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Life-course risk factors are associated with activity of daily living disability in older adults

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Background: Multiple risk factors accumulate over the life-course and contribute to higher rates of disability at older ages. This study investigates whether three life-course risk factors (low educational attainment, poor health in childhood and multimorbidity) are associated with increased risk of disability [defined as any limitation in basic activities of daily living (BADL)] in older adults and whether this relationship is moderated by the national socio-economic context, measured by the Human Development Index (HDI). **Methods:** Data include 100 062 adults (aged 50 and over) participating in longitudinal studies of aging conducted in 19 countries. Analyses include multivariable Poisson models with robust standard errors to assess the associations between HDI, life-course risk factors and other individual-level control variables (sex and age) with any BADL disability. **Results:** In country-specific analyses, both educational attainment and multimorbidity are independently associated with disability in nearly every country. The interaction between these risk factors further increases the magnitude of this association. In pooled regression analyses, the relationship between life-course risk factors and disability is moderated by a country's HDI. For individuals with all three life-course risk factors, the predicted probability of disability ranged from 36.7% in the lowest HDI country to 21.8% in the highest HDI country. **Conclusions:** Social and health system policies directed toward reducing the development of life-course risk factors are essential to reduce disability in all countries, but are even more urgently needed in those with lower levels of socioeconomic development.

Introduction

Population aging is poised to become the major global public health challenge for countries of all income levels. Under this scenario, a key question is how to prevent or slow age-related progression to functional disability.[1] Promoting healthy aging is particularly challenging in low- and middle-income countries, where an increasingly large proportion of older people live, the effects of extreme social inequalities have accumulated over the life-course, and where societies generally have fewer resources.[2–4] Comparisons among countries can help to identify how different individual factors contribute to disability within different social and

economic contexts. This information is essential to inform more targeted and contextually-informed public health strategies to reduce the burden of disability in different contexts.

Based on the idea that there is a chain of risks over the life-course, childhood socioeconomic and health status can be considered important distal determinants of disability in older ages.[4–7]Early-life socioeconomic and health conditions may influence adult health directly (e.g. through organ and tissue growth during critical and sensitive periods of development) and indirectly through cognitive and behavioral factors that influence educational attainment and later family and employment trajectories, all raising the risk of future chronic diseases and disability.[5,7] In large cities in Latin American and the Caribbean, e.g. childhood conditions have been found to have a strong influence on basic activities of daily living (BADL) disability in later life, both by increasing the likelihood of chronic diseases and by increasing the risk of disability as a consequence of such diseases.[7] In China, men who were exposed to the Great Famine were more likely to suffer BADL limitations in old age.[8] In the USA and European countries, low childhood socioeconomic position was associated with severe BADL disabilities and its trajectory in later life.[5]

Socioeconomic status (SES) reflects an accumulation of resources over the life-course and is recognized as an important determinant of health and health-related conditions.[9] Education, one component of SES, is accomplished relatively early in life and is widely recognized to be a fundamental determinant of health inequalities. Higher education affects how individuals achieve higher income, safer occupations and psychosocial well-being, which are associated with better health outcomes.[10,11] SES, as assessed by income or educational level, has been consistently associated with BADL disability or disability-free life expectancy in diverse contexts.[3,12–15]

Chronic diseases are strongly associated with disability.[16–19] Chronic diseases represent the first phase of the disablement process and appear to be the most important factor in explaining disability trajectories.[17] The presence of two or more chronic conditions (multimorbidity) increases the likelihood of disability relative to most single chronic diseases.[18,20] However, there is evidence from European countries suggesting that the association between multimorbidity and BADL disability may vary by geographical area.[19]

Given the geographic variation in the relationship between risk factors associated with increased disability risk, it is plausible that the national social and economic context may help to explain such variation. A previous systematic review examined the literature on the association between national socioeconomic development indicators and functioning in old age, as assessed by gait speed.[21] The authors found evidence of a strong relationship between gait speed and education, income and life expectancy—three measures that compose the Human Development Index (HDI).[21]

Nonetheless, there is a need to examine how individual life-course risk factors influence BADL disability in older adults across countries with diverse levels of human development. We address this gap using data from the latest wave of nationally representative longitudinal studies of older adults conducted in 19 countries that are part of the family of Health and Retirement Study (HRS). These data provide an opportunity to compare determinants of health and health-related conditions in countries at different levels and stages of human development with two main objectives[1]: to examine the association between health conditions in childhood, educational level and multimorbidity with BADL disability within each of the 19 participating countries; and[2] to assess whether the association between life-course risk factors and BADL disability varies by national level of HDI.

