



Informal caregiving and physical activity among 204,315 adults in 38 low- and middle-income countries: A cross-sectional study

Louis Jacob^{a,b,*}, Lee Smith^c, Sarah E. Jackson^d, Jae Il Shin^e, Josep Maria Haro^b, Davy Vancampfort^{f,g}, Brendon Stubbs^{h,i}, Ai Koyanagi^{b,j}

^a Faculty of Medicine, University of Versailles Saint-Quentin-en-Yvelines, Montigny-le Bretonneux 78180, France

^b Research and Development Unit, Parc Sanitari Sant Joan de Déu, CIBERSAM, Dr. Antoni Pujadas, 42, Sant Boi de Llobregat, Barcelona 08830, Spain

^c The Cambridge Centre for Sport and Exercise Sciences, Anglia Ruskin University, Cambridge, United Kingdom

^d Department of Behavioural Science and Health, University College London, United Kingdom

^e Department of Pediatrics, Yonsei University College of Medicine, Yonsei-ro 50, Seodaemun-gu, C.P.O. Box 8044, Seoul 03722, Republic of Korea

^f KU Leuven, Department of Rehabilitation Sciences, Leuven, Belgium

^g KU Leuven, University Psychiatric Center KU Leuven, Leuven, Kortenberg, Belgium

^h Institute of Psychiatry, Psychology and Neuroscience, King's College London, London, United Kingdom

ⁱ South London and Maudsley NHS Foundation Trust, Denmark Hill, London SE5 8AZ, United Kingdom

^j ICREA, Pg. Lluís Companys 23, Barcelona, Spain

ARTICLE INFO

Keywords:

Informal caregiving
Physical activity
Low- and middle-income countries
Epidemiology
Multi-country study

ABSTRACT

Data on the association between informal caregiving and physical activity (PA) levels are scarce, especially from low- and middle-income countries (LMICs). Furthermore, previous research has yielded conflicting results. Thus, we investigated this association in adults from 38 LMICs. Data from the World Health Survey (WHS), a cross-sectional, predominantly nationally representative survey conducted in 2002–2004, were analyzed. PA was assessed by the International Physical Activity Questionnaire and participants were dichotomized into those who do (≥ 150 min of moderate-to-vigorous PA per week) and do not (< 150 min = low PA) comply with the World Health Organization PA recommendations. Those who provided help to a relative or friend (adult or child), because this person has a long-term physical or mental illness or disability, or is getting old and weak in the past year were considered to be informal caregivers. Multivariable logistic regression analysis was conducted to assess the associations. There were 204,315 adults aged ≥ 18 years from 38 LMICs included in this study [mean (standard deviation) age 38.6 (16.1) years; 50.7% female]. Overall, the prevalence of caregiving and low PA was 19.5% and 29.9%, respectively. After adjustment for potential confounders, caregivers were at a lower risk for low PA compared to non-caregivers (OR = 0.79; 95% CI = 0.72–0.86). Engagement in greater number of caregiving activities was associated with lower odds for low PA dose-dependently. Informal caregiving was associated with higher levels of PA in adults in LMICs. Future studies of longitudinal design are warranted to understand causality and the underlying mechanisms of this association.

1. Introduction

The prevalence of people aged over 65 years in the world is expected to increase from 9% in 2019 to 16% in 2050, while the number of individuals aged 80 years or over is projected to triple from 143 to 426 million (United Nations, 2019). In addition, disability has steadily expanded in the past two decades, and the number of years lived with disability has increased from 562 million in 1990 to 853 million in

2017 (GBD 2017 Disease and Injury Incidence and Prevalence Collaborators, 2018). The rate of ageing and the prevalence of disability are higher in low- and middle-income countries (LMICs) than in high-income countries (HICs) (Mitra and Sambamoorthi, 2014; Siriwardhana et al., 2018), underlying the importance of the problem associated with population ageing and disability in this part of the world.

In this context, there will be an increase over the upcoming years in the number of individuals requiring formal (e.g., nurse services) and

* Corresponding author at: Faculty of Medicine, University of Versailles Saint-Quentin-en-Yvelines, 2 avenue de la Source de la Bièvre, Montigny-le Bretonneux 78180, France.

E-mail addresses: louis.jacob.contacts@gmail.com (L. Jacob), Lee.Smith@anglia.ac.uk (L. Smith), s.e.jackson@ucl.ac.uk (S.E. Jackson), SHINJI@yuhs.ac (J.I. Shin), jmharo@pssjd.org (J.M. Haro), davy.vancampfort@kuleuven.be (D. Vancampfort), brendon.stubbs@kcl.ac.uk (B. Stubbs), a.koyanagi@pssjd.org (A. Koyanagi).

<https://doi.org/10.1016/j.ypmed.2020.106007>

Received 24 October 2019; Received in revised form 20 January 2020; Accepted 25 January 2020

Available online 27 January 2020

0091-7435/ © 2020 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

informal care (e.g., assistance from a family member). In LMICs, there is limited access to formal care due to several factors such as low capacity of health centers, large geographical distances to the closest health center and insufficient financial means to pay the costs (Peters et al., 2008). Thus, informal caregivers play an essential role in the management of the elderly and people with disability in these countries, and the health of the caregiver is vital to sustain care provision in this setting.

In the past decades, numerous studies have investigated the impact of informal caregiving on several health outcomes. Although the majority of previous reports have focused on adverse health outcomes (e.g., psychological distress, depression) associated with caregiving (Bom et al., 2018), also in LMICs (Thrush and Hyder, 2014), some studies have shown that caregiving may also be associated with positive health outcomes (Buyck et al., 2011; Campen et al., 2013; Freedman et al., 2014; O'Reilly et al., 2017; Roth et al., 2013; Toljamo et al., 2012). Specifically, previous studies have shown that caregiving can increase levels of life-satisfaction, well-being, fulfillment and happiness, and also reduce premature mortality of the caregiver (Roth et al., 2013). Furthermore, it has been reported that caregiving with low levels of burden is associated with better mental and physical health (Buyck et al., 2011). Although the reason why caregiving may be associated with both negative and positive outcomes is largely unknown, it is possible that health behaviors such as physical activity (PA) may be playing a role as the beneficial effects of PA on mental and physical health is well-established (Buchman et al., 2012; Ghaderpanahi et al., 2011; Goodwin, 2003), while there is increasing interest in the promotion of PA as a strategy to improve the well-being of caregivers (Lambert et al., 2016). Caregiving may increase PA via increasing number of daily chores (Lam and Garcia, 2017), increased awareness of the beneficial effects of PA (Lo, 2009), and coping (Litzelman et al., 2018), but it is also possible that caregiving may lead to reduced levels of PA, via burden (del-Pino-Casado et al., 2019), stress (Longacre et al., 2017) and fatigue (Peters et al., 2015). For example, informal caregiving may be physically challenging when informal caregivers help care recipients with household activities (Lam and Garcia, 2017) or when they walk for several hours to reach the nearest health center in the context of LMICs (Blanford et al., 2012). Thus, it is of vital importance to understand PA levels among caregivers for the establishment of effective strategies to improve the well-being of caregivers.

