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Functional Independence, Widowhood, and Cardio-metabolic Health: Evidence from India's Longitudinal Ageing Study

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Functional Independence, Widowhood, and Cardio-metabolic Health: Evidence from India's Longitudinal Ageing Study

Does Marital Status Moderate the Protective Effect of Functional Status on Hypertension and Sleep Problems in Elderly Indian Women?

Abstract

India's population of female older women is growing rapidly and out of this number, more than 50 per cent are likely to spend the final years of their life as widows. This study explores whether the ability to perform basic daily activities without assistance, known as functional status, protects widowed women from hypertension and sleep problems in the same way as it protects their married peers. Using nationally representative data on 16,512 women aged 60 and above from Wave 1 (2017-18) of the Longitudinal Ageing Study of India (LASI), I estimate logistic regression models of hypertension and regular trouble sleeping as functions of functional status, marital status, and their interaction. Results show that better functional status is associated with remarkably lower odds of both hypertension (adjusted OR = 0.88, 95% CI 0.79-0.98) and sleep trouble (OR = 0.73, 95% CI 0.66-0.81). Widowed and separated women have 16% higher chances of having hypertension than married women (OR = 1.16, 95% CI 0.99-1.35, significant only at the 10% level) and the protective association between functional status and hypertension is significantly weaker among widows (interaction OR = 1.15, 95% CI 1.02–1.31, p = .026). Inverse-probability-weighted estimates suggest that widowhood is associated with roughly two percentage points higher probabilities of hypertension and of sleep trouble. An instrumental-variables check, using regional variation in widowhood prevalence, corroborates the sleep-trouble estimates but not the hypertension estimates. Together, the results suggest that physical independence is a less reliable health buffer once the spousal relationship is gone, that widowhood's harm operates mostly through channels other than functional decline, and that health policy for older adults should treat widowhood itself, not just functional status, as a target for intervention.

Keywords: functional status; Katz ADL Index; widowhood; hypertension; sleep problems; LASI

1. Introduction

India is ageing faster than a lot of countries that are in the same demographic bracket and income group. The share of population aged 60 and above stands around 10.5% of India's total population

and by the year 2050, this number is expected to double to 347 million (UNFPA, 2023). Within this group, widows form a demographic bloc of significant size: the 2011 Census counted roughly 56 million widowed individuals in India, of whom 78% were women (Arora, 2016). Widowhood in later life does not merely signify a marital-status; it typically means the loss of a co-resident caregiver, a shrinking of the household economy, and for many Indian women, a change in social standing within the extended family (Choudhary et al., 2025; Perkins et al., 2016a). Understanding whether and how widowhood changes the health consequences of physical ageing is therefore a question with direct relevance for geriatric health policy in India.

This paper investigates one specific question. Does functional independence protect against poor cardio-metabolic and sleep health for widowed women as it does for married women? Or does becoming a widow weaken that protection? Functional status which includes the ability to dress, bathe, eat, walk, transfer and use the toilet without help is a foundational measure of healthy ageing. Its decline is a leading marker of frailty, disability, and eventual mortality (Keeler et al., 2010). Hypertension and sleep problems are, in turn, two of the most consequential and modifiable health conditions in old age: hypertension is the leading driver of cardiovascular disease, the top cause of death among India's older adults (Geldsetzer et al., 2018; Jha et al., 2006) and poor sleep is independently associated with worse cognitive and cardiovascular outcomes and lower quality of life in later life (Cappuccio et al., 2011; Kwok et al., 2018; Sella et al., 2023; Xu et al., 2020).

Prior literature has documented each of these relationships separately: decline in functional status predicts poor health outcomes (Baptista et al., 2018; Dombrowsky, 2017), widowhood elevates cardiovascular risk in Indian older adults (Loganathan et al., 2023) and it is also associated with loneliness and disrupted sleep after bereavement (Monk et al., 2008; Yang & Gu, 2021). The gap identified in the research highlights whether the health returns to staying functionally independent are same for widows as it is for married women. If widowhood weakens the protective value of functional independence, it has a clear policy implication: functional-status screening in geriatric care should be paired with marital-status-sensitive follow-up, since a widow who scores well on activities of daily living may still be at elevated cardio-metabolic risk relative to a similarly independent married woman.

Using the Wave-1 of the Longitudinal Ageing Study of India (LASI), a nationally representative survey of 72,270 adults aged 45 and above, this paper analyzes 16,512 women aged 60 and above

with non-missing data on hypertension, sleep trouble, functional status, marital status and the covariates (HRQoL, income, disability, insurance, residence and age). I estimate logistic regression models of hypertension and regular sleep trouble, with functional status, widowhood and their interaction as the key explanatory variables, net of health-related quality of life (HRQoL), income, disability, insurance, residence, and age.

The results point to three key findings. First, better functional status is associated with lower odds of both outcomes, i.e., hypertension and sleep trouble. Second, widowhood is associated with somewhat higher odds of hypertension, although this association is only marginally significant. Third, functional status appears to offer less protection against hypertension among widowed women than it does among the married women.