Methods

Data sources

Our data were derived from nationally representative surveys of people aged 50 years and over conducted in Brazil (Brazilian Longitudinal Study of Aging: ELSI),[22] China (Chinese Health and Retirement Longitudinal Study: CHARLS),[23] Mexico (Mexican Health and Aging Study: MHAS),[24] USA (HRS)[25] and 15 European countries (Survey of Health and Ageing and Retirement in Europe: SHARE).[26] Survey inclusion criteria were the existence of information on BADL and selected life-course risk factors for all participants in the most recent wave of each survey.

ELSI data were extracted from the baseline survey conducted in 2015–16. MHAS data were from wave 4 (2015). Harmonized CHARLS Version C (wave 4 from 2015) and harmonized SHARE Version D5 (wave 6 from 2014 to 15) were extracted from the Gateway to Global Aging project. HRS data (from the 2016 12th wave) were extracted from the RAND HRS Longitudinal File (V1).

Two countries from SHARE (Croatia, Israel) had very few individuals reporting values for poor early childhood health and one country (Portugal) did not collect this data during the same wave. These countries were therefore excluded from the study. The final analysis was based on 100 062 respondents with complete data from 19 countries.

Measures

The main outcome, BADL disability (a dichotomous variable), was based on self-report of difficulties in performing at least one task related to five BADL: dressing, eating, bathing, toileting and getting in or up from bed.

Our exposure variables were three potentially modifiable risk factors that operate over the life-course. They are 1) self-rated health status during childhood 2) educational level; and 3) current multimorbidity. Childhood health status was assessed by self-report of one's own health from birth to 15 years of age for all but one survey; in Mexico, self-reported health was assessed as compared to other children up to 10 years of age. Educational level was harmonized across surveys based on the UNESCO 1997 International Standard Classification of Education and categorized into less than upper secondary education, upper secondary education and vocational training and tertiary education using previously published standardized criteria.[27] All surveys asked respondents whether a doctor had ever told them they had any of a list of chronic diseases associated with the aging process. For our analysis, we used data on diseases that were available for all surveys: hypertension, diabetes, cancer, stroke, arthritis and cardiovascular diseases (myocardial infarction and/or angina and/or heart failure). Multimorbidity was defined by the report of two or more of the above conditions.

Our measure of national socioeconomic development is the HDI. The HDI is based on the concept of human capacity, and it has three dimensions: health (measured by life expectancy), education (measured by mean years of schooling for adults aged 25 years and over and expected years of schooling for children entering school) and living standards (measured by Gross National Income per capita adjusted for purchasing power parity).[28] Each component is normalized to scale between 0 and 1, and the HDI is computed as the geometric mean of the three components. For the current analysis, the 2015 HDI value was extracted for each country from the United Nations Development Program.[29]

Statistical analysis

Descriptive analyses included bivariate statistics and graphical examination of the correlation between HDI and age- and sex-adjusted BADL disability by country. We then implemented country-specific robust Poisson regressions to assess the association between multiple life-course risk factors and BADL disability in each country. All country-specific models were adjusted for health conditions in childhood, educational level and multimorbidity (all as dichotomous variables), plus age (continuous) and sex.

