



RESEARCH ARTICLE

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# Cross-country differences in the association between diabetes and disability

Shervin Assari<sup>1,2\*</sup>, Reza Moghani Lankarani<sup>3</sup> and Maryam Moghani Lankarani<sup>4,5</sup>

## Abstract

**Purpose:** This study tested possible cross-country differences in the associations between diabetes and activities of daily living (ADLs), and possible confounding / mediating effects of socio-economic status, obesity, and exercise.

**Methods:** Data came from Research on Early Life and Aging Trends and Effects (RELATE). The study included a total number of 25,372 community sample of adults who were 40 years or older. We used data from community based surveys in seven countries including China, Mexico, Barbados, Brazil, Chile, Cuba, and Uruguay. Demographics (age and gender), socio-economic status (education and income), obesity, exercise, and ADL (bath, dress, toilet, transfer, heavy, shopping, meals) were measured. Self-reported data on physician diagnosis of diabetes was the independent variable. We tested if diabetes is associated with ADL, before and after adjusting for socio-economics, obesity, and exercise in each country.

**Results:** Based on *Model I* (age and gender adjusted model), diabetes was associated with limitation in at least one ADL in Mexico, Barbados, Brazil, Chile, Cuba, and Uruguay, but not China. Based on *Model II* that also controlled for education and income, education explained the association between diabetes and limitation in ADL in Mexico and Uruguay. Based on *Model III* that also controlled for exercise and obesity, in Cuba and Brazil, exercise explained the link between diabetes and limitation in performing ADLs. Thus, the link between diabetes and ADL was independent of our covariates only in Chile and Barbados.

**Conclusions:** There are cross-country differences in the link between diabetes and limitation in ADL. There are also cross-country differences in how socio-economic status, obesity, and exercise explain the above association.

**Keywords:** Diabetes, Socio-economics, Disability, Exercise, Obesity, Cross country study

## Introduction

About three hundred fifty million people have diabetes worldwide [1]. With a direct medical cost of 465 billion U.S. dollars in the year 2011, diabetes is responsible for more than 10% of total healthcare expenditures in adults [2].

People with diabetes are more likely to experience limitations in activities of daily living (ADL), mobility, and role functioning [3-5]. Given the growing rate of diabetes and its associated disability burden in the world

[2], for different reasons, more research is still needed on the link between diabetes and ADLs [6].

First, research on disability among people with diabetes may suggest avenues for reducing the disability attributable to this common chronic disease [3]. Second, although diabetes has been consistently related to a broad spectrum of health outcomes, including quality of life, ADL and mobility disability [7], and lower extremity function [8], it is not clear if the association between diabetes and ADL remains significant after controlling for other factors, and also it is not clear if the same link exists in different countries [9]. Third, a large proportion of a major part of evidence on the link between diabetes and burden of mobility-related disability has originated from studies conducted on patients, or disabled individuals [9]. However, clinical samples and community individuals vary on many factors and there is a need to show the ADLs among individuals with

\* Correspondence: assari@umich.edu

<sup>1</sup>Department of Health Behavior and Health Education, University of Michigan School of Public Health, 1415 Washington Heights, Ann Arbor, MI 48109-2029, USA

<sup>2</sup>Center for Research on Ethnicity, Culture and Health, School of Public Health, University of Michigan, 1415 Washington Heights, Ann Arbor, MI 48109-2029, USA

Full list of author information is available at the end of the article

diabetes in a community sample. Finally, more research is needed on cross-country differences in associations between diabetes and disabilities.

Although literature has frequently shown that diabetes has a role in the disablement of people, further research is needed to extend the current limited knowledge about this association [9]. The current study tested cross-country differences in association between diabetes and ADLs.

## Methods

Data came from Research on Early Life and Aging Trends and Effects (RELATE), that included seven different studies [10]. This analysis included 25,372 individuals who were age 40 or older. These individuals were sampled in the following seven countries: China, Mexico, Barbados, Brazil, Chile, Cuba, and Uruguay. All surveys were fully in compliance with the Helsinki Declaration on ethical principles for medical research involving humans. Different institutional review boards approved participating surveys.