However, to date, there are only a few studies on caregiving and its association with PA with mixed results. These studies have found either higher (Lambert et al., 2017) or lower levels of PA among caregivers compared to non-caregivers (Stacey et al., 2019), or no difference between the two groups (Hoffman et al., 2012; Litzelman et al., 2014; Marquez et al., 2012; Son et al., 2011). Although these studies are of importance, they display several limitations that should be acknowledged. First, some of them were of small sample size, and the lack of significant findings in these studies may have been due to insufficient statistical power. Second, the majority of studies failed to adjust for important potential confounders such as disability or depression, and this may have biased their results. Third, all except one study (Lambert et al., 2017) were conducted in HICs, and therefore, little is known about the informal caregiving-PA relationship in LMICs. Exploring this association in LMICs is of particular interest as for many informal caregivers in this part of the world, their priority is actually to fulfil their own basic human needs (e.g., food, accommodation, income, education) rather than looking after a relative or neighbor (Lempp et al., 2018). Fourth, only one of these studies was nationally representative, and therefore generalizability is limited (Lambert et al., 2017). Finally, many of the studies only focused on one aspect of PA (e.g., leisure-time PA) and data on caregiving and compliance with the World Health Organization (WHO) PA guidelines (≥ 150 min of moderate-to-vigorous PA per week) are scarce.

Therefore, the goal of this study was to investigate the potential association between informal caregiving and PA (compliance with the

WHO PA guidelines) in adults from 38 LMICs using predominantly nationally representative datasets.

2. Methods

2.1. The survey

The World Health Survey (WHS) was a cross-sectional survey conducted in 70 countries in 2002–2004. Survey details are available from the WHO (<http://www.who.int/healthinfo/survey/en/>). Briefly, single-stage random sampling was carried out in 10 countries, while the remaining 60 countries used stratified multi-stage random cluster sampling. All adults aged ≥ 18 years with a valid home address were assigned a non-zero chance of inclusion. Standard translation procedures for the survey questionnaire were followed to ensure comparability across countries. Face-to-face interviews and telephone interviews were conducted by trained interviewers. Individual level response rates were over 82%. Post-stratification corrections were made to sampling weights to adjust for non-response and the population distribution reported by the United Nations Statistical Division. Ethical boards at each study site provided ethical approval for the survey with all participants providing informed consent.

In 2003, LMICs were countries with gross national income (GNI) per capita $\leq \$9385$ (low-income countries $\leq \$765$; lower-middle income countries: \$766–\$3035; upper-middle income countries \$3036–\$9385) (The World Bank, 2020). Data from 69 countries were publically available in the WHS. In the current analysis, a total of 38 LMICs ($n = 204,315$) were included (reasons for the exclusion of countries are provided in Fig. S1). These countries corresponded to 16 low-income countries (LICs) ($n = 83,905$) and 22 middle-income countries (MICs) ($n = 120,410$). The data were nationally representative for all countries with the exception of China, Comoros, India, Ivory Coast, and Russia.

2.2. Variables

2.2.1. Physical activity (outcome variable)

Items from the International Physical Activity Questionnaire were used to categorize PA (Stubbs et al., 2017, 2016). Specifically, participants were asked how many days over the past week on average they engaged in moderate and vigorous PA. Secondly, participants were asked for how many minutes on average, they engage in PA at a moderate and vigorous level. The total amount of moderate-to-vigorous PA over the last week was calculated and those scoring ≥ 150 min were classified as meeting the recommended guidelines (coded 0), and those scoring < 150 min (low PA) were classified as not meeting the recommended guidelines (coded 1) (World Health Organization, 2010).

2.2.2. Informal caregiving (exposure variable)

Those who answered affirmatively to the question “During the past year, did you provide help to a relative or friend (adult or child), because this person has a long-term physical or mental illness or disability, or is getting old and weak?” were considered to be informal caregivers (Hosseinpoor et al., 2013). This question is comparable to those used in previous surveys to identify informal caregivers (Smith et al., 2014). Furthermore, questions on five types of caregiving activities (i.e., personal care, medical care, household activities, supervision, transport/mobility) with “Yes” and “No” options were asked to caregivers (see Table S1 for actual questions). The number of caregiving activities was summed. Non-caregivers were assigned a score of 0.

2.2.3. Control variables

The selection of the control variables used in this analysis was based on past literature (Koyanagi et al., 2018a, 2018b) and included age, sex, marital status (married/cohabiting, never married, separated/divorced/widowed), wealth, highest education attained (no formal

education, primary education, secondary or high school completed, and tertiary education completed), household size (1, 2, 3–5, ≥ 6), employment status (not working for pay or currently in paid employment), disability, and depression. Country-wise wealth quintiles were created using principal component analysis based on 15–20 assets. Individuals who had severe/extreme difficulty in either moving around, performing self-care, concentrating/remembering things, or seeing and recognizing a person across the road in the past 30 days were considered to have disability (Mitra and Sambamoorthi, 2014). Depression was assessed with the Diagnostic and Statistical Manual of Mental Disorders (DSM)-IV algorithm based on duration and persistence of depressive symptoms in the past 12 months (Cifuentes et al., 2008; Loerbroks et al., 2012). The algorithms used are provided in Table S2.

2.3. Statistical analysis

Statistical analyses were performed with Stata 14.1 (Stata Corp LP, College station, Texas). Multivariable logistic regression analysis was conducted to assess the association between informal caregiving (exposure variable) and low PA (outcome variable). Analyses using the overall sample and those stratified by age groups (18–44, 45–64, ≥ 65 years) and sex were conducted. These analyses adjusted for age, sex (apart from the sex-stratified analysis), marital status, wealth, education, household size, employment status, disability, depression, and country. Adjustment for country was conducted by including dummy variables for each country as in previous WHS publications (Koyanagi et al., 2017, 2016). Using the overall sample, we repeated a similar analysis with the number of caregiving activities as the exposure variable.

Finally, to assess the generalizability of the findings based on the pooled sample across all countries, we conducted country-wise regression analyses for the association between caregiving and low PA adjusting for age and sex. A pooled estimate was obtained by meta-analysis with random effects. To assess the level of between-country heterogeneity, the Higgins's I^2 statistic was calculated. This represents the degree of heterogeneity that is not explained by sampling error with values of 25%, 50%, and 75% often being considered to represent low, moderate, and high levels of heterogeneity, respectively (Higgins et al., 2003).

All variables were included in the models as categorical variables with the exception of age (continuous variable). Taylor linearization methods were used in all analyses to account for the sample weighting and complex study design. Results from the logistic regression analyses are presented as odds ratios (ORs) with 95% confidence intervals (CIs).