We then used multivariable Poisson models with robust country-clustered standard errors in a pooled analysis to assess the

Table 1 Characteristics of study participants, by country

Country	Number of respondents	Mean age (SD)	Females	Poor self-rated health in childhood	Less than upper secondary education	Multi-morbidity[a]	BADL disability[b]	Age–sex adjusted BADL disability[b]	Human Development Index, 2015
Austria	3330	66.5 (10.4)	54	2.7	23.4	69.7	10.5	9.4	0.906
Belgium	5664	65.8 (11.1)	53.4	2.6	37.8	72.5	15.3	14.1	0.913
Brazil	9163	62.4 (9.7)	54	6.6	76.2	68.8	16.2	17.6	0.755
China	12 987	63.3 (9.4)	52.4	13.4	85.5	68.2	17.5	22.9	0.742
Czech Republic	4777	65.3 (10.0)	54.6	3	36	79.4	12.7	12.2	0.882
Denmark	3645	65.7 (10.4)	52.3	2.4	18.6	69.7	8.8	8.3	0.926
Estonia	5518	66.4 (10.7)	60.2	5.9	24.6	75.3	14.3	12.6	0.871
France	3853	66.0 (11.4)	54.5	2.8	38	72.9	14.1	12.7	0.888
Germany	4326	66.3 (10.5)	53.6	2.6	13.9	75.6	12.3	11.2	0.933
Greece	4774	66.8 (11.1)	54	0.2	52.7	60	8.4	7.5	0.868
Italy	5179	66.6 (11.2)	54.4	1.3	68.3	67.4	11.9	10.5	0.875
Luxembourg	1542	64.6 (10.8)	52	3.1	44.1	66.7	9.7	9.5	0.899
Mexico	13 399	64.6 (9.6)	55.3	5	85.5	58.1	16.2	16.2	0.759
Poland	1789	64.8 (10.4)	56	2.8	33.6	73.2	15	14.5	0.858
Slovenia	4168	65.4 (10.5)	53.9	3.6	33	65.8	11.8	11.1	0.886
Spain	5541	66.6 (11.2)	53.8	2	75.5	73.9	11.4	10.1	0.885
Sweden	3864	66.7 (10.4)	52.1	1.9	31.2	64.8	8.6	7.7	0.932
Switzerland	2764	66.2 (10.3)	52.9	2	18.3	64	6.7	6.1	0.943
USA	18 015	67.5 (9.6)	54.1	1.3	13.3	84	15.2	13.3	0.917
Mean	100 062	64.83 (9.5)	52.8	4.6	51.6	75.7	15.6	15.5	0.852

All results are weighted percentages, unless otherwise specified; SD, standard deviation.
a: Two or more of the following conditions: hypertension, diabetes, cancer, stroke, arthritis and cardiovascular diseases (myocardial infarction and/or angina and/or heart failure).
b: BADL disability: at least one limitation in dressing, eating, bathing, toileting or getting in and out of bed.
Data source: Health and Retirement family of studies, 2014–16.

association between contextual (HDI) and individual-level variables (life-course risk factors, sex and age) with any BADL disability. Robust Poisson models were used as an alternative to logistic regression given that most outcomes had prevalence rates of 10% or higher.[30] These analyses additionally tested interactions among each combination of life-course risk factors as well as their interactions with national HDI to assess whether such relationships varied along the continuum of human development. Based on the final model, we calculated the predicted probabilities of any BADL disability by life-course risk factors and the national HDI and plotted the results. We note that multilevel models were not used due to the small number of higher-level (country) units of analysis.

Differences in the prevalence of chronic diseases by country could be the result of differential access to health services, especially given that countries in our sample are at different stages in achieving universal health coverage. Therefore, as a sensitivity analysis, we examined the influence of having had any doctor visit during the study recall period on the strength of the associations between multimorbidity and BADL disability by country.

All analyses incorporated the individual cross-sectional sample weights provided by each survey. We used Stata version 16.1 for all analyses.

Results

As shown in table 1, the mean age of survey participants varied from 62.4 years in Brazil to 67.5 years in the USA. Women predominated in all samples (from 52.0% in Luxembourg to 60.2% in Estonia). The prevalence of poor self-rated health in childhood was highest in China (13.4%) and lowest in Greece (0.2%). Less than secondary education largely predominated in Brazil, China, Mexico, Spain and Italy (from 68.3% to 85.5%) relative to other countries (from 13.3% in the USA to 52.7% in Greece). The prevalence of multimorbidity was highest in the US (84.0%) and lowest in Mexico (58.1%). The age-adjusted prevalence of BADL disability was highest in China (22.9%) and lowest in Switzerland (6.1%). Countries varied significantly in terms of their HDI. A cluster of countries (China, Brazil and Mexico) had values from 0.74–0.76, another cluster of countries (primarily those in Eastern and Southern Europe) had values between 0.86 and 0.89 and a final group (Northern and Western European countries and the USA) had values over 0.90.