The following countries were participating in RELATE project and represented countries from a diverse range in national income levels: Barbados represents high income countries; Cuba, Uruguay, Chile, Brazil, and Mexico represent upper middle income countries; and China represents lower middle income countries [11].

Although most country-specific surveys had sampling weights, as recommended, the current study did not apply sampling weights. The main reason was that sampling weights were not applicable to data from China (China Health and Nutrition Study; CHNS).

## Measures

### *Demographic characteristics*

The study measured age (continuous variable) and gender (dichotomous variable of male and female) as two demographic variables.

### *Socio-economic status*

The study measured education (four level categorical variable of 1) no schooling, 2) primary to elementary, 3) secondary to intermediate, and 4) higher), and income (continuous variable) as socio-economic status.

### *Obesity and exercise*

The study measured obesity and exercise based on self reported data. BMI larger than 30 was considered as obesity.

### *Main outcome*

Seven activities of daily living (ADLs) were measured by a modified Barthel index [12-15]. ADL items that were included in this study included bath, dress, toilet,

transfer, heavy, shopping, and meals. These items have been frequently used to assess ADLs in the community sample [16,17].

## Data analysis

Data analysis was conducted using SPSS for Windows. We used country specific logistic regressions to determine if diabetes is associated with ADLs, and if this link is independent of socio-economic factors (education, and income), obesity and exercise. In all models, at least one ADL limitation was our outcome. In *Model I*, we only adjusted for age and gender. In *Model II*, we also adjusted for education and income. In *Model III*, we also adjusted for obesity and exercise.

## Results

Table 1 shows country differences by means of mean age, education, income, and ADLs. Mean age was lowest in China, and highest in Brazil. ADL limitation was highest in Chile, and lowest in Uruguay. Education was lowest in Brazil, and highest in Cuba. Income was highest in Uruguay and lowest in Cuba.

### *Model I*

Based on the first model, with an exception of China, diabetes was associated with ADL, and this link was independent of age and gender. Gender and age were associated with ADL in all countries (Table 2).

### *Model II*

Based on Model II that also controlled for education and income, education explained the association between diabetes and limitation in ADL in Mexico and Uruguay. Based on this model, gender and age were associated with ADL in all countries. However, education was not correlated with ADL in Barbados, Cuba, and Uruguay. Income was linked to ADL in China and Brazil (Table 3).

### *Model III*

Based on Model III that also controlled for obesity and exercise, in Cuba and Brazil, exercise explained the link between diabetes and limitation in performing ADLs. Based on this model, the link between diabetes and ADL was independent of our covariates only in Chile and Barbados. Based on this model, gender and age were associated with ADL in all countries. Obesity was linked to ADL only in Barbados. Exercise was linked to ADL in all countries (Table 4).

## Discussion

Our study showed at least four important cross-country differences in the pattern of association between diabetes and disability; 1) in most (i.e. Mexico, Barbados, Brazil,

**Table 1 Age, income, education, and activities of daily living in different countries among 25,372 community sample of adults**

	Min	Max	Mean	SD
<b>China</b>				
Age	40	100	60.60	10.30
Income	0	500000	8645.24	15404.23
Education	1	4	2.18	0.85
Activities of daily living	0	7	0.63	1.35
<b>Mexico</b>				
Age	40	97	68.81	8.41
Income	0	714285	11716.48	29825.89
Education	1	4	2.02	0.75
Activities of daily living	0	7	0.71	1.23
<b>Barbados</b>				
Age	60	97	72.17	8.13
Income	0	804800	9321.03	37361.75
Education	1	4	2.22	0.56
Activities of daily living	0	7	0.32	0.84
<b>Brazil</b>				
Age	60	100	72.94	8.26
Income	0	99900	3705.36	7495.84
Education	1	4	1.83	0.68
Activities of daily living	0	7	0.84	1.36
<b>Chile</b>				
Age	60	99	71.44	8.00
Income	0	989232	279282.30	266840.20
Education	1	4	2.19	0.81
Activities of daily living	0	7	0.92	1.49
<b>Cuba</b>				
Age	60	102	71.63	8.66
Income	0	109992	1456.25	5071.77
Education	1	4	2.46	0.70
Activities of daily living	0	7	0.69	1.28
<b>Uruguay</b>				
Age	60	97	70.67	7.28
Income	0	960000	39607.53	71022.13
Education	1	4	2.37	0.78
Activities of daily living	0	7	0.46	0.95