3. Results

3.1. Sample characteristics

The mean (standard deviation) age of the sample was 38.6 (16.1) years with 50.7% of the sample being females. The prevalence of informal caregiving overall was 19.5% (95% CI = 18.9%–20.0%) with this figure being higher in MICs (23.7%; 95% CI = 22.9%–24.4%) than in LICs (16.1%; 95% CI = 15.5%–17.0%). Overall, 4.9%, 3.5%, 3.6%, 2.9%, and 3.1% engaged in 1, 2, 3, 4, and 5 caregiving activities over the past year. The overall prevalence of low PA was 29.9% (95% CI = 29.1%–30.8%). The prevalence of informal caregiving and low PA ranged from 8.4% (Pakistan) to 38.2% (Paraguay), and 9.6% (Comoros) to 81.8% (Mauritania), respectively (Table 1). Informal caregivers tended to be younger, women, richer, employed, and have higher levels of education, household size of 2–5, disability, and depression than non-caregivers (Table 2). The prevalence of each type of caregiving activity among informal caregivers by country is illustrated in Table S3. There was a wide variation in informal caregiving activities between countries. For example, only 23.7% of caregivers in Malawi were involved in transport/mobility (i.e., providing help getting around

Table 1
Sample size and prevalence of informal caregiving and low physical activity by country.

Country-income	Country	N	Informal caregiving (%)	Low physical activity (%)
Low	Bangladesh	5942	17.5	22.3
	Burkina Faso	4948	17.9	14.4
	Comoros	1836	15.8	9.6
	Ghana	4165	10.7	29.5
	India	10,687	17.3	18.9
	Ivory Coast	3251	16.1	36.4
	Kenya	4640	25.1	12.4
	Laos	4988	21.5	26.3
	Malawi	5551	18.0	16.6
	Mauritania	3902	20.8	81.8
	Myanmar	6045	22.1	24.1
	Nepal	8820	27.8	14.7
	Pakistan	6501	8.4	51.1
	Vietnam	4174	19.6	17.9
	Zambia	4165	16.8	25.6
	Zimbabwe	4290	23.4	20.4
Middle	Bosnia & Herzegovina	1031	15.6	25.7
	Brazil	5000	36.6	33.6
	China	3994	10.5	39.3
	Croatia	993	27.1	26.4
	Czech Republic	949	18.2	35.6
	Dominican Republic	5027	22.8	58.9
	Estonia	1020	25.1	20.0
	Georgia	2950	18.4	32.1
	Hungary	1419	24.0	18.6
	Kazakhstan	4499	20.4	38.6
	Malaysia	6145	25.6	31.8
	Mauritius	3968	21.7	29.5
	Mexico	38,746	11.8	31.5
	Namibia	4379	15.7	48.7
	Paraguay	5288	38.2	25.6
	Philippines	10,083	22.9	11.9
	Russia	4427	22.5	30.6
	South Africa	2629	15.7	66.6
	Sri Lanka	6805	12.0	22.3
	Tunisia	5202	28.0	46.9
	Ukraine	2860	20.2	20.6
	Uruguay	2996	17.3	63.9

outside the home) while this figure was 80.3% in Nepal.

3.2. Association between informal caregiving and low physical activity

Overall, after adjustment for a variety of potential confounders (i.e., age, sex, marital status, wealth, education, household size, employment status, disability, depression, country), caregivers were at a lower risk for low PA compared to non-caregivers (OR = 0.79; 95% CI = 0.72–0.86) (Table 3). Among those aged ≥ 65 years, this effect was particularly pronounced with the OR being 0.70 (95% CI = 0.55–0.90). The association between the number of caregiving activities and low PA estimated by multivariable logistic regression is shown in Fig. 1. Compared to non-caregivers, there was a gradual decrease in the OR for low PA with increasing number of caregiving activities although the estimates for 2 and 3, or 4 and 5 caregiving activities were similar. Specifically, engaging in one caregiving activity was associated with 13% lower odds for low PA while this figure was 32%–34% for 4–5 caregiving activities. The country-wise associations between informal caregiving and low PA are shown in Fig. 2. Informal caregiving was inversely associated with low PA in the vast majority of the countries. The pooled estimate based on a meta-analysis was 0.70 (OR = 0.63–0.77) with a high-level of between-country heterogeneity ($I^2 = 78.7\%$).

Table 2
Sample characteristics (overall and by informal caregiving).

Characteristic	Category	Overall	Informal caregiving	
			No	Yes
Low physical activity	No	70.1	68.9	75.4
	Yes	29.9	31.1	24.6
Age (years)	18–44	67.3	67.1	68.5
	45–64	23.8	23.5	25.1
	≥65	8.9	9.5	6.3
Sex	Male	49.3	49.8	47.0
	Female	50.7	50.2	53.0
Marital status	Married/cohabiting	66.5	66.3	67.4
	Never married	23.2	23.3	22.9
	Separated/divorced/widowed	10.3	10.4	9.7
Wealth	Poorest	20.1	20.9	17.2
	Poorer	19.9	20.3	18.1
	Middle	20.0	19.9	19.8
	Richer	20.0	19.8	21.1
	Richest	20.0	19.1	23.9
Education	No formal	23.8	25.7	15.3
	Primary	31.5	31.0	34.1
	Secondary	34.8	34.2	38.1
	Tertiary	9.9	9.2	12.5
Household size	1	3.6	3.7	3.2
	2	7.9	7.8	8.8
	3–5	44.6	43.9	47.4
	≥6	43.9	44.5	40.6
Unemployment	No	57.7	57.4	59.3
	Yes	42.3	42.6	40.7
Disability	No	86.7	87.0	85.3
	Yes	13.3	13.0	14.7
Depression	No	93.2	93.8	90.4
	Yes	6.8	6.2	9.6

Data are weighted %.

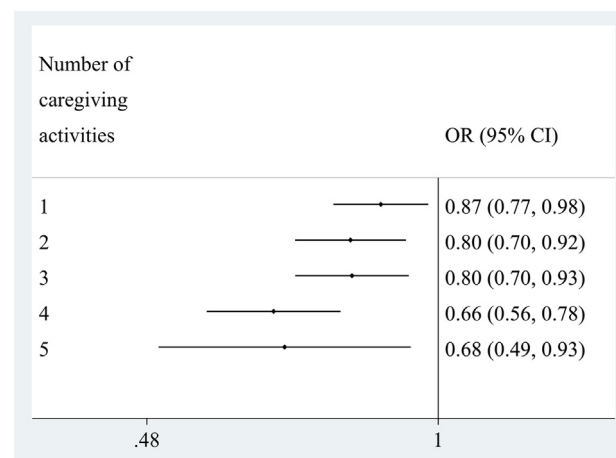


Fig. 1. Association between number of informal caregiving activities and low physical activity.

Abbreviation: OR odds ratio; CI confidence interval.

Reference category is no informal caregiving activities.