Table 2 shows the results of analyses of the association between the independent variables and BADL disability by country. As expected, older age (70 years and over) was associated with increased BADL disability in all countries [Prevalence ratios (PRs) ranged from 1.42 in the USA to 5.04 in Greece]. Women were more likely to report BADL disability in six countries. At the same time, men were more likely to report disability only in Denmark, and no significant association with sex ($P>0.05$) was observed in the remaining countries. Poor self-rated childhood health was significantly ($P<0.05$) associated with increased disability prevalence in eight countries (PRs ranged from 1.25 in China to 3.77 in Greece). Less than upper secondary education was associated with disability in all countries except Poland with PRs ranging from 1.49 in Estonia to 2.21 in Spain. Multimorbidity showed strong associations with disability in all countries with PRs ranging from 2.07 in Brazil to 6.23 in the USA.

As Supplementary appendix figure S1 shows, there is an inverse relationship between HDI and the prevalence of age- and sex-adjusted disability (Pearson's r coefficient $=-0.7837$). This relationship is examined in table 3, which presents results from pooled multivariable analyses.

In table 3, results confirm that across all countries, women and those aged 70 and over had increased prevalence of disability. Poor (as compared to very good) childhood health contributed to about a 29% higher prevalence of disability and, compared with completed secondary education or more, less than secondary education was similarly associated with increased disability (PR=1.64). In all models, multimorbidity had the largest single contribution to disability (PR=2.80). The HDI was strongly negatively associated with the prevalence of disability (PR=0.18). The only interactions between life-course factors found to be statistically significant were between education and multimorbidity. The interaction between low educational attainment and HDI was negatively associated with disability,

Table 2 Country-specific association[a] between age, sex and life-course risk factors with BADL disability[b] among adults aged 50 years and over, by country

Country	Age 70 and over vs. <70	Female vs. male	Poor self-rated health in childhood vs. fair/good	Less than upper secondary education vs. higher	Multimorbidity vs. none[c]
Austria	3.44***	1	1.51	1.71***	2.26***
	2.56, 4.62	0.79, 1.28	0.76, 3.00	1.36, 2.14	1.37, 3.70
Belgium	2.29***	1.21*	1.72**	1.58***	2.86***
	1.94, 2.72	1.04, 1.41	1.20, 2.45	1.36, 1.84	2.00, 4.10
Brazil	1.52***	1	1.71***	1.79***	2.07***
	1.36, 1.69	0.90, 1.12	1.47, 2.00	1.51, 2.14	1.78, 2.42
China	1.91***	1.35***	1.25***	1.92***	2.6***
	1.76, 2.07	1.25, 1.47	1.13, 1.39	1.58, 2.33	2.30, 2.94
Czech Republic	2.03***	0.85	1.17	1.91***	3.48***
	1.52, 2.70	0.64, 1.15	0.72, 1.88	1.42, 2.57	1.73, 7.02
Denmark	2.17***	0.76*	2.26***	1.68***	3.53***
	1.70, 2.75	0.61, 0.96	1.42, 3.60	1.30, 2.16	2.26, 5.52
Estonia	1.85***	1.14	1.22	1.49***	4.06***
	1.58, 2.16	0.98, 1.33	0.95, 1.56	1.30, 1.70	2.67, 6.18
France	2.5***	0.96	1.29	1.49***	4.9***
	2.05, 3.04	0.82, 1.14	0.87, 1.92	1.25, 1.77	3.00, 7.99
Germany	2.42***	1.04	1.18	1.59***	2.74***
	1.98, 2.94	0.86, 1.26	0.73, 1.91	1.26, 1.99	1.85, 4.04
Greece	5.04***	1.35	3.77***	1.8*	3.47**
	2.98, 8.52	0.95, 1.92	1.80, 7.91	1.13, 2.88	1.58, 7.63
Italy	3.31***	1.55***	1.45	1.66***	3.17***
	2.54, 4.31	1.27, 1.90	0.79, 2.69	1.26, 2.19	1.81, 5.56
Luxembourg	2.9***	1.12	0.68	1.71*	2.44*
	1.92, 4.39	0.76, 1.65	0.20, 2.32	1.12, 2.62	1.09, 5.45
Mexico	2.02***	1.26*	1.68***	1.91*	2.11***
	1.73, 2.35	1.06, 1.51	1.25, 2.26	1.12, 3.26	1.68,2.66
Poland	2.35***	1.04	0.93	1.24	4.05***
	1.76, 3.15	0.81, 1.34	0.48, 1.80	0.95, 1.62	1.83, 8.95
Slovenia	2.84***	0.88	1.39	1.57***	2.3***
	2.18, 3.70	0.69, 1.12	0.88, 2.21	1.23, 2.01	1.50, 3.54
Spain	3.36***	1.29*	1.86*	2.21***	2.79***
	2.29, 4.92	1.01, 1.64	1.12, 3.07	1.40, 3.47	1.56, 4.98
Sweden	1.5**	1.07	1.9	1.58**	2.21***
	1.12, 2.00	0.83, 1.38	0.96, 3.74	1.20, 2.07	1.47, 3.34
Switzerland	2.01***	0.97	1.61	1.84***	4.35***
	1.42, 2.85	0.70, 1.33	0.80, 3.22	1.30, 2.60	2.49, 7.57
USA	1.42***	1.13**	1.84***	2.07***	6.23***
	1.31, 1.54	1.04, 1.23	1.47, 2.30	1.89, 2.25	4.60, 8.43