Chile, Cuba, and Uruguay) but not all countries (China), diabetes seems to be associated with ADL, 2) in some countries (i.e. Mexico and Uruguay), education explains the association between diabetes and ADL limitation, 3) in some countries (i.e. Cuba and Brazil), exercise explains the link between diabetes and ADLs, and 4) in some countries (i.e. Chile and Barbados), the link

between diabetes and ADL seems to be independent of our covariates/mediators.

Only in Chile and Barbados was the link between diabetes and ADL independent of all study covariates/mediators. Based on a study in Japan, history of diabetes, bone fractures, and heart diseases contributed to some specific aspects of ADL disabilities, however, cerebrovascular disease influenced all aspects of ADL [18].

We showed that in Cuba and Brazil, physical activity might be a mechanism behind the link between diabetes and ADL. According to the literature, at least a part of the limitations in ADLs of patients with diabetes might be due to function in extremities. A study examined how hand disorders contribute to ADLs among elderly men with diabetes, and showed that limited joint motion (measured by prayer sign and Dupuytren's contracture) was more common in individuals with diabetes, compared to non-diabetics. Vibrotactile sense was impaired symmetrically in the index and little fingers in diabetics [19].

Peripheral artery disease and peripheral nerve dysfunction are known causes of diabetes-related disability [9,20], and may explain more than 30% of the association of diabetes with disability related dysfunction in physical activity. Physical activity is particularly important for people with diabetes, because being physically active can improve the body's ability to use insulin and facilitate weight loss [21-25]. In the United States, for example, only one-third of individuals with diabetes and obesity are physically active [26,27]. Interventions need to enhance physical activity of patients, and this may break the cycle by which diabetes causes limitation in performing ADLs.

The current study failed to show mediating or confounding effects of obesity on the association between diabetes and ADLs. However, obesity had an independent association with ADLs in one of the seven countries (Barbados). Literature suggests that obesity and overweight may mediate or confound the link between diabetes and disability. In a survey among obese diabetic individuals, ADL was linked to current exercise, using exercise programs, and self-reported weight history [28]. In a qualitative study among obese (body mass index [BMI] > 30 kg/m<sup>2</sup>) individuals with diabetes, patients believed that their performance of daily activities would improve with weight loss of 5–10% of body weight [29].

The ability to remain physically active is an essential aspect of quality of life and is critical for the preservation of independence among patients with diabetes. Lower extremity function is a strong predictor of poor health outcomes, including disability, hospitalization, and death among patients [30,31]. Recently, a search for potentially modifiable conditions associated with impaired mobility and lower extremity function identified