2. Literature Review

2.1 Functional status as a health indicator in old age

Functional status, commonly operationalized through the Katz Index of Independence in Activities of Daily Living (ADL), developed for geriatric assessment in the 1950s and still in wide clinical use, measures a person's ability to perform six basic tasks: bathing, dressing, toileting, transferring, continence and feeding (Katz et al., 1963). A score of six indicates full independence and zero indicates complete dependence. A decline in functional independence is associated with a wide range of downstream outcomes. Keeler et al. (2010) found that 75-year-olds with high ADL independence had roughly five additional years of life expectancy relative to those with low independence and Banerjee & Boro, (2022) linked functional limitation to lower life satisfaction among India's older population, partly through its effect on sleep quality. Baptista et al. (2018) and Dombrowsky (2017), both note that the relationship between functional status and health outcomes does not follow a strict pattern. It is conditioned by social and economic context, including income, disability and the availability of caregiving support.

2.2 Widowhood, cardio-metabolic risk and sleep in later life

Widowhood is one of the most disruptive life events an older adult can experience and a substantial literature links it to worse physical and mental health. In the Indian context specifically, Srivastava et

al. (2021), using LASI Wave 1, show that widowhood combined with living alone is associated with substantially higher odds of depression relative to currently married older adults living with family. The authors attribute this pattern to the compounding loss of both a spouse and daily social contact. Using the same dataset , Loganathan et al. (2023) find that widowed older adults face significantly elevated ten-year cardiovascular disease risk relative to married respondents, even after adjusting for other socio-demographic characteristics (about 59% higher odds). Clougherty et al. (2011) document a related pathway through work: hourly and lower-status jobs are associated with higher incident hypertension for women specifically, which is relevant given that Indian widows are more likely to remain in or re-enter the paid workforce out of economic necessity as compared to the married women in the same age group.

The research on sleep issues outside India offers a crucial insight. Monk et al. (2008) found significant sleep disruption among the older adults who have experienced spousal bereavement as compared to the non-bereaved peers. Evidence from large-scale studies of ageing populations in Asia further show that following spousal loss, loneliness can persist and intensify over the years (Yang & Gu, 2021). Towards this end, the research on loneliness has shown a consistent correlation with sleep disturbance and hypertension both. Goel et al. (2003) found that the spousal loss is seen as one of the primary sources of adjustments for an older person and this adjustment intensifies within rural areas where the social safety is week and feeble. They describe spousal loss as one of the most demanding adjustments an older person can face, particularly in rural settings with thin social safety nets.

2.3 The gap: does widowhood influence the association between the functional status and health among widowed and other married older adults?

There is sufficient literature available that mentions functional status as the predictor of health related outcomes in older adults. Apart from this, it is also established through research that widowhood acts as an independent risk factor for older adults (Manzoli et al., 2007; Perkins et al., 2016b; Shor et al., 2012; Stuck et al., 1999; Studenski et al., 2011). However, these two strands of evidence are rarely considered together. Halder et al. (2023), who studied a Kolkata slum population in India, document that functional impairment among older adults is closely tied to unmet rehabilitation and social-support needs, while Srivastava et al. (2021), using LASI Wave 1, document that BMI-based obesity is markedly more prevalent among older Indian women than men (26.3%

vs. 17.6%) and is itself associated with higher multi-morbidity. Neither literature, however, asks whether a given level of functional independence buys the same cardio-metabolic and sleep-health protection for widows as for married women. This paper addresses that gap directly, using an interaction-term specification that lets the functional-status-health gradient differ by marital status rather than assuming it is constant across the population.

3. Data and Methods

3.1 Data source and analytic sample

This study uses Wave 1 (2017-18) of the Longitudinal Ageing Study of India (LASI), a nationally representative survey of the health, economic and social well-being of India's population aged 45 and above, harmonized with sister studies including the U.S. Health and Retirement Study (HRS), England's ELSA, and Mexico's MHAS. LASI surveyed 72,270 respondents across all Indian states and union territories using a multistage stratified area-probability sampling design. All estimates use the LASI individual survey weight, with states as strata and primary sampling units as clusters (survey-weighted logit with design-based standard errors); the inverse-probability-weighting, mediation, instrumental-variable and decomposition analyses use the same weights. Unweighted estimates are compared with the weighted results in Appendix Table S4.

The final sample for analysis is restricted to women aged 60 and above (n = 16,562), the population this study is designed to speak to, and further restricted to the 16,512 women (99.7%) with complete data on all outcome and model variables and a valid survey weight. Current work status was excluded from the main specification because it is missing for roughly half of women in this age group in LASI (a module administered to a filtered sub-sample); it is added back in a robustness check on the smaller sub-sample for which it is observed (Section 4.3).

3.2 Variables

Outcome variables: Hypertension is a binary indicator equal to 1 if the respondent reports ever being diagnosed with hypertension. Trouble sleeping is derived from a four-point item on frequency of difficulty falling asleep (never / rarely / occasionally / frequently) and is coded 1 if the respondent reports any regular trouble (rarely or more often) and 0 if never.

Functional status: The Katz ADL Index is constructed from six binary items (dressing, walking, bathing, eating, transferring/bed mobility, and toileting), summed into a 0-6 score where 6 indicates complete independence and 0 indicates complete dependence. For regression models, the index is standardized (z-score) so that coefficients are interpretable as the change in log-odds per one-standard-deviation improvement in functional status.

Marital status: Widowed/separated is a binary indicator equal to 1 for women who are widowed, divorced, separated, deserted, in a live-in relationship, or never married, and 0 for currently married women, following LASI's standard collapsed marital-status coding. Among women aged 60 and above, 53.9% fall into the widowed/separated category: 51.3% are widowed and the remaining 2.6% are divorced (0.3%), separated (0.7%), deserted (0.4%), in a live-in relationship (0.4%) or never married (0.8%).