a: Prevalence ratios and 95% confidence intervals. Each country estimate calculated separately using survey-weighted robust Poisson regression mutually adjusted for all variables listed in the table.
b: BADL disability: at least one limitation in dressing, eating, bathing, toileting, getting in and out of bed.
c: Two or more of the following conditions: hypertension, diabetes, cancer, stroke, arthritis and cardiovascular diseases (myocardial infarction and/or angina and/or heart failure).
*: $P<0.05$.
**: $P<0.01$.
***: $P<0.001$.
Data source: Health and Retirement family of studies, 2014–16.

but the three-way interaction between multimorbidity, educational attainment and the HDI (data not shown) was not statistically significant.

Figure 1 plots the relationship between each life-course risk factor and national HDI from the results presented in table 3 (model 3). The Figure shows (left panel) that for individuals who have completed upper secondary education or more, the influence of childhood self-rated health on disability does not vary by national HDI. However, among those with multimorbidity, there is an inverse relationship between national HDI and disability. For those with less than secondary education (right panel), the probability of disability is higher, regardless of additional life-course risk factors. Moreover, there is a stronger HDI-related gradient for both self-rated childhood health and multimorbidity. The highest probability of disability (36.7%) is observed among those with all three life-course risk factors within the lowest HDI country. This is in contrast with an otherwise similar individual living in the highest HDI country, where the estimated likelihood of disability would be 21.8%.

In sensitivity analyses presented in Supplementary appendix table S1, access to health services only moderately attenuates the previously reported relationships between life-course risk factors and disability.

Because the HDI has been criticized for ignoring within-country inequality, we tested an alternative measure, the inequality-adjusted HDI, which incorporates inequalities in each of the three measures comprising the HDI.[31] Results were nearly identical to those reported using the standard HDI (see Supplementary appendix table S2).

Discussion

Major findings from this analysis are: 1) the age–sex adjusted prevalence of BADL disability was higher in countries with lower HDI with the highest value observed in China (23%) 2) in pooled analyses, poor health in childhood, educational attainment and multimorbidity were all associated with disability, independent of age and

Table 3 Association[a] between contextual and individual characteristics with BADL disability[b] among adults aged 50 years and over in 19 countries