**Table 2 Results of models I, with age and gender as covariates among 25,372 community sample of adults**

	B	S.E.	Wald	Sig.	Exp(B)	95% C.I. for EXP(B)	
						Lower	Upper
<b>China</b>							
Diabetes	.046	.057	0.636	.425	1.047	0.936	1.171
Age	.119	.002	4322.269	< .001	1.126	1.122	1.13
Female gender	.823	.038	474.844	< .001	2.277	2.115	2.452
<b>Mexico</b>							
Diabetes	.294	.149	3.866	.049	1.342	1.001	1.798
Age	.073	.008	78.043	< .001	1.075	1.058	1.093
Female gender	1.087	.134	66.085	< .001	2.966	2.282	3.855
<b>Barbados</b>							
Diabetes	.575	.151	14.59	< .001	1.778	1.323	2.389
Age	.064	.008	65.319	< .001	1.066	1.05	1.083
Female gender	.625	.143	19.177	< .001	1.869	1.413	2.472
<b>Brazil</b>							
Diabetes	.298	.121	6.036	.014	1.347	1.062	1.708
Age	.075	.006	164.576	< .001	1.078	1.066	1.09
Female gender	.973	.098	98.472	< .001	2.646	2.183	3.207
<b>Chile</b>							
Diabetes	.372	.176	4.494	.034	1.451	1.029	2.048
Age	.065	.008	69.835	< .001	1.067	1.051	1.083
Female gender	1.095	.134	66.678	< .001	2.99	2.299	3.89
<b>Cuba</b>							
Diabetes	.378	.138	7.532	.006	1.459	1.114	1.91
Age	.062	.006	112.843	< .001	1.064	1.052	1.076
Female gender	1.009	.112	80.636	< .001	2.742	2.2	3.417
<b>Uruguay</b>							
Diabetes	.323	.172	3.532	.060	1.382	0.986	1.936
Age	.06	.008	54.291	< .001	1.062	1.045	1.079
Female gender	.785	.133	34.711	< .001	2.193	1.689	2.847

several socio-demographic and behavioral characteristics, along with acute and chronic medical conditions [32,33]. Among the latter group, diabetes has been shown to be consistently a correlate of poor extremity performance [34,35].

Several impairments and comorbidities are involved in the disablement process associated with diabetes. Obesity, visual impairment, and cardiovascular diseases may mediate the association between diabetes and disability among diabetic patients. These conditions are important causes of different aspects of physical dysfunction in older individuals [36,37].

The association between diabetes and ADLs did not stay significant in the multivariable models in most countries. The literature is also not informative about the question of whether or not the link between diabetes and disability is independent of other factors that

contribute to disability. We know that several conditions that may contribute to the impairment in ADLs are more prevalent in diabetic patients than controls. These conditions may be the actual mechanisms by which diabetes is associated with physical disability. Some of these conditions include cardiovascular diseases, peripheral neuropathy, obesity, and visual deficits [35].

Our findings are important for different reasons. As very few studies have shown exact mechanisms by which disability is seen among patients with diabetes [35], our knowledge about the mechanisms underlying the disability among diabetic patients is limited. Further research is needed to know which complication of the disease plays a more important role in the disablement process. Further research is also needed on possible synergistic effects of different conditions associated with diabetes [38]. In addition, prevalence of diabetes is expected to increase

**Table 3 Results of models II, with age, gender and socio-economic status as covariates among 25,372 community sample of adults**

	B	S.E.	Wald	Sig.	Exp(B)	95% C.I. for EXP(B)	
						Lower	Upper
<b>China</b>							
Diabetes	.062	.059	1.081	.299	1.063	.947	1.194
Age	.118	.002	4050.944	.000	1.125	1.121	1.129
Female gender	.730	.042	305.224	< .001	2.075	1.912	2.252
Education	-.169	.026	41.884	< .001	.844	.802	.889
Income	.000	.000	4.355	.037	1.000	1.000	1.000
<b>Mexico</b>							
Diabetes	.236	.151	2.438	.118	1.266	.942	1.701
Age	.070	.008	71.441	< .001	1.073	1.056	1.091
Female gender	1.045	.135	60.226	< .001	2.843	2.184	3.701
Education	-.250	.078	10.385	.001	.779	.669	.907
Income	.000	.000	.269	.604	1.000	1.000	1.000
<b>Barbados</b>							
Diabetes	.666	.163	16.737	< .001	1.947	1.415	2.680
Age	.064	.009	52.773	< .001	1.066	1.047	1.084
Female gender	.588	.159	13.715	< .001	1.800	1.319	2.457
Education	-.137	.122	1.259	.262	.872	.687	1.107
Income	.000	.000	1.540	.215	1.000	1.000	1.000
<b>Brazil</b>							
Diabetes	.290	.123	5.562	.018	1.336	1.050	1.701
Age	.070	.006	135.643	< .001	1.072	1.060	1.085
Female gender	.923	.099	86.452	< .001	2.516	2.071	3.056
Education	-.237	.069	11.764	< .001	.789	.689	.903
Income	.000	.000	18.748	< .001	1.000	1.000	1.000
<b>Chile</b>							
Diabetes	.392	.180	4.750	.029	1.480	1.040	2.105
Age	.065	.008	67.121	< .001	1.067	1.051	1.084
Female gender	1.070	.137	60.798	< .001	2.917	2.229	3.817
Education	-.248	.062	16.089	< .001	.781	.692	.881
Income	.000	.000	1.143	.285	1.000	1.000	1.000
<b>Cuba</b>							
Diabetes	.381	.138	7.578	.006	1.463	1.116	1.919
Age	.058	.006	93.065	< .001	1.059	1.047	1.072
Female gender	.980	.113	75.287	< .001	2.666	2.136	3.327
Education	-.222	.073	9.251	.002	.801	.694	.924
Income	.000	.000	3.320	.068	1.000	1.000	1.000
<b>Uruguay</b>							
Diabetes	.227	.183	1.541	.214	1.255	.877	1.798
Age	.052	.009	36.573	< .001	1.054	1.036	1.072
Female gender	.820	.142	33.140	< .001	2.270	1.717	3.000
Education	-.238	.074	10.441	.001	.788	.682	.911
Income	.000	.000	.178	.673	1.000	1.000	1.000