Covariates: Health-related quality of life (HRQoL) is a 0-12 score built from twelve LASI items chosen to approximate the SF-12 instrument's coverage of physical, emotional, and role functioning (standardized for regression). Additional covariates are income quintile (1 = poorest to 5 = richest), a binary disability indicator, binary health insurance coverage, urban residence, and age (centered at 60). The Table S1 in the appendix mentions the details on the construction of HRQoL score based on the variables in the LASI dataset with closest proximity with SF-12 questionnaire and all the vatriables are defined in Table S2.

[Table S1 here]

[Table S2 here]

3.3 Empirical strategy

As both the outcomes are binary, I estimate logistic regression models of the form:

$$logit[P(Y_i = 1)] = \beta_0 + \beta_1 FS_i + \beta_2 Widowed_i + \beta_3 (FS_i * Widowed_i) + \beta_4 HRQoL_i + \beta_5 Income_i + \beta_6 Disability_i + \beta_7 Insurance_i + \beta_8 Urban_i + \beta_9 Age_i + \varepsilon_i$$

where, *Y* is, in turn, hypertension and trouble sleeping, and FS is standardized functional status for *i* individual. The coefficient of interest, β_0, tests whether the functional-status–health gradient differs by marital status. All models are estimated separately with unadjusted (bivariate) and fully adjusted specifications and standard errors are design-based, using the LASI survey weights, with states as

strata and primary sampling units as clusters. As a robustness check, work status is added to the adjusted models on the sub-sample for which it is observed.

4. Results

4.1 Descriptive statistics

Table 1 summarizes the descriptive statistics. On average, the age of widowed and separated women is higher than married women (71.19 vs. 65.9 years) and poorer as well. Along with this the widowed and separated women score lower on both functional status (5.21 vs. 5.54 out of 6) and health-related quality of life, which is 7.71/12, as compared to 8.27/12 for married women. Hypertension and sleep trouble are common in both the group. However, it is more prevalent among widows. About 40.96% of widowed women report a hypertension diagnosis compared with 36.87% of married women ($p = .008$), and 51.46% report regular trouble sleeping compared with 47.72% of married women (not statistically significant, $p = .19$) as shown in Figure 1. All descriptive statistics are survey-weighted.

Widowed/separated (1) vs. currently married (0)

Currently married	mean	sd
age	65.9	5.488
residence urban pct	32.791	46.948
income poorest pct	19.362	39.516
income richest pct	19.795	39.848
insurance pct	.63	7.913
disability pct	1.562	12.401
Functional Status	5.549	1.175
HRQoL	8.271	1.89
hypertension pct	36.873	48.249
sleep pct	47.729	49.952
Widowed/separated		
age	71.196	8.379
residence urban pct	36.35	48.104
income poorest pct	22.555	41.796
income richest pct	16.73	37.327
insurance pct	.787	8.837
disability pct	1.597	12.535
Functional Status	5.219	1.572
HRQoL	7.714	2.184
hypertension pct	40.96	49.179
sleep pct	51.462	49.981

Table 1. Sample characteristics by marital status (survey-weighted)[1]

Figure 2 shows that the large majority of women in both marital-status groups score at or near full functional independence. However, towards the lower end of the scores, widowed women are more concentrated as compared to the married women which show that the absence of husband in older women's life leads to lower functional independence.

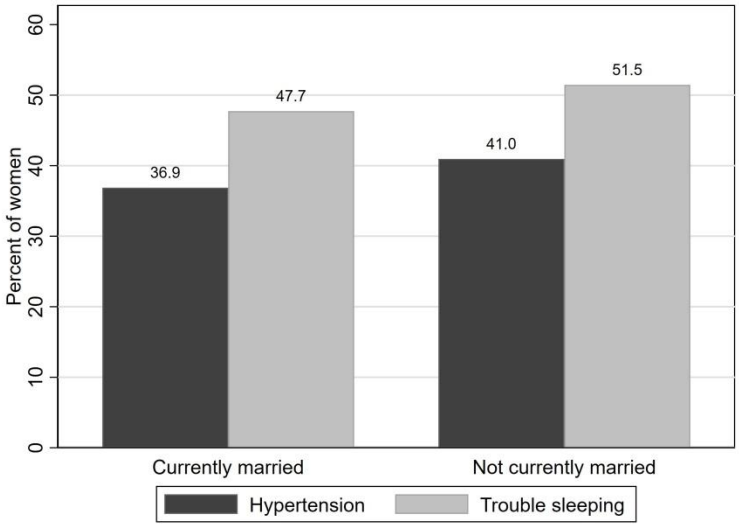


Figure 1. Hypertension and sleep-trouble prevalence by marital status, women aged 60+