	Model 1	Model 2	Model 3	Model 4	Model 5
Female (vs. male)	1.27***	1.29***	1.29***	1.29***	1.29***
	1.16, 1.39	1.18, 1.41	1.19, 1.40	1.19, 1.40	1.18, 1.40
Age 70+ (vs. younger)	1.82***	1.9***	1.89***	1.89***	1.9***
	1.70, 1.94	1.74, 2.06	1.73, 2.06	1.73, 2.06	1.74, 2.08
Poor childhood health	1.35***	1.29***	1.29***	1.29***	1.29***
(vs. good)	1.20, 1.53	1.21, 1.37	1.21, 1.37	1.21, 1.38	1.21, 1.37
Less than secondary education	1.95***	1.64***	2.75***	2.42***	9.99***
(vs. secondary or more)	1.76, 2.16	1.41, 1.91	1.97, 3.83	1.76, 3.33	4.04, 24.70
Multimorbidity[c] (vs. none)	2.74***	2.8***	4.5***	1.18	4.36***
	2.39, 3.15	2.41, 3.26	3.36, 6.02	0.29, 4.73	3.22, 5.91
HDI		0.18*	0.18*	0.04**	0.52
		0.04, 0.83	0.04, 0.81	0.01, 0.30	0.25, 1.10
Education×multimorbidity			0.57***	0.65***	0.59***
			0.43, 0.75	0.53, 0.80	0.44, 0.78
Multimorbidity×HDI				4.95	–
				0.76, 32.24	–
Education×HDI					0.21*
					0.05, 0.85
N	100 062	100 062	100 062	100 062	100 062

a: Adjusted prevalence ratios and 95% CIs from pooled Poisson regression with country cluster-robust variance and individual survey weights.
b: BADL disability: at least one limitation in dressing, eating, bathing, toileting, getting in and out of bed.
c: Two or more of the following conditions: hypertension, diabetes, cancer, stroke, arthritis and cardiovascular diseases (myocardial infarction and/or angina and/or heart failure).
*: $P<0.05$.
**: $P<0.01$.
***: $P<0.001$.
Data source: Health and Retirement family of studies, 2014–16.

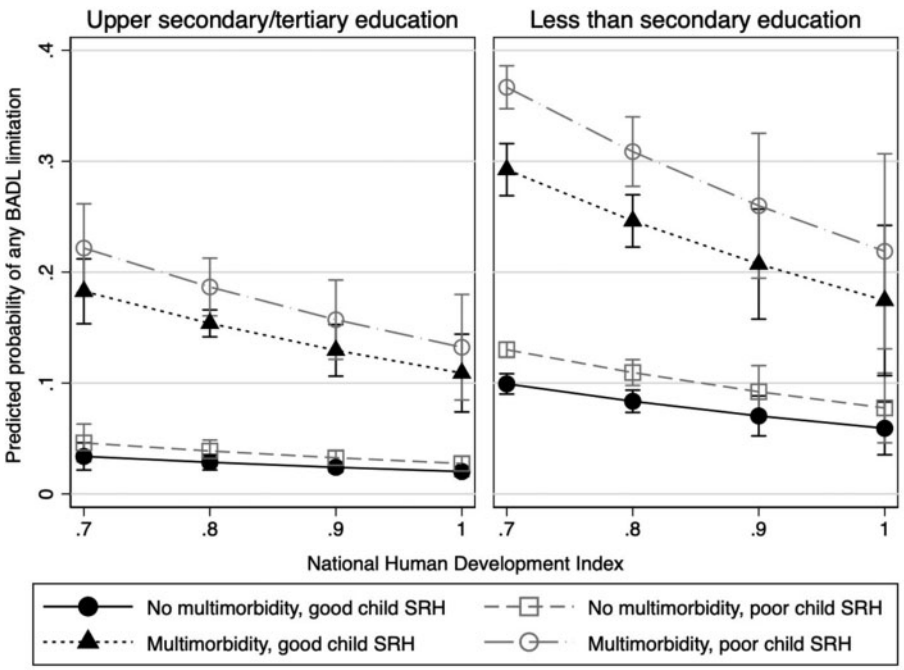

Figure 1 Predicted probability of BADL disability, by life-course risk factors and national HDI

Predicted probabilities from robust Poisson regression controlling for variables listed in table 3 (model 3).

BADL, basic activities of daily living; SRH, self-rated health during childhood.

sex and the presence of more than one of these factors significantly increased the likelihood of disability; 3) the relationship between life-course risk factors and disability was moderated by the national socioeconomic context whereby for individuals with all three risk factors, there was a 14% higher adjusted prevalence of disability in countries with the lowest HDI, as compared to those with the highest HDI.