The model is adjusted for age, sex, marital status, wealth, education, household size, employment status, disability, depression, and country.

4. Discussion

4.1. Main findings

Among a sample of > 204,300 adults from 38 LMICs, the overall prevalence of informal caregiving and low PA was around 20% and 30%, respectively. After adjusting for several potential confounders, there was a negative association between informal caregiving and low

Table 3
Association of informal caregiving (and other covariates) with low physical activity.

Characteristic	Category	Overall		Age 18–44 years		Age 45–64 years		Age ≥ 65 years		Male		Female	
		OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Informal caregiving	No	1.00		1.00		1.00		1.00		1.00		1.00	
	Yes	0.79	[0.72,0.86]	0.83	[0.75,0.90]	0.79	[0.68,0.93]	0.70	[0.55,0.90]	0.82	[0.72,0.93]	0.76	[0.69,0.84]
Age (years)		1.02	[1.02,1.03]	1.00	[1.00,1.01]	1.03	[1.02,1.04]	1.06	[1.05,1.08]	1.03	[1.02,1.03]	1.02	[1.02,1.03]
Sex	Male	1.00		1.00		1.00		1.00		1.00		1.00	
	Female	1.20	[1.13,1.28]	1.39	[1.28,1.50]	0.97	[0.86,1.10]	1.13	[0.93,1.36]				
Marital status	Married/cohabiting	1.00		1.00		1.00		1.00		1.00		1.00	
	Never married	1.35	[1.24,1.47]	1.16	[1.05,1.27]	1.20	[0.91,1.58]	0.95	[0.58,1.55]	1.25	[1.10,1.43]	1.51	[1.36,1.68]
	Separated/divorced/widowed	1.30	[1.20,1.41]	1.17	[1.01,1.35]	1.30	[1.13,1.50]	1.17	[0.96,1.42]	1.13	[0.95,1.34]	1.45	[1.32,1.61]
Wealth	Poorest	1.00		1.00		1.00		1.00		1.00		1.00	
	Poorer	1.12	[1.04,1.22]	1.14	[1.02,1.27]	1.04	[0.90,1.21]	1.19	[0.96,1.47]	1.23	[1.10,1.39]	1.04	[0.93,1.16]
	Middle	1.17	[1.06,1.30]	1.19	[1.05,1.34]	1.10	[0.92,1.32]	1.15	[0.88,1.51]	1.25	[1.08,1.44]	1.12	[0.99,1.26]
	Richer	1.30	[1.18,1.43]	1.27	[1.13,1.43]	1.30	[1.10,1.52]	1.54	[1.21,1.97]	1.55	[1.36,1.76]	1.11	[0.97,1.26]
	Richest	1.67	[1.50,1.86]	1.61	[1.42,1.83]	1.92	[1.60,2.30]	1.43	[1.08,1.90]	1.89	[1.64,2.18]	1.50	[1.29,1.73]
Education	No formal	1.00		1.00		1.00		1.00		1.00		1.00	
	Primary	0.96	[0.89,1.05]	1.07	[0.95,1.20]	0.88	[0.75,1.04]	0.82	[0.66,1.02]	1.08	[0.95,1.23]	0.94	[0.84,1.05]
	Secondary	1.13	[1.02,1.25]	1.28	[1.12,1.46]	0.94	[0.77,1.15]	0.94	[0.70,1.25]	1.24	[1.07,1.44]	1.12	[0.97,1.30]
	Tertiary	1.36	[1.18,1.58]	1.61	[1.34,1.94]	0.97	[0.74,1.27]	1.11	[0.76,1.63]	1.50	[1.22,1.84]	1.27	[1.04,1.55]
Household size	1	1.00		1.00		1.00		1.00		1.00		1.00	
	2	1.04	[0.91,1.19]	0.83	[0.67,1.02]	0.81	[0.63,1.03]	1.52	[1.15,2.01]	0.88	[0.70,1.11]	1.12	[0.95,1.32]
	3–5	0.91	[0.80,1.05]	0.71	[0.58,0.86]	0.77	[0.60,0.98]	1.33	[1.01,1.76]	0.72	[0.58,0.88]	1.08	[0.91,1.27]
	≥6	0.89	[0.77,1.03]	0.68	[0.56,0.83]	0.73	[0.56,0.94]	1.53	[1.11,2.11]	0.68	[0.55,0.84]	1.08	[0.90,1.30]
Unemployment	No	1.00		1.00		1.00		1.00		1.00		1.00	
	Yes	1.80	[1.68,1.93]	1.48	[1.35,1.62]	2.18	[1.94,2.45]	2.47	[1.98,3.08]	2.06	[1.84,2.31]	1.54	[1.40,1.68]
Disability	No	1.00		1.00		1.00		1.00		1.00		1.00	
	Yes	1.61	[1.46,1.79]	1.52	[1.32,1.74]	1.31	[1.12,1.54]	2.10	[1.73,2.55]	1.86	[1.58,2.20]	1.49	[1.33,1.67]
Depression	No	1.00		1.00		1.00		1.00		1.00		1.00	
	Yes	1.05	[0.92,1.19]	0.90	[0.76,1.06]	1.32	[1.03,1.68]	1.29	[0.99,1.69]	1.40	[1.15,1.70]	0.92	[0.80,1.06]

Abbreviation: OR odds ratio; CI confidence interval.

Models were conducted using the overall sample and those stratified by age and sex groups.

Models are adjusted for age, sex (apart from the sex-stratified analysis), marital status, wealth, education, household size, employment status, disability, depression, and country.