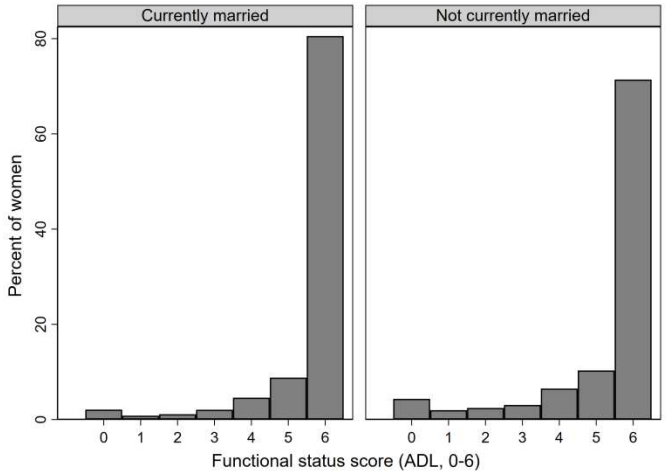


Figure 2. Distribution of the Katz functional-status index by marital status

[1] Survey-weighted means and percentages; the widowed/separated group is 95% widowed (unweighted) and also includes divorced, separated, deserted, live-in and never-married women (about 5%)

4.2 Regression results

Table 2 reports odds ratios from four logistic regression models. In the unadjusted models (M1, M3), functional status is strongly protective: each one-standard-deviation improvement in functional status is associated with 9% lower odds of hypertension (OR = 0.91, p < .01) and 28% lower odds of regular sleep trouble (OR = 0.72, p < .001).

The adjusted models (M_2, M_4) add health-related quality of life (HRQoL), income, disability, insurance, residence and age, along with the widowhood main effect and the functional-status-by-widowhood interaction. Three results are worth noting. First, functional status remains a significant protective factor for both outcomes even after adjustment (hypertension OR = 0.88, p = .02; sleep trouble OR = 0.73, p < .001). Second, widowed and separated women have somewhat higher odds of suffering from hypertension as compared to married women, even if the model accounts for functional status and other covariates (OR = 1.16, 95% CI 0.99-1.35, p = .065, significant only at the 10% level); This pattern does not follow sleep trouble, where the main effect of widowhood is not significant (OR = 1.03, p = .61). Third, the interaction between functional-status and widowhood is statistically significant for hypertension (OR = 1.15, 95% CI 1.02-1.31, p = .026) and also for sleep trouble (OR = 1.15, 95% CI 1.02-1.29, p = .020): This suggests that the protective slope of functional status is flatter for widowed women than for married women.

	M1 Hypertension	M2 Hypertension	M3 Sleep trouble	M4 Sleep trouble
main				
Functional status (z-score)	0.91**	0.88*	0.72***	0.73***
	[0.85,0.98]	[0.79,0.98]	[0.68,0.76]	[0.66,0.81]
Widowed/separated (ref: married)		1.16		1.03
		[0.99,1.35]		[0.92,1.15]
Functional status x Widowed/separated		1.15*		1.15*
		[1.02,1.31]		[1.02,1.29]
HRQoL (z-score)		0.84***		0.69***
		[0.78,0.91]		[0.64,0.75]
Income (MPCE)		1.25***		1.03

quintile				
		[1.17,1.32]		[0.99,1.08]
Disability		0.81		1.07
		[0.56,1.17]		[0.72,1.58]
Insurance		0.92		1.38
		[0.49,1.72]		[0.74,2.57]
Urban residence		2.48***		0.95
		[1.96,3.14]		[0.83,1.09]
Age (centred at 60)		1.00		0.98***
		[0.99,1.01]		[0.97,0.99]
N (unweighted)	16512	16512	16512	16512

*Survey-weighted logit; odds ratios with 95% CI, design-based standard errors. *** p<.001, ** p<.01, * p<.05*
** p < 0.05, ** p < 0.01, *** p < 0.001*

Figure 3 translates the interaction into predicted probabilities, holding covariates at their sample means. Among married women, the predicted probability of hypertension falls steeply with the rise in functional status from about 46% at complete dependence to about 33% at complete independence. Among widowed women, it is much flatter, moving from about 37% to about 38%: widows with poor functional status have somewhat lower hypertension risk as compared to the married women with poor functional status but they gain far less benefit from being functionally independent. The two lines cross at moderate functional-status levels (around a score of 4) and at full independence the order is reversed and married women have the lower predicted probability (about 33% vs. about 38%). A similar pattern appears for sleep trouble, with the two lines crossing at a score of about 5.

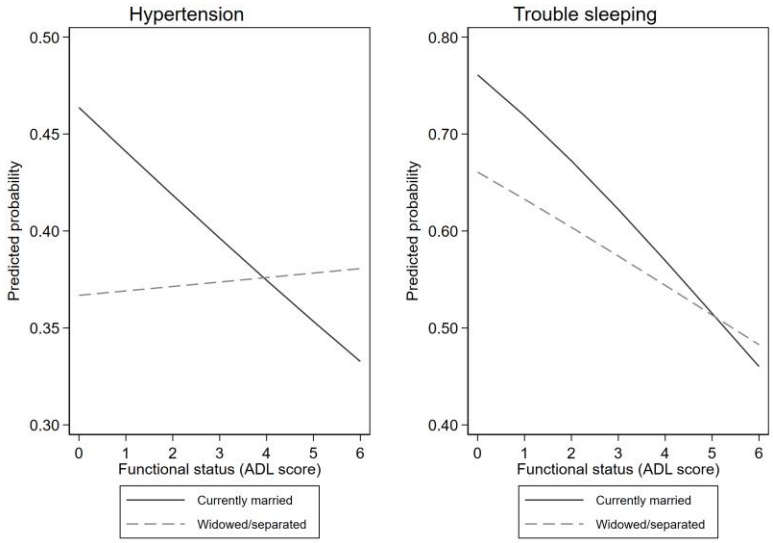


Figure 3. Predicted probability of hypertension and sleep trouble by functional status and marital status (covariates held at sample means)