We used self-reported health in childhood as an indicator of risk factors in early life. The strength of the association between poor health in childhood and disability varied by country and the HDI

did not entirely explain this heterogeneity. Because self-rated health in childhood is a subjective measure, it might be influenced by memory and cultural factors, which could explain part of such variation. This, and small sample sizes in some countries may partially explain why those who reported poor childhood were more likely to present BADL disability in only 7 out of 19 countries included in this analysis. In pooled analyses, poor childhood health was consistently associated with disability even after controlling for other individual and contextual factors. This result supports recommendations of the WHO Commission on the Social Determinants of Health, highlighting the role of childhood conditions as a primary source of health inequities.[9]

Educational attainment affects the life-course in fundamental ways, through occupation and occupational prestige, wages and the composition and strength of social networks, among others. These social advantages can then be used to gain health knowledge, to practice healthy behaviors, to better navigate complex health and social service systems, and to purchase healthcare and other preventive and curative products and services.[10] Low educational skills are also associated with lower adherence to prescribed medications and greater difficulty interpreting medication labels and warnings.[32] Results of the current analysis reveal a consistent inverse association between low educational attainment and BADL disability in all countries. These results suggest that improving the educational level of populations has great potential to decrease disability, particularly in those countries where low educational levels predominate.

The available evidence indicates that chronic diseases predict future functional decline, with greater declines in persons with a higher number of risk factors.[33] Our analysis indicates a high prevalence of multimorbidity in all countries with the highest value observed in the USA and the lowest in Mexico. Further, among all life-course characteristics, multimorbidity showed the strongest association with BADL disability, and this finding was consistent for all countries. Considering these countries together, older adults with multimorbidity were nearly three times more likely to present disability.

Our measure of multimorbidity was based on self-reported diseases whose accuracy depends on memory and awareness of having been diagnosed with the condition. Further, it is reasonable to hypothesize that people living in middle-income countries have worse access to health services, which could result in fewer chronic disease diagnoses. To examine this hypothesis, we implemented a sensitivity analysis examining the use of health services (doctor visits) on the association between multimorbidity and BADL disability by country (Supplementary appendix table S1). Results show that further adjustments for health service use only moderately attenuate the previously-observed associations in all contexts. Thus, differential diagnosis did not appear to explain the heterogeneity of the strength of the association between multimorbidity and disability across countries. Chronic conditions included in this analysis comprise the most common ones that occur in older people. However, it is not possible to know the potential impact that other chronic diseases could have on our results. This raises the possibility that different diseases might have different consequences in the middle relative to high-HDI countries. Further cross-national studies are needed to disentangle the complex relationship between chronic diseases and disability in countries in different stages of demographic and epidemiologic transition.

We observed an inverse correlation between HDI and the strength of the association between multimorbidity and disability, where the lower the HDI, the greater the magnitude of the association between life-course risk factors and disability. A series of ecological studies have similarly found higher HDI values to be negatively associated with several health outcomes including lower incidence and mortality for several chronic conditions[34,35] but other studies have found positive correlations with skin, uterine and colorectal cancer incidence and mortality.[36] One explanation for the relationship observed in this study is evidence that countries with higher HDIs have tended to invest public spending in social programs and policies that increase educational attainment, enhance economic productivity and improve health outcomes for the population as a whole.[37] This is consistent with research highlighting the role of the welfare state in reducing the impact of social inequalities on disability at older ages.[38] In addition, national HDI may reflect fundamental differences in national economies, such as the types of occupations cohort participants practiced over their lifetimes (manual vs. clerical vs. service-related, e.g.) and level of occupational safety protections, which have both been linked to differential risk of disability, especially in middle-income (and lower HDI) countries.[39]

Key strengths of our study were the large population from which the samples were drawn, the national-level representativeness of the samples, the documented quality and comparability of the data collected and the fact that all surveys were conducted in 2014–16. Chronic conditions included in this analysis comprise the most common conditions that occur in older adults. However, it is not possible to know the potential impact that other chronic diseases could have on our results, this being a major limitation of the study. Other limitations are those inherent to cross-sectional analysis: the impossibility of establishing a temporal relationship between exposure and disability (as was the case of multimorbidity in our analysis, e.g.). We believe that reverse causality is unlikely because longitudinal analyses have shown that chronic diseases generally predict future BADL trajectories.[40] The use of prevalence measures of disability is another limitation given that prevalence is affected by both the incidence and the duration of the condition. Under this assumption, higher BADL prevalence might be explained by longer survival with the condition. However, it is unlikely that the highest prevalence of BADL in China, e.g. is explained by longer survival with disability relative to higher-income countries with higher life expectancies.

