maintaining) had the highest SF-36 scores [28]. Another study with Taiwanese older adults, with two cohorts of adults (young cohort 50–66 and older cohort 60+), analyzed successful aging trajectories and their relationship with life satisfaction. The authors reported four groups: successful aging, usual aging, insecure aging, and health declining. The trajectories with more significant deterioration predicted lower life satisfaction in both cohorts [29]. The findings of this study, although using different outcomes, corroborate that healthier aging trajectories are associated with better health outcomes such as a higher quality of life and lower levels of disability.

One strength of this study is the application of the GMM approach that can be useful to identify distinct trajectories of healthy aging, and hence could help researchers and policymakers design early specific interventions focused on individuals with the worse aging profiles. However, some limitations must be also considered. First, the attrition rate (17%) that occurred during the eight years of follow-up. Significant attrition because of death could create a survival bias. So, the association between IC trajectories and the distal outcomes would be underestimated since the healthiest older people were included in the study. Second, recall bias could be another limitation for epidemiological studies with older adult participants. It could be, for example, that older adults with alterations in any of the IC five domains tend to overestimate their physical limitations compared to healthiest individuals. Third, most of the variables in the SAGE study, including the questions related to the IC, are self-reported. This fact may have led to an unknown bias (overestimation or underestimation) of the actual IC measurement.

5. Conclusion

The findings of this study show significant heterogeneity in aging trajectories among older Mexicans and that these trajectories are associated with QoL and disability. These findings suggest that IC could help to predict a healthy aging trajectory. In fact, the association between IC trajectories and distal outcomes remains significant after adjusting for relevant factors such as chronological age, frailty, comorbidities, and socioeconomic status, which usually explain most of the disability variation in older ages. Our results also highlight the need for health policies and prevention strategies in middle-aged adults to strengthen IC. Specifically, we see two main opportunity areas for population-based interventions: (a) intervene in those with low IC levels to prevent them from further decline, and (b) intervene in those with average IC levels to re-adjust their trajectory into a non-declining one. These findings have significant relevance in Mexico because of the rapid growth of our aging population and the need for population health interventions to ensure healthy aging.

Funding

No external funding was received for this study. However, SAGE is supported by WHO and the US National Institute on Aging through Interagency Agreements (OGHA04034785, YA1323-08-CN-0020, and Y1-AG-1005-01) and competitive grant: R01AG034479.

Ethical approval

The study was approved by the research and ethics committees of the National Institute of Public Health, Cuernavaca, Mexico (CI/2013/550). All procedures performed involving human participants were in accordance with the ethical standards of the Ethics Committee, National Institute of Public Health, Cuernavaca, Mexico, and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Provenance and peer review

This article was not commissioned and was externally peer reviewed.

Research data (data sharing and collaboration)

The datasets analyzed in the current study are available in the WHO repository, http://apps.who.int/healthinfo/systems/surveydata/index.php/catalog/sage/about.

Declaration of competing interests

The authors declare that they have no competing interests.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.maturitas.2022.02.005.