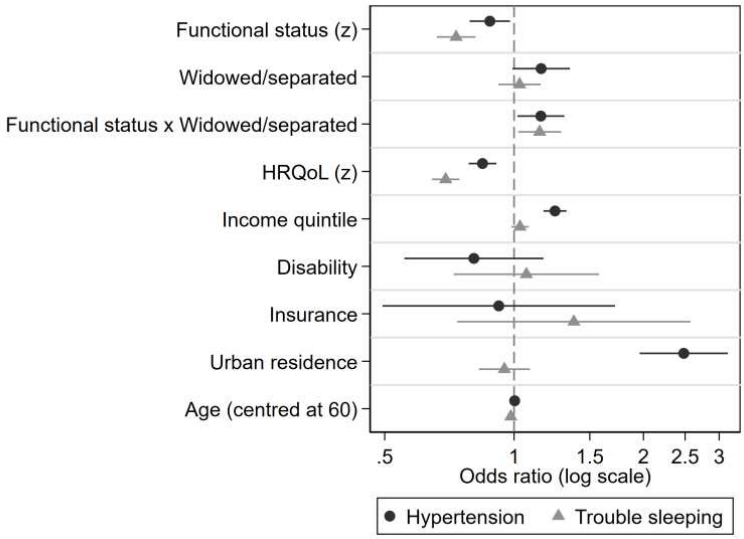


Figure 4. Adjusted odds ratios with 95% confidence intervals (Models M2 and M4)

Apart from the variables of primary interest, urban residence is associated with substantially higher odds of hypertension (OR = 2.48, $p < .001$), seemingly reflecting a mix of better diagnostic access and more stationary urban lifestyles, but is not significantly associated with sleep trouble (OR = 0.95, 95% CI 0.83-1.09). Higher income quintile is associated with higher hypertension odds, consistent with recent evidence that hypertension diagnosis and awareness in India rise with socioeconomic status and healthcare access (Geldsetzer et al. (2018) and higher HRQoL is strongly protective against both outcomes. Disability and insurance coverage are not statistically significant predictors of either outcome in this sample, likely reflecting the very low prevalence of both (about 2% and 1%, respectively) or correspondingly wide confidence intervals. Table S3 shows that the main results are robust to alternative specifications of the HRQoL index, and Table S4 compares the survey-weighted estimates with unweighted estimates (both in Appendix)

[Table S1 here]

[Table S2 here]

4.3 Robustness check: work status

As roughly half of women aged 60+ in LASI dataset have missing data on current work status, it was excluded from the main models in this paper to keep the sample size similar throughout the analysis. As a robustness check, Table 3 re-estimates the adjusted models with work status included, on the 8,355 women for whom it is observed. The widowhood results are broadly stable, but the functional-status results are weaker. Functional status remains associated with lower odds of sleep trouble (OR = 0.76, $p < .001$) but not with hypertension (OR = 0.98, 95% CI 0.84-1.14), and the main association between widowhood and hypertension remains significant and similar in size. The interaction between functional status and widowhood also points in the same direction. In the smaller sub-sample, this interaction is not statistically significant for either hypertension (OR = 1.01, 95% CI 0.85-1.20) or sleep trouble (OR = 1.15, 95% CI 0.97-1.37). The loss of significance is likely to reflect the smaller sample and the resulting loss of statistical power rather than a meaningful change in the overall pattern.

Currently working is itself strongly protective against hypertension (OR = 0.69, $p < .001$), plausibly reflecting both a healthy-worker selection effect and the physical activity associated with continued work in old age.

	(1) Hypertension	(2) Sleep trouble
FS_z	0.98 [0.84,1.14]	0.76*** [0.65,0.89]
widowed	1.23* [1.01,1.50]	0.96 [0.81,1.13]
wxz	1.01 [0.85,1.20]	1.15 [0.97,1.37]
HRQoL_z	0.85*** [0.78,0.92]	0.68*** [0.61,0.76]
income_group	1.20*** [1.13,1.27]	1.04 [0.98,1.10]
disability	0.71 [0.44,1.16]	1.34 [0.80,2.25]
insurance	1.11 [0.61,2.03]	1.26 [0.67,2.37]
residence_urban	1.95*** [1.58,2.39]	1.03 [0.84,1.26]
age_c	1.00 [0.99,1.01]	0.99 [0.98,1.00]
work_status	0.69*** [0.58,0.83]	0.92 [0.79,1.07]
Observations (sub-population, unweighted)	8355	8355
Pseudo R^2	n/a	n/a

Survey-weighted odds ratios; 95% confidence intervals in brackets
**** p<.001, ** p<.01, * p<.05*

Table 3. Robustness check: adjusted models with work status added (sub-sample with non-missing work status)

5. Towards a Causal Interpretation

The models described above show the association: functional status, widowhood, and their interaction predict hypertension and sleep trouble net of observed covariates. This section asks a sharper question. If widowhood itself has a causal effect on hypertension and sleep trouble, how large is it, and how much of that effect operates through the decline in functional status documented above, versus other pathways, lost spousal monitoring of medication and diet, loneliness, or reduced household income? Answering this requires being explicit about a causal model, not just a statistical one.