Our results support the view that disability is shaped over the life-course, with childhood health, educational attainment and multimorbidity playing central roles. Further, these life-course factors may cluster together to accelerate the progression to disability. From a macro-level perspective, the types of social and health-related investments that countries with higher human development have tended to make may support individuals with such risk factors in such a way as to reduce their contribution to disability. While these investments are crucial in any country, they are even more urgently needed in countries with lower levels of socioeconomic development, where such life-course conditions are more prevalent and populations are aging at an unprecedented rate.

Supplementary data

Supplementary data are available at *EURPUB* online.

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from the Harmonized HRS dataset and Codebook, Version A as of February 2018, and the Harmonized MHAS programming codes and Codebook, Version A. All were developed by the Gateway to Global Aging Data. ELSI information and programming codes were developed by the ELSI research team.

Data availability

Links to all publicly available cohort data are available from the following sites: www.g2aging.org and www.elsi.cpqrr.fiocruz.br.

Conflicts of interest: None declared.

Key points

- There is currently little known about whether individual life-course risk factors (multimorbidity, poor childhood health, low educational attainment) influence disability in older adults in a similar fashion across countries with different values of the Human Development Index (HDI).
- Among individuals with all three life-course risk factors, predicted disability prevalence ranged from 36.7% in the lowest HDI country to 21.8% in the countries with the highest HDI, after controlling for confounders.
- Social and health-related investments are crucial in any country, but they are even more urgently needed in countries with lower levels of socioeconomic development, where life-course risk factors are more prevalent, and populations are aging at an unprecedented rate.

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Determinants of inequalities in years with disability: an international-comparative study

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Background: Persons with a lower socioeconomic position spend more years with disability, despite their shorter life expectancy, but it is unknown what the important determinants are. This study aimed to quantify the contribution to educational inequalities in years with disability of eight risk factors: father's manual occupation, low income, few social contacts, smoking, high alcohol consumption, high body-weight, low physical exercise and low fruit and vegetable consumption. **Methods:** We collected register-based mortality and survey-based disability and risk factor data from 15 European countries covering the period 2010–14 for most countries. We calculated years with disability between the ages of 35 and 80 by education and gender using the Sullivan method, and determined the hypothetical effect of changing the prevalence of each risk factor to the prevalence observed among high educated ('upward levelling scenario'), using Population Attributable Fractions. **Results:** Years with disability among low educated were higher than among high educated, with a difference of 4.9 years among men and 5.5 years among women for all countries combined. Most risk factors were more prevalent among low educated. We found the largest contributions to inequalities in years with disability for low income (men: 1.0 year; women: 1.4 year), high body-weight (men: 0.6 year; women: 1.2 year) and father's manual occupation (men: 0.7 year; women: 0.9 year), but contributions differed by country. The contribution of smoking was relatively small. **Conclusions:** Disadvantages in material circumstances (low income), circumstances during childhood (father's manual occupation) and high body-weight contribute to inequalities in years with disability.

Introduction

Persons with low levels of education spend more years with disability despite their shorter life expectancy than persons with higher levels of education.[1,2] This is the net result of two opposing effects: (i) more years with disability at the expense of fewer years free of disability and (ii) fewer years with disability at the expense of years lost to mortality.[3] Years with disability impose an additional societal challenge to aging populations, because persons with disability are hospitalized more often, need more medical and long-term care and participate less in (paid) work.

In an influential article on compression of morbidity, James Fries[4] postulated that avoiding smoking, physically inactivity and an unhealthy diet would reduce the number of years with disability. Most unhealthy behaviours are more frequent among persons with a lower education.[5] Also other factors, including poor housing