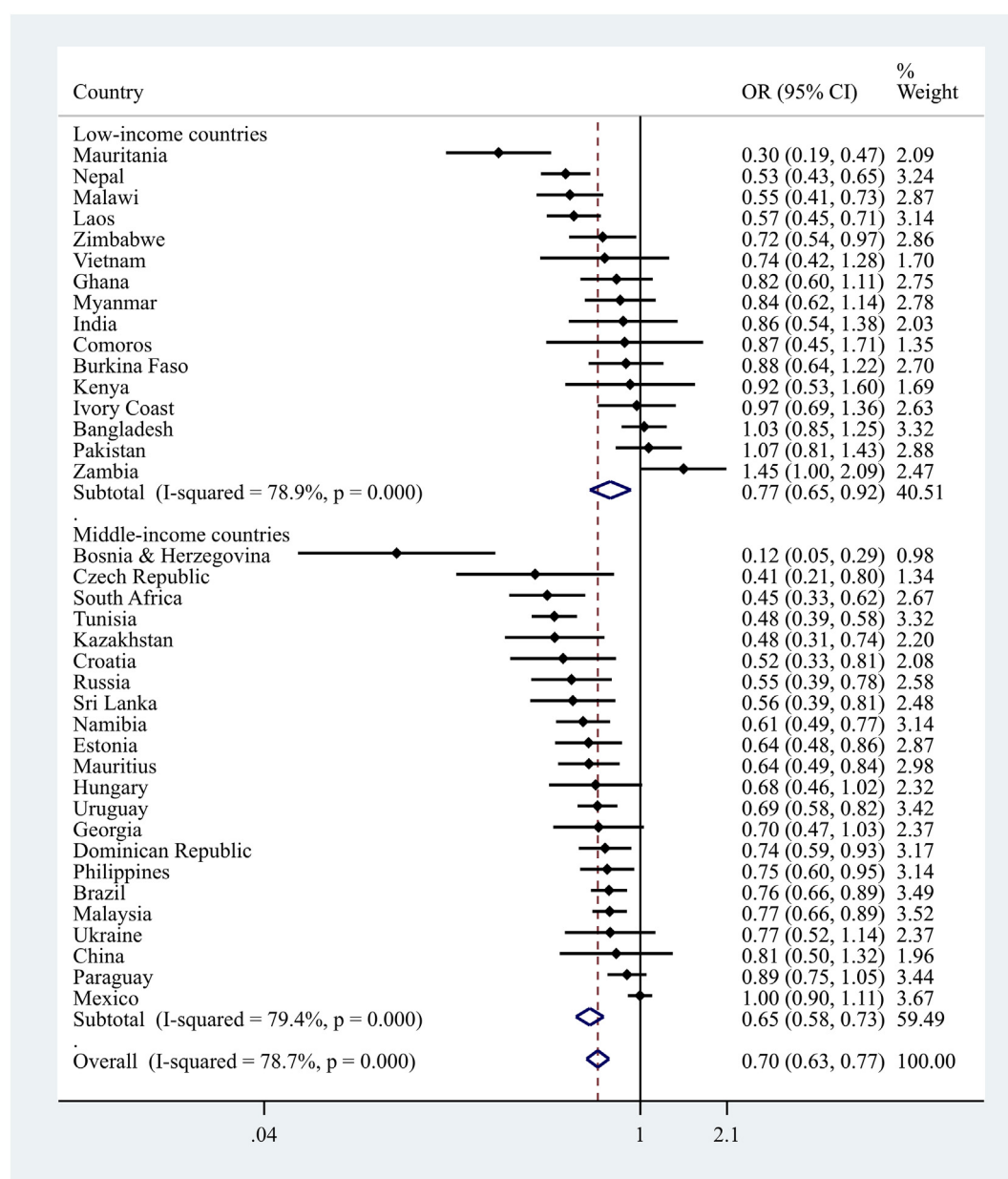


Fig. 2. Country-wise associations between informal caregiving (exposure) and low physical activity (outcome).

Abbreviation: OR odds ratio; CI confidence interval.

Overall estimate was obtained by meta-analysis with random effects.

The model is adjusted for age and sex.

PA (OR = 0.79; 95% CI = 0.72–0.86). Furthermore, a dose-response relationship was observed with increasing number of caregiving activities. These findings were corroborated in the country-wise analysis although a high level of country-wise heterogeneity was observed.

4.2. Interpretation of the findings

Previous studies focusing on the association between informal caregiving and PA have yielded contradicting findings. One large multi-country study including three LMICs found that caregivers engage in significantly greater amount of PA in India and Russia but not in Ghana (Lambert et al., 2017). Furthermore, a Korean study observed that physical inactivity was less frequent in caregivers than in controls, but this result did not reach statistical significance (Son et al., 2011). Next, a large study including 546,156 caregivers and 246,927 non-caregivers from the US found that the metabolic equivalent of task-minutes per

week did not significantly differ between the caregiving and control groups (2031 versus 1762) (Litzelman et al., 2014). Finally, a population-based longitudinal biomedical cohort study conducted in Southern Australia showed that the odds for sufficient PA were significantly lower in caregivers than in non-caregivers (Stacey et al., 2019). The discrepancy between our findings and that of some of the previous studies may be explained by methodological differences such as the definition of PA (e.g., overall PA, leisure-time PA), the tools used to measure PA, the representativeness of the sample (e.g., nationally representative or subgroups) or the setting in which the study was conducted.

We propose three hypotheses that may explain the negative association between caregiving and low PA in LMICs found in our study. First, several types of informal caregiving (e.g., personal care, household activities, transport/mobility) may be considered as physical activities per se. For example, household activities were a frequent type of

informal caregiving in this study, and this is in line with previous research. A US study including > 19,500 participants revealed that caregivers spent more time on daily housework (24 min more) than their counterparts not involved in caregiving (Lam and Garcia, 2017). Next, a substantial proportion of informal caregivers may be involved in long-distance informal caregiving. A study including child adult-older parent dyads from China found that between 26.0% and 32.4% of caregivers lived in or beyond the same province as their parents (Zuo et al., 2014). Help with transport and mobility may be particularly challenging for many people in LMICs. For example, walking for several hours to reach the nearest hospital is not rare in this setting. A study conducted in Niger found that 61% and 76% of the population needed to walk for at least 1 h to access health facilities during the dry and wet season, respectively (Blanford et al., 2012). Second, informal caregivers may be more aware of the benefits of practicing health-promoting behaviors than their counterparts not involved in caregiving. Interestingly, it was observed in a Taiwanese cross-sectional study of 137 participants that caregivers had healthier lifestyles than non-caregivers in several domains (i.e., health responsibility, PA, stress management) (Lo, 2009). Another study with 657 participants also showed that PA increased in around 24% of the family and friends of cancer patients after a cancer diagnosis, suggesting that a cancer diagnosis may favor changes in health behaviors not only in the patients but also relatives and friends (Humpel et al., 2007). This may be explained by increased recognition of the importance of healthy lifestyles following the illness of a close relative/friend in need of care, or more frequent contact with health professionals. Third, engaging in PA may be a coping strategy in informal caregivers. A study including almost 1500 caregivers of cancer survivors showed that there was a positive association between problem-focused coping and PA (Litzelman et al., 2018). Similar results were found in a US study of 162 family caregivers, where leisure-time PA participation was a significant moderator in the relationship between type of caregiving and daily psychological distress (Wong et al., 2016).

Another interesting finding of this multi-country study was the high between-country heterogeneity in the association between informal caregiving and low PA. This between-country heterogeneity may be explained by differences in factors such as quality of social service, intensity or content of caregiving, family size, and underlying disease of the care recipient. For example, personal care such as moving around was less frequent in Ghana (23.7%) and India (45.4%) than in Russia (67.9%) (Lambert et al., 2017), and thus participants from the first two countries may have been involved in caregiving activities of less intensity when compared with those from Russia. Furthermore, in countries with low fertility rates, it is possible that people have fewer sibling or other family members to share the caregiving task and this might also influence levels of PA associated with caregiving. Finally, the burden on the informal caregivers may also depend on the underlying illness of the care-recipient (Ringer et al., 2016), and the between-country heterogeneity may also be explained by different disease profiles of the care-recipient across countries.