5.1 Identifying assumptions: a directed acyclic graph

Figure 5 demonstrates the assumed causal structure. Age is likely to influence both the likelihood of being widowed and, independently, functional status and the risk of hypertension or sleep problems. It is therefore an important confounder that needs to be accounted for in the analysis. Urban residence is treated in the same way, although its association with widowhood is weaker and less certain, as indicated by the dashed edge.

Health-related quality of life (HRQoL) and income are conceptualized as potential post-treatment variables rather than pre-treatment confounders, as both may be affected by widowhood. Accordingly, they are excluded from the treatment-assignment (propensity score) model in Section 5.2. Including these variables could constitute conditioning on post-treatment factors ("bad controls") and potentially attenuate or bias the estimated total effect of widowhood.

Functional status is treated as a mediator: partially as a consequence of widowhood status, i.e., loss of a caregiving partner, reduced mobility support and partly a cause of hypertension and sleep trouble.

The dotted red paths highlight the most crucial concern to this analysis: an unmeasured factor: frailty or pre-existing health status could increase the likelihood of becoming widowed. For example,

through assortative mating on health or caregiving burden affecting a sicker spouse's own health while also leading to worsened hypertension and sleep trouble. LASI Wave 1's cross-sectional design fails to rule this out. The estimates below should be read as "causal under the assumption of no unmeasured confounding beyond age and residence," not as definitive causal proof.

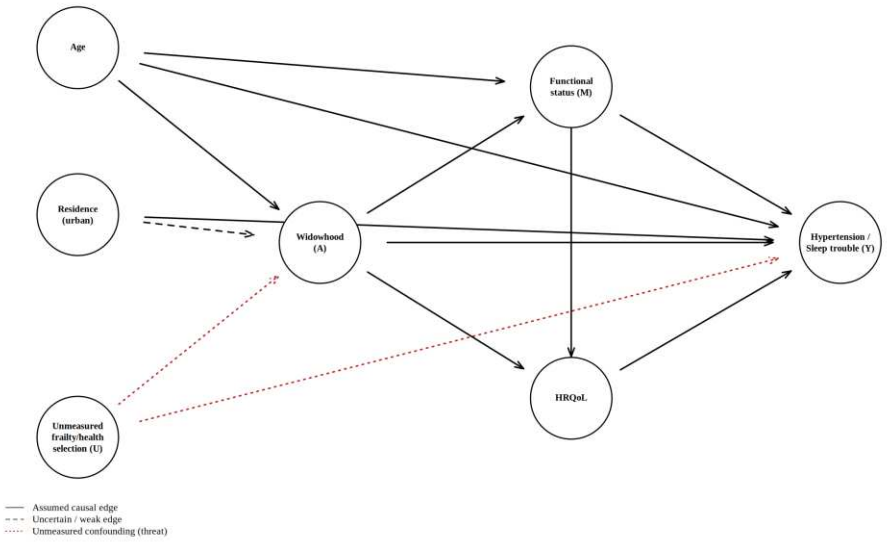


Figure 5. Assumed causal structure (DAG). Solid edges: assumed causal pathways among measured variables. Dashed: a weaker/uncertain edge. Dotted red: unmeasured confounding not addressed by this design.

5.2 Widowhood's overall impact: inverse-probability weighting

I created stabilized inverse-probability-of-treatment weights (IPTW), trimmed at the first and 99th percentiles to reduce the impact of extreme weights, after fitting a propensity-score model for widowhood using only the pre-treatment confounders in the DAG (age and urban residence) to estimate the overall causal effect of widowhood on each outcome.

Weighting reduces the residence imbalance from 0.13 to 0.01 and the age imbalance between married and widowed women from a standardized mean difference of 0.77 to 0.10, demonstrating the effectiveness of the weights (see Table S5 in Appendix for details).

[Table S1 here]

There is a 5.1 percentage point difference in the naive (survey-weighted) prevalence of hypertension between married and widowed women. After IPTW adjustment, the estimated total causal effect falls to 2.1 percentage points (SE = 1.6, p = .18, doubly robust estimate = 1.7 points, SE = 1.5), a smaller effect that is no longer statistically distinguishable from zero, and less than half the size of the naive comparison, indicating that age differences account for much of the raw gap. For sleep trouble, a naive gap of 1.7 points falls to 1.5 points after IPTW adjustment (SE = 1.5; doubly robust estimate = 1.7 points, SE = 1.8), also not statistically significant.

Under the assumptions in Figure 5, becoming widowed is associated with an older Indian woman's probability of hypertension and of regular sleep trouble being roughly two percentage points higher each, independent of age and residence, although neither estimate is statistically significant (p = .18 for hypertension).

5.3 How much runs through functional status? A mediation decomposition

Given a total effect, the next question demands the focus on the channel of mechanism.

I break it down into a natural direct effect that captures everything else (loneliness, lost household monitoring, economic strain, and any other unmeasured pathway) and a natural indirect effect, which is the portion of widowhood's effect that works by first lowering functional status, which then affects health.