**Table 4 Results of models III, with age, gender, socio-economic status, exercise and obesity as covariates among 25,372 community sample of adults**

	B	S.E.	Wald	Sig.	Exp(B)	95% C.I. for EXP(B)	
						Lower	Upper
<b>China</b>							
Diabetes	.036	.316	.013	.909	1.037	.558	1.926
Age	.103	.009	134.296	< .001	1.108	1.089	1.128
Female gender	.836	.136	37.870	< .001	2.307	1.768	3.011
Education	-.128	.054	5.520	.019	.880	.791	.979
Income	.000	.000	3.445	.063	1.000	1.000	1.000
Exercise	-.711	.160	19.680	< .001	.491	.359	.673
Obesity	-.390	.326	1.427	.232	.677	.357	1.284
<b>Mexico</b>							
Diabetes	.185	.166	1.236	.266	1.203	.868	1.668
Age	.062	.009	42.516	< .001	1.064	1.044	1.084
Female gender	1.042	.153	46.221	< .001	2.836	2.100	3.830
Education	-.238	.089	7.106	.008	.788	.661	.939
Income	.000	.000	.003	.953	1.000	1.000	1.000
Exercise	-.569	.160	12.663	< .001	.566	.413	.774
Obesity	.079	.154	.260	.610	1.082	.800	1.463
<b>Barbados</b>							
Diabetes	.438	.178	6.072	.014	1.550	1.094	2.196
Age	.053	.010	27.477	< .001	1.054	1.034	1.075
Female gender	.478	.176	7.411	.006	1.613	1.143	2.275
Education	-.038	.131	.084	.772	.963	.744	1.245
Income	.000	.000	2.459	.117	1.000	1.000	1.000
Exercise	-.602	.176	11.730	.001	.548	.388	.773
Obesity	.513	.185	7.716	.005	1.671	1.163	2.400
<b>Brazil</b>							
Diabetes	.125	.137	.831	.362	1.133	.866	1.484
Age	.061	.007	78.208	< .001	1.063	1.048	1.077
Female gender	.974	.114	72.657	< .001	2.649	2.117	3.314
Education	-.210	.081	6.757	.009	.811	.692	.950
Income	.000	.000	9.882	.002	1.000	1.000	1.000
Exercise	-1.075	.143	56.711	< .001	.341	.258	.451
Obesity	.198	.132	2.235	.135	1.219	.940	1.580
<b>Chile</b>							
Diabetes	.413	.188	4.848	.028	1.512	1.046	2.183
Age	.061	.008	52.554	< .001	1.063	1.045	1.080
Female gender	1.068	.145	54.130	< .001	2.911	2.190	3.870
Education	-.213	.064	11.033	.001	.808	.713	.916
Income	.000	.000	.587	.443	1.000	1.000	1.000
Exercise	-.764	.168	20.648	< .001	.466	.335	.648
Obesity	.012	.141	.007	.933	1.012	.767	1.335