4.3. Public health implications and areas for future research

In our study, although informal caregivers were more likely to engage in PA than non-caregivers, 24.6% of caregivers did not reach the PA targets recommended by the WHO, while caregiving was not associated with increased PA in some countries, and thus, further efforts to improve PA levels in caregivers may lead to improvements in various aspects of health. Assessment of PA (including type) among informal caregivers and provision of adequate advice on PA by health care workers may be important given increasing evidence that promotion of PA among informal caregivers may be an effective strategy to improve health outcomes (Farran et al., 2008). In particular, although caregivers may already be engaging in more PA, it is important to assess the type of PA that they are engaging in as some types of PA may be deleterious

to health (e.g., strenuous activities which may lead to injury and musculoskeletal symptoms), and provide advice on how to increase other types of PA (e.g., leisure-time PA) which are more likely to be beneficial for health. Future studies, ideally of longitudinal design, should seek to understand the underlying mechanisms of our findings. In addition, the role of PA in the association between caregiving and health outcomes should be investigated particularly in LMICs. This is particularly relevant given the recent increasing interest in promoting PA among caregivers as a strategy to improve well-being, quality of life, and self-efficacy (Lambert et al., 2016).

4.4. Strengths and limitations

The strengths of the study include the large number of participants and countries, and the use of predominantly nationally representative datasets. However, the findings should be interpreted in light of several limitations. First, there was no information on caregiving intensity, although there may be important differences in PA between low- and high-intensity caregivers. Second, more detailed variables on PA (e.g., type, frequency, context) may have led to a better understanding of the informal caregiving-PA relationship. Third, although the IPAQ is a tool to assess PA that has been validated in a variety of settings (Deng et al., 2008; Hallal et al., 2010; Helou et al., 2017), it still relies on self-report, which entails some limitations. Thus, future research should employ more sophisticated tools (e.g., accelerometry) to obtain more accurate measures on PA levels. Finally, this was a cross-sectional study, and it was thus not possible to determine causality and temporality in the association between informal caregiving and PA. For example, it is possible that those who are healthier with greater levels of PA are more likely to engage in caregiving activities.

5. Conclusions

There was an inverse relationship between informal caregiving and low PA in adults in LMICs. Given the increasing interest in PA promotion as a strategy to improve well-being among caregivers, future studies should investigate the underlying mechanisms that link informal caregiving and PA, while the role of PA in the association between caregiving and various health outcomes should also be investigated.

List of abbreviations

CI	confidence interval
DSM	Diagnostic and Statistical Manual of Mental Disorders
HICs	high-income countries
LICs	low-income countries
LMICs	low- and middle-income countries
MICs	middle-income countries
OR	odds ratio
PA	physical activity
WHO	World Health Organization
WHS	World Health Survey

Ethics approval and consent to participate

Ethical boards at each study site provided ethical approval for the survey with all participants providing informed consent.

Availability of data and materials

The datasets supporting the conclusions of this article are available in the World Health Survey repository, available at <http://www.who.int/healthinfo/survey/en/>.

Funding

Ai Koyanagi's work is supported by the PI15/00862 project, integrated into the National R + D + I and funded by the ISCIII - General Branch Evaluation and Promotion of Health Research - and the European Regional Development Fund (ERDF-FEDER). Brendon Stubbs is supported by a Clinical Lectureship (ICA-CL-2017-03-001) jointly funded by Health Education England (HEE) and the National Institute for Health Research (NIHR). Brendon Stubbs is part funded by the NIHR Biomedical Research Centre at South London and Maudsley NHS Foundation Trust. Brendon Stubbs is also supported by the Maudsley Charity, King's College London and the NIHR South London Collaboration for Leadership in Applied Health Research and Care - Greater Manchester (CLAHRC) funding. This paper presents independent research. The views expressed in this publication are those of the authors and not necessarily those of the acknowledged institutions.

CRediT authorship contribution statement

Louis Jacob: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Lee Smith:** Methodology, Writing - review & editing. **Sarah E. Jackson:** Methodology, Writing - review & editing. **Jae Il Shin:** Methodology, Writing - review & editing. **Josep Maria Haro:** Methodology, Writing - review & editing. **Davy Vancampfort:** Methodology, Writing - review & editing. **Brendon Stubbs:** Methodology, Writing - review & editing. **Ai Koyanagi:** Conceptualization, Methodology, Formal analysis, Writing - review & editing.

Declaration of competing interest

The authors have no conflicts of interest to disclose.

Acknowledgments

Nothing to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ypmed.2020.106007>.