This matches the moderation result in Section 4.2 by using a linear mediator model for functional status and a linear probability outcome model that incorporates a widowhood-by-functional-status interaction; the closed-form decomposition uses 95% confidence intervals from a 2,000-replicate nonparametric bootstrap and standard causal-mediation formulas for linear systems with an exposure-mediator interaction (Valeri & Vanderweele, 2013).Table 4 and Figure 6 show the result of the analysis: functional status is at most a modest mechanism. For hypertension, the indirect (functional-status) pathway accounts for only about 1.0% of widowhood's total effect (indirect effect 0.02 points, 95% CI -0.05 to 0.14). The indirect effect is not statistically distinguishable from zero. For sleep trouble, the mediated share is larger, about 12.4% (indirect effect 0.20 points, 95% CI -0.17 to 0.57; also not statistically significant), consistent with functional limitations more directly disrupting sleep (e.g., through pain, night-time toileting difficulty, or reduced daytime activity) than they disrupt blood pressure regulation.

The large part of the estimated causal effect of widowhood is direct in both situations. The physical-independence channel that this paper otherwise highlights does not seem to be the route it takes.

This part is a substantively important complement to the moderation finding in Section 4.2. The outcome showed that functional status is not a strong shield for widows as it is for married women; this result shows that widowhood's own harm to health is mostly not explained by its effect on functional status in the first place. Together, they suggest two distinct policy levers rather than one: interventions that build functional independence among widows will help, but on this evidence they will not close most of the widowhood health gap, which instead points toward psychosocial support, loneliness interventions, and economic protection for widows as the larger levers.

These causal estimates inherit the limitations discussed in Section 5.1: they assume no unmeasured confounding of the widowhood-outcome relationship beyond age and residence, and no unmeasured confounding of the functional-status-outcome relationship ("sequential ignobility"), assumptions that are plausible but not testable in a single cross-sectional wave. Section 5.4 subjects this "selection on observables" assumption to a genuinely different test.

	NDE	NDE lo	NDE hi	NIE	NIE lo	NIE hi	Total	PctMediated
Hypertension	2.51	-1.11	5.77	.02	-.05	.14	2.53	.95
Sleep trouble	1.4	-1.41	4.17	.2	-.17	.57	1.6	12.38

Table 4. Mediation decomposition: widowhood's effect on health, direct vs. via functional status

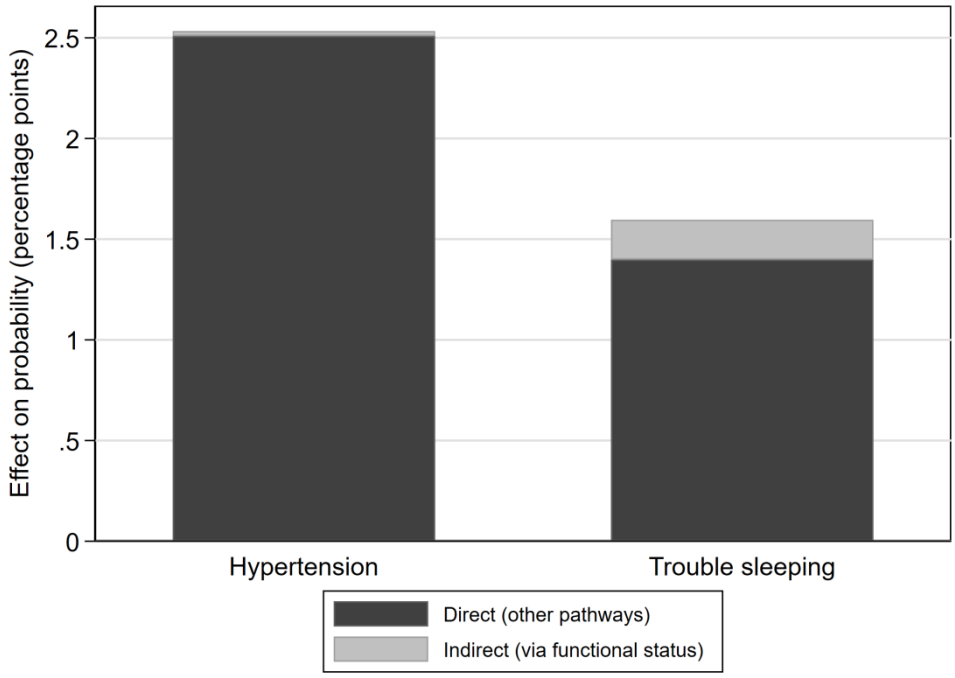


Figure 6. Decomposing widowhood's total effect into direct and indirect (via functional status) components

5.4 An instrumental-variables check

The IPTW and mediation results above assume that age and residence are sufficient to account for the confounding effect of the widowhood-health relationship.

This is a strong assumption: even a fully covariate-adjusted comparison would be biased in ways that no amount of control variables could correct because women with better underlying health may also be more likely to still have a living spouse.

Instead of restating the paper's design-based causal claims, instrumental-variables (IV) estimation serves as an independent check on them because it provides a genuinely different identification strategy that does not depend on this assumption. Instrument. For each woman, the instrument is the leave-one-out mean widowhood rate among other women aged 60+ in her state, state-level variation in male longevity, age structure, and marriage-market conditions that plausibly shifts an individual woman's chance of being widowed without being mechanically driven by her own health.

Individual widowhood is strongly predicted by the instrument (first-stage coefficient = 0.94, partial F = 119.8), well above the typical weak-instrument threshold of 10 (Staiger & Stock, 1997). Estimation follows the standard two-stage least squares (2SLS) approach described in (Angrist & Pischke, 2009), with heteroskedasticity-robust standard errors. Because the instruments varies only across states, Table 5 also reports state-clustered standard errors; they are roughly twice as large as the robust ones (0.161 and 0.213 versus 0.096 and 0.105, in probability units), so the 95% interval for the hypertension 2SLS estimate is very wide (about 0.5 to 63 percentage points) and the 2SLS estimates should be read with considerable caution.