References

[1] Z. Ungvari, R. Adany, The future of healthy aging: translation of geroscience discoveries to public health practice, Eur. J. Public Health 31 (2021) 455–456, https://doi.org/10.1093/eurpub/ckaa212.
[2] K. Donnellan, T. Sands, E. Bayer, M. Plescia, Creating a culture of healthy aging in public health, J. Public. Health Manag. Pract. 27 (2021) 213–214, https://doi.org/10.1097/PHH.0000000000001339.
[3] World Health Organization, World Report on Ageing and Health, WHO Press, Geneva, 2015.
[4] L.M. Verbrugge, A.M. Jette, The disablement process, Soc. Sci. Med. 38 (1994) 1–14, https://doi.org/10.1016/0277-9536(94)90294-1.
[5] T.V. Ustun, N. Kostanjesek, S. Chatterji, J. Rehm, & World Health Organization, Measuring Health and Disability: Manual for WHO Disability Assessment Schedule WHODAS 2.0, WHO Press, Geneva, 2010.
[6] C. Kralj, C. Daskalopoulou, F. Rodríguez-Artalejo, E. García-Esquinas, T.D. Cosco, M. Prince, A.M. Prina. Healthy ageing: a systematic review of risk factors. (ATHLOS Consortium. London). http://athlosproject.eu/wp-content/uploads/2018/05/KIOPPN_HealthyAgeing-Report2018.pdf, 2021 (accessed 2 May 2021).
[7] C.A. Depp, D.V. Jeste, Definitions and predictors of successful aging: a comprehensive review of larger quantitative studies, Am. J. Geriatr. Psychiatry 14 (2006) 6–20, https://doi.org/10.1097/01.JGP.0000192501.03069.bc.
[8] World Health Organization, Ageing and Health, World Health Organization, 2021. http://www.who.int/en/news-room/fact-sheets/detail/ageing-and-health. accessed 13 May 2021.
[9] A.A.L. Kok, M.J. Aartsen, D.J.H. Deeg, M. Huisman, Capturing the diversity of successful aging: an operational definition based on 16-year trajectories of functioning, Gerontologist (2015) gnv127, https://doi.org/10.1093/geront/gnv127.
[10] J. de la Fuente, F.F. Caballero, A. Sánchez-Niubó, D.B. Panagiotakos, A.M. Prina, H. Arndt, J.M. Haro, S. Chatterji, J.L. Ayuso-Mateos, Determinants of health trajectories in England and the United States: an approach to identify different patterns of healthy aging, J. Gerontol. Ser. A 73 (2018) 1512–1518, https://doi.org/10.1093/gerona/gly006.
[11] J.E. Byles, M.M. Rahman, E.M. Princehorn, E.G. Holliday, L. Leigh, D. Loxton, J. Beard, P. Kowal, C. Jagger, Successful ageing from old to very old: a longitudinal study of 12,432 women from Australia, Age Ageing 48 (2019) 803–810, https://doi.org/10.1093/ageing/afz116.
[12] W. He, M.N. Muenchrath, P. Kowal, Shades of Gray: A Cross-Country Study of Health andwell-Being of the Older Populations in SAGE Countries, 2007–2010, US Government Printing Office, Washington, DC, 2012.
[13] S.M. Skevington, M. Lotfy, K.A. O'Connell, The world health organization's WHOQOL-BREF quality of life assessment: psychometric properties and results of the international field trial. A report from the WHOQOL Group, Qual. Life Res. 13 (2004) 299–310, https://doi.org/10.1023/B:QURE.0000018486.91360.00.
[14] T.B. Üstün, S. Chatterji, N. Kostanjsek, J. Rehm, C. Kennedy, J. Epping-Jordan, S. Saxena, M. von Korff, C. Pull, Developing the world health organization disability assessment schedule 2.0, Bull. World Health Organ. 88 (2010) 815–823, https://doi.org/10.2471/BLT.09.067231.
[15] M. Cesari, I. Araujo de Carvalho, J. Amuthavalli Thiyagarajan, C. Cooper, F. C. Martin, J.Y. Reginster, B. Vellas, J.R. Beard, Evidence for the domains supporting the construct of intrinsic capacity, J. Gerontol. Ser. A 73 (2018) 1653–1660, https://doi.org/10.1093/gerona/gly011.
[16] F. Samejima, Estimatio of latent ability using a response pattern of graded scores, ETS Res. Bull. Ser. 1968 (1968) i–169, https://doi.org/10.1002/j.2333-8504.1968.tb00153.x.
[17] D. Thissen, L. Steinberg, A taxonomy of item response models, Psychometrika 51 (1986) 567–577, https://doi.org/10.1007/BF02295596.
[18] N. Ram, K.J. Grimm, Methods and measures: growth mixture modeling: a method for identifying differences in longitudinal change among unobserved groups, Int. J. Behav. Dev. 33 (2009) 565–576, https://doi.org/10.1177/0165025409343765.
[19] K.L. Nylund, T. Asparouhov, B.O. Muthén, Deciding on the number of classes in latent class analysis and growth mixture modeling: a monte carlo simulation study, Struct. Equ. Model. A Multidiscip. J. 14 (2007) 535–569, https://doi.org/10.1080/10705510701575396.
[20] L.K. Muthén, B.O. Muthén, Mplus User's Guide, 8th ed., Muthén & Muthén, Los Angeles, CA, 1998. –2017.
[21] R. van de Schoot, M. Sijbrandij, S.D. Winter, S. Depaoli, J.K. Vermunt, T. GRoLTS-Checklist, Guidelines for reporting on latent trajectory studies, Struct. Equ. Model. A Multidiscip. J. 24 (2017) 451–467, https://doi.org/10.1080/10705511.2016.1247646.
[22] C.J. Browning, J.C. Enticott, S.A. Thomas, H. Kendig, Trajectories of ageing well among older Australians: a 16-year longitudinal study, Ageing Soc. 38 (2018) 1581–1602, https://doi.org/10.1017/S0144686X17000162.
[23] N.H. Jonkman, V. Del Panta, T. Hoekstra, M. Colpo, N.M. van Schoor, S. Bandinelli, L. Cattelani, J.L. Helbostad, B. Vereijken, M. Pijnappels, A.B. Maier, Predicting trajectories of functional decline in 60- to 70-year-old people, Gerontology 64 (2018) 212–221, https://doi.org/10.1159/000485135.
[24] T.D. Cosco, B.C.M. Stephan, C. Brayne, G. Muniz, Education and successful aging trajectories: a longitudinal population-based latent variable modelling analysis, Can. J. Aging 36 (2017) 427–434, https://doi.org/10.1017/S0714980817000344. /La Rev. Can. Du Vieil.
[25] H. Nguyen, D. Moreno-Agostino, K.C. Chua, S. Vitoratou, A.M. Prina, Trajectories of healthy ageing among older adults with multimorbidity: a growth mixture model using harmonised data from eight ATHLOS cohorts, PLoS One 16 (2021), e0248844, https://doi.org/10.1371/journal.pone.0248844.
[26] M. Locquet, D. Sanchez-Rodriguez, O. Bruyère, A. Geerinck, L. Lengelé, J. Y. Reginster, C. Beaudart, Intrinsic capacity defined using four domains and mortality risk: a 5-year follow-up of the SarcoPhAge cohort, J. Nutr. Health Aging 26 (2022) 23–29, https://doi.org/10.1007/s12603-021-1702-7.
[27] C. Daskalopoulou, A. Koukounari, Y.T. Wu, G.M. Terrera, F.F. Caballero, J. de la Fuente, S. Tyrovolas, D.B. Panagiotakos, M. Prince, M. Prina, Healthy ageing trajectories and lifestyle behaviour: the Mexican health and aging study, Sci. Rep. 9 (2019) 11041, https://doi.org/10.1038/s41598-019-47238-w.
[28] L. Vaughan, X. Leng, M.J. La Monte, H.A. Tindle, B.B. Cochrane, S.A. Shumaker, Functional independence in late-life: maintaining physical functioning in older adulthood predicts daily life function after age 80, J. Gerontol. Ser. A Biol. Sci. Med. Sci. 71 (2016) S79–S86, https://doi.org/10.1093/gerona/glv061.
[29] H.C. Hsu, B.L. Jones, Multiple trajectories of successful aging of older and younger cohorts, Gerontologist 52 (2012) 843–856, https://doi.org/10.1093/geront/gns005.