References

- Blanford, J.I., Kumar, S., Luo, W., MacEachren, A.M., 2012. It's a long, long walk: accessibility to hospitals, maternity and integrated health centers in Niger. *Int. J. Health Geogr.* 11, 24. <https://doi.org/10.1186/1476-072X-11-24>.
- Bom, J., Bakx, P., Schut, F., van Doorslaer, E., 2018. The impact of informal caregiving for older adults on the health of various types of caregivers: a systematic review. *The Gerontologist*. <https://doi.org/10.1093/geront/gny137>.
- Buchman, A.S., Boyle, P.A., Yu, L., Shah, R.C., Wilson, R.S., Bennett, D.A., 2012. Total daily physical activity and the risk of AD and cognitive decline in older adults. *Neurology* 78, 1323–1329. <https://doi.org/10.1212/WNL.0b013e3182535d35>.
- Buyck, J.-F., Bonnaud, S., Boumendil, A., Andrieu, S., Bonenfant, S., Goldberg, M., Zins, M., Ankri, J., 2011. Informal caregiving and self-reported mental and physical health: results from the Gaze Cohort Study. *Am. J. Public Health* 101, 1971–1979. <https://doi.org/10.2105/AJPH.2010.300044>.
- Campen, C. van, Boer, A.H. de, Iedema, J., 2013. Are informal caregivers less happy than noncaregivers? Happiness and the intensity of caregiving in combination with paid and voluntary work. *Scand. J. Caring Sci.* 27, 44–50. <https://doi.org/10.1111/j.1471-6712.2012.00998.x>.
- Cifuentes, M., Sembajwe, G., Tak, S., Gore, R., Kriebel, D., Punnett, L., 2008. The association of major depressive episodes with income inequality and the human development index. *Soc. Sci. Med.* 1982 (67), 529–539. <https://doi.org/10.1016/j.socscimed.2008.04.003>.
- del-Pino-Casado, R., Rodríguez Cardosa, M., López-Martínez, C., Orgeta, V., 2019. The association between subjective caregiver burden and depressive symptoms in carers of older relatives: a systematic review and meta-analysis. *PLoS One* 14. <https://doi.org/10.1371/journal.pone.0217648>.
- Deng, H.B., Macfarlane, D.J., Thomas, G.N., Lao, X.Q., Jiang, C.Q., Cheng, K.K., Lam, T.H., 2008. Reliability and validity of the IPAQ-Chinese: the Guangzhou Biobank Cohort study. *Med. Sci. Sports Exerc.* 40, 303–307. <https://doi.org/10.1249/mss.0b013e31815b0db5>.
- Farran, C.J., Staffileno, B.A., Gilley, D.W., McCann, J.J., Li, Y., Castro, C.M., King, A.C., 2008. A lifestyle physical activity intervention for caregivers of persons with Alzheimer's disease. *Am. J. Alzheimers Dis. Other Dement.* 23, 132–142. <https://doi.org/10.1177/1533317507312556>.
- Freedman, V.A., Cornman, J.C., Carr, D., 2014. Is spousal caregiving associated with enhanced well-being? New evidence from the panel study of income dynamics. *J. Gerontol. B Psychol. Sci. Soc. Sci.* 69, 861–869. <https://doi.org/10.1093/geronb/gbu004>.
- GBD 2017 Disease and Injury Incidence and Prevalence Collaborators, 2018. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet Lond. Engl.* 392, 1789–1858. [https://doi.org/10.1016/S0140-6736\(18\)32279-7](https://doi.org/10.1016/S0140-6736(18)32279-7).
- Ghaderpanahi, M., Fakhrzadeh, H., Sharifi, F., Badamchizade, Z., Mirarefin, M., Ebrahim, R.P., Ghotbi, S., Nouri, M., Larijani, B., 2011. Association of physical activity with risk of type 2 diabetes. *Iran. J. Public Health* 40, 86–93.
- Goodwin, R.D., 2003. Association between physical activity and mental disorders among adults in the United States. *Prev. Med.* 36, 698–703. [https://doi.org/10.1016/S0091-7435\(03\)00042-2](https://doi.org/10.1016/S0091-7435(03)00042-2).
- Hallal, P.C., Gomez, L.F., Parra, D.C., Lobelo, F., Mosquera, J., Florindo, A.A., Reis, R.S., Pratt, M., Sarmiento, O.L., 2010. Lessons learned after 10 years of IPAQ use in Brazil and Colombia. *J. Phys. Act. Health* 7 (Suppl. 2), S259–S264. <https://doi.org/10.1123/jpah.7.s2.s259>.
- Helou, K., El Helou, N., Mahfouz, M., Mahfouz, Y., Salameh, P., Harmouche-Karak, M., 2017. Validity and reliability of an adapted Arabic version of the long international physical activity questionnaire. *BMC Public Health* 18. <https://doi.org/10.1186/s12889-017-4599-7>.
- Higgins, J.P.T., Thompson, S.G., Deeks, J.J., Altman, D.G., 2003. Measuring inconsistency in meta-analyses. *BMJ* 327, 557–560. <https://doi.org/10.1136/bmj.327.7414.557>.
- Hoffman, G.J., Lee, J., Mendez-Luck, C.A., 2012. Health behaviors among baby boomer informal caregivers. *The Gerontologist* 52, 219–230. <https://doi.org/10.1093/geront/gns003>.
- Hosseinpour, A.R., Bergen, N., Chatterji, S., 2013. Socio-demographic determinants of caregiving in older adults of low- and middle-income countries. *Age Ageing* 42, 330–338. <https://doi.org/10.1093/ageing/afz196>.
- Humpel, N., Magee, C., Jones, S.C., 2007. The impact of a cancer diagnosis on the health behaviors of cancer survivors and their family and friends. *Support Care Cancer* 15, 621–630. <https://doi.org/10.1007/s00520-006-0207-6>.
- Koyanagi, A., Stickley, A., Haro, J.M., 2016. Psychotic symptoms and smoking in 44 countries. *Acta Psychiatr. Scand.* 133, 497–505. <https://doi.org/10.1111/acps.12566>.
- Koyanagi, A., Vancampfort, D., Carvalho, A.F., DeVylder, J.E., Haro, J.M., Pizzol, D., Veronese, N., Stubbs, B., 2017. Depression comorbid with tuberculosis and its impact on health status: cross-sectional analysis of community-based data from 48 low- and middle-income countries. *BMC Med.* 15, 209. <https://doi.org/10.1186/s12916-017-0975-5>.
- Koyanagi, A., DeVylder, J.E., Stubbs, B., Carvalho, A.F., Veronese, N., Haro, J.M., Santini, Z.I., 2018a. Depression, sleep problems, and perceived stress among informal caregivers in 58 low-, middle-, and high-income countries: a cross-sectional analysis of community-based surveys. *J. Psychiatr. Res.* 96, 115–123. <https://doi.org/10.1016/j.jpsychires.2017.10.001>.
- Koyanagi, A., Stubbs, B., Vancampfort, D., 2018b. Correlates of low physical activity across 46 low- and middle-income countries: a cross-sectional analysis of community-based data. *Prev. Med.* 106, 107–113. <https://doi.org/10.1016/j.ypmed.2017.10.023>.
- Lam, J., Garcia, J., 2017. General and proximal associations between unpaid eldercare, time constraints and subjective well-being. *Int. J. Care Caring* 1, 83–96. <https://doi.org/10.1332/239788217X14866303262183>.
- Lambert, S.D., Duncan, L.R., Kapellas, S., Bruson, A.-M., Myrand, M., Santa Mina, D., Culos-Reed, N., Lambrou, A., 2016. A descriptive systematic review of physical activity interventions for caregivers: effects on caregivers' and care recipients' psychosocial outcomes, physical activity levels, and physical health. *Ann. Behav. Med. Publ. Soc. Behav. Med.* 50, 907–919. <https://doi.org/10.1007/s12160-016-9819-3>.
- Lambert, S.D., Bowe, S.J., Livingston, P.M., Heckel, L., Cook, S., Kowal, P., Orellana, L., 2017. Impact of informal caregiving on older adults' physical and mental health in low-income and middle-income countries: a cross-sectional, secondary analysis based on the WHO's Study on global AGEing and adult health (SAGE). *BMJ Open* 7, e017236. <https://doi.org/10.1136/bmjopen-2017-017236>.
- Lempp, H., Abayneh, S., Gurung, D., Kola, L., Abdulmalik, J., Evans-Lacko, S., Semrau, M., Alem, A., Thornicroft, G., Hanlon, C., 2018. Service user and caregiver involvement in mental health system strengthening in low- and middle-income countries: a cross-country qualitative study. *Epidemiol. Psychiatr. Sci.* 27, 29–39. <https://doi.org/10.1017/S2045796017000634>.
- Litzelman, K., Witt, W.P., Gangnon, R.E., Nieto, F.J., Engelman, C.D., Mailick, M.R., Skinner, H.G., 2014. Association between informal caregiving and cellular aging in the Survey of the Health of Wisconsin: the role of caregiving characteristics, stress, and strain. *Am. J. Epidemiol.* 179, 1340–1352. <https://doi.org/10.1093/aje/kwu066>.
- Litzelman, K., Kent, E.E., Rowland, J.H., 2018. Interrelationships between health behaviors and coping strategies among informal caregivers of cancer survivors. *Health Educ. Behav. Off. Publ. Soc. Public Health Educ* 45, 90–100. <https://doi.org/10.1177/1090198117705164>.
- Lo, M.H., 2009. Health-promoting behavior and quality of life among caregivers and non-caregivers in Taiwan: a comparative study. *J. Adv. Nurs.* 65, 1695–1704. <https://doi.org/10.1111/j.1365-2648.2009.05441.x>.