**Table 4 Results of models III, with age, gender, socio-economic status, exercise and obesity as covariates among 25,372 community sample of adults (Continued)**

<b>Cuba</b>							
Diabetes	.278	.149	3.472	.062	1.320	.986	1.768
Age	.047	.007	50.995	< .001	1.048	1.035	1.061
Female gender	.956	.124	59.358	< .001	2.601	2.040	3.318
Education	-.132	.080	2.736	.098	.876	.749	1.025
Income	.000	.000	1.888	.169	1.000	1.000	1.000
Exercise	-.729	.149	23.980	< .001	.483	.361	.646
Obesity	.263	.154	2.907	.088	1.301	.961	1.760
<b>Uruguay</b>							
Diabetes	.155	.197	.623	.430	1.168	.794	1.718
Age	.047	.009	25.884	< .001	1.049	1.030	1.068
Female gender	.724	.156	21.482	< .001	2.062	1.518	2.801
Education	-.196	.081	5.878	.015	.822	.701	.963
Income	.000	.000	.382	.536	1.000	1.000	1.000
Exercise	-1.413	.282	25.015	< .001	.244	.140	.424
Obesity	.112	.145	.594	.441	1.118	.842	1.485

considerably in the next decades [38]. And knowledge from similar studies may be important for planning strategies aimed at preventing or slowing functional decline in older persons and for tertiary prevention in subjects with diabetes [9].

Our study has strengths and limitations. This was a cross-national survey composed of different surveys conducted in seven countries [10]. Research on Early Life and Aging Trends and Effects (RELATE) did not collect data on duration of diabetes, or mental health of the participants. Duration of diabetes is known to be strongly linked to disability among patients with diabetes. We also did not collect data on degree of metabolic imbalance, as we know loss of control of glucose may be a mediator for the disabling effect of diabetes [9]. Based on the literature, high prevalence of depression among diabetic patients may explain a substantial proportion of the excess risk of disability associated with diabetes. Depression is common among patients with diabetes [39-41]. Longitudinal studies are warranted to elucidate the role of depression in the pathway from diabetes to disability. Our study is one of very few studies that contribute to our understandings of cross – country differences in morbidity related to diabetes. To study cross – country differences in mental health associates of diabetes, one study used data from World Mental Health, and showed that with a consistent pattern, in all countries, mood and anxiety disorders occurred with somewhat greater frequency among persons with diabetes than those without diabetes, and the strength of association did not differ significantly across countries [42]. It is essential to conduct more research to test if

the association between diabetes and disability is independent of other chronic conditions or not [9].

Our study sheds light on cross – country differences in factors associated with well-being. Considerable differences in morbidity, life satisfaction, and well-being have been shown across the globe [43,44]. The World Values Survey, European Values Study, Eurobarometer, and Latinobarometer, have consistently shown that life expectancy, physical health, all-cause mortality, and also subjective well-being vary across countries [45-48].

## Conclusion

To conclude, our study showed considerable differences in the association between diabetes and disability across countries. The study also suggests that there might be some cross-country differences in the factors that may explain this link.

## Competing interests

The authors declare that they have no competing interests.

## Authors' contributions

SA designed the study and conducted data analysis, MML and RML conducted the literature review and drafted the manuscript. All authors read and approved the final manuscript.

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#### Author details

<sup>1</sup>Department of Health Behavior and Health Education, University of Michigan School of Public Health, 1415 Washington Heights, Ann Arbor, MI 48109-2029, USA. <sup>2</sup>Center for Research on Ethnicity, Culture and Health, School of Public Health, University of Michigan, 1415 Washington Heights, Ann Arbor, MI 48109-2029, USA. <sup>3</sup>Tehran University of Medical Sciences, Tehran, Iran. <sup>4</sup>Medicine and Health Promotion Institute, Tehran, Iran. <sup>5</sup>Universal Network for Health Information Dissemination and Exchange (UNHIDE), Tehran, Iran.

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