- org/10.1111/j.1365-2648.2009.05032.x.
- Loerbroeks, A., Herr, R.M., Subramanian, S., Bosch, J.A., 2012. The association of asthma and wheezing with major depressive episodes: an analysis of 245 727 women and men from 57 countries. *Int. J. Epidemiol.* 41, 1436–1444. <https://doi.org/10.1093/ije/dys123>.
- Longacre, M.L., Valdimanis, V.G., Handorf, E.A., Fang, C.Y., 2017. Work impact and emotional stress among informal caregivers for older adults. *J. Gerontol. B Psychol. Sci. Soc. Sci.* 72, 522–531. <https://doi.org/10.1093/geronb/gbw027>.
- Marquez, D.X., Bustamante, E.E., Kozey-Keadle, S., Kraemer, J., Carrion, I., 2012. Physical activity and psychosocial and mental health of older caregivers and non-caregivers. *Geriatr. Nurs. N. Y. N* 33, 358–365. <https://doi.org/10.1016/j.gerinurse.2012.03.003>.
- Mitra, S., Sambamoorthi, U., 2014. Disability prevalence among adults: estimates for 54 countries and progress toward a global estimate. *Disabil. Rehabil.* 36, 940–947. <https://doi.org/10.3109/09638288.2013.825333>.
- O'Reilly, D., Rosato, M., Ferry, F., Moriarty, J., Leavy, G., 2017. Caregiving, volunteering or both? Comparing effects on health and mortality using census-based records from almost 250,000 people aged 65 and over. *Age Ageing* 46, 821–826. <https://doi.org/10.1093/ageing/afx017>.
- Peters, D.H., Garg, A., Bloom, G., Walker, D.G., Brieger, W.R., Rahman, M.H., 2008. Poverty and access to health care in developing countries. *Ann. N. Y. Acad. Sci.* 1136, 161–171. <https://doi.org/10.1196/annals.1425.011>.
- Peters, M.E., Goedendorp, M.M., Verhagen, S.A., Smilde, T.J., Bleijenbergh, G., van der Graaf, W.T., 2015. A prospective analysis on fatigue and experienced burden in informal caregivers of cancer patients during cancer treatment in the palliative phase. *Acta Oncol. Stockh. Swed.* 54, 500–506. <https://doi.org/10.3109/0284186X.2014.953254>.
- Ringer, T.J., Hazzan, A.A., Kennedy, C.C., Karampatos, S., Patterson, C., Marr, S., Misiaszek, B., Woo, T., Ioannidis, G., Papaioannou, A., 2016. Care recipients' physical frailty is independently associated with subjective burden in informal caregivers in the community setting: a cross-sectional study. *BMC Geriatr.* 16. <https://doi.org/10.1186/s12877-016-0355-6>.
- Roth, D.L., Haley, W.E., Hovater, M., Perkins, M., Wadley, V.G., Judd, S., 2013. Family caregiving and all-cause mortality: findings from a population-based propensity-matched analysis. *Am. J. Epidemiol.* 178, 1571–1578. <https://doi.org/10.1093/aje/kwt225>.
- Siriwardhana, D.D., Hardoon, S., Rait, G., Weerasinghe, M.C., Walters, K.R., 2018. Prevalence of frailty and prefrailty among community-dwelling older adults in low-income and middle-income countries: a systematic review and meta-analysis. *BMJ Open* 8. <https://doi.org/10.1136/bmjopen-2017-018195>.
- Smith, L., Onwumere, J., Craig, T., McManus, S., Bebbington, P., Kuipers, E., 2014. Mental and physical illness in caregivers: results from an English national survey sample. *Br. J. Psychiatry* 205, 197–203. <https://doi.org/10.1192/bjp.bp.112.125369>.
- Son, K.Y., Park, S.M., Lee, C.H., Choi, G.J., Lee, D., Jo, S., Lee, S.H., Cho, B., 2011. Behavioral risk factors and use of preventive screening services among spousal caregivers of cancer patients. *Support Care Cancer* 19, 919–927. <https://doi.org/10.1007/s00520-010-0889-7>.
- Stacey, A.F., Gill, T.K., Price, K., Taylor, A.W., 2019. Biomedical health profiles of unpaid family carers in an urban population in South Australia. *PLoS One* 14, e0208434. <https://doi.org/10.1371/journal.pone.0208434>.
- Stubbs, B., Koyanagi, A., Schuch, F.B., Firth, J., Rosenbaum, S., Veronese, N., Solmi, M., Mugisha, J., Vancampfort, D., 2016. Physical activity and depression: a large cross-sectional, population-based study across 36 low- and middle-income countries. *Acta Psychiatr. Scand.* 134, 546–556. <https://doi.org/10.1111/acps.12654>.
- Stubbs, B., Koyanagi, A., Hallgren, M., Firth, J., Richards, J., Schuch, F., Rosenbaum, S., Mugisha, J., Veronese, N., Lahti, J., Vancampfort, D., 2017. Physical activity and anxiety: a perspective from the World Health Survey. *J. Affect. Disord.* 208, 545–552. <https://doi.org/10.1016/j.jad.2016.10.028>.
- The World Bank, 2020. How does the World Bank classify countries? WWW Document World Bank Data Help Desk <https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries>, Accessed date: 13 January 2020.
- Thrush, A., Hyder, A., 2014. The neglected burden of caregiving in low- and middle-income countries. *Disabil. Health J.* 7, 262–272. <https://doi.org/10.1016/j.dhjo.2014.01.003>.
- Toljamo, M., Perälä, M.-L., Laukkala, H., 2012. Impact of caregiving on Finnish family caregivers. *Scand. J. Caring Sci.* 26, 211–218. <https://doi.org/10.1111/j.1471-6712.2011.00919.x>.
- United Nations, 2019. *World Population Prospects 2019: Highlights*.
- Wong, J., Shobo, Y., Hodgdon, B., 2016. THE roles of leisure and physical activity on family caregivers' daily well-being & health symptoms. *The Gerontologist* 56, 493. <https://doi.org/10.1093/geront/gnw162.1985>.
- World Health Organization, 2010. *Global Recommendations on Physical Activity for Health*.
- Zuo, D., Li, S., Mao, W., Chi, I., 2014. End-of-life family caregiving for older parents in China's Rural Anhui province. *Can. J. Aging Rev. Can. Vieil.* 33, 448–461. <https://doi.org/10.1017/S0714980814000373>.