Two-stage least squares (2SLS) estimates, corresponding OLS (linear probability) estimates, and a control-function (Hausman-type) test of whether widowhood can be treated as exogenous after controlling for age, residence, functional status, HRQoL, income, disability, and insurance are presented in Table 5 and Figure 7. The two outcomes tell different stories, and the difference is itself informative.

The control-function test fails to reject exogeneity (p = .75), and the 2SLS estimate (−2.0 percentage points, SE = 10.5) for difficulty sleeping is statistically indistinguishable from both zero and the OLS estimate (1.1 points). The OLS- and IPTW-based conclusions in Sections 4 and 5.3 are given some external support by this reassuring result, which finds no evidence that unmeasured health-based selection into widowhood is contaminating the sleep-trouble estimates elsewhere in this paper. For hypertension, the picture is very different, and worth taking seriously rather than reporting uncritically. The 2SLS estimate (32.0 percentage points, SE = 9.6) is about ten times the OLS estimate (3.3 points) and the IPTW total effect from Section 5.2 (about 2.1 points), and the control-function test rejects exogeneity (p = .001). Taken at face value, this would say OLS drastically understates widowhood's true effect on hypertension. But a jump of this size is implausible on its own terms, and there is a specific, plausible reason to distrust the exclusion restriction here rather than the smaller estimates: hypertension in this dataset is a self-reported diagnosis, not a measured blood pressure reading, and diagnosis is strongly shaped by healthcare access, recall that urban residence alone is associated with more than double the odds of a hypertension diagnosis (Table 2), the largest covariate effect in the paper. A state's aggregate widowhood rate likely proxies for exactly the kind of regional healthcare-infrastructure and screening differences that would violate the exclusion restriction by affecting diagnosis rates directly, not only through individual widowhood.

We therefore read the hypertension 2SLS estimate as evidence that the instrument is not credible for this particular outcome, rather than as evidence of a much larger true causal effect.

	OLS	OLS se	IV	IV se robust	IV se state cluster	FS coef	FS F	ControlFn p
Hypertension	.033	.017	0.320	.096	.161	.942	119.806	.001
Sleep trouble	.011	.018	-0.020	.105	.213	.942	119.806	.751

Table 5. OLS vs. 2SLS (instrumental-variables) estimates of widowhood's effect on health

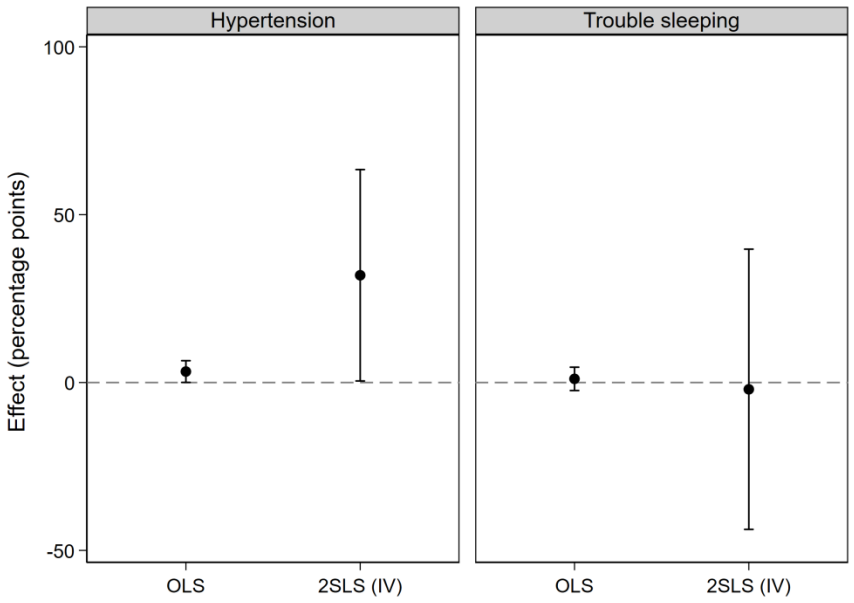


Figure 7. OLS vs. 2SLS estimates with 95% confidence intervals, full-control specification

A single instrument rarely validates or invalidates a causal story consistently across outcomes, and responsible reading reports where the check succeeds (sleep trouble) and where it fails (hypertension) rather than selectively emphasizing whichever result is more convenient. The larger lesson is methodological as much as substantive. Future work utilizing LASI's panel structure would naturally move toward a sharper instrument, such as one constructed from spousal age gaps combined with state-level male life tables or from geographic variation at a finer level than the state, where within-person transitions into widowhood could be tracked directly.

5.5 Sensitivity to unobserved confounding and instrument validity

Cluster-robust inference: Design-based standard errors that cluster at the primary sampling unit have been reported thus far, but they allow no correlation across PSUs within a state. Because the sample spans 36 states and Section 5.4's instrument is itself defined at the state level, within-state correlation could understate standard errors (the classic Moulton (1990) problem.

The main conclusions of the paper remain unchanged when Models M2 and M4 are re-estimated with standard errors clustered by state: the widowhood coefficient for hypertension is still significant under clustering (coefficient = 0.145 log-odds, cluster-robust SE = 0.061, about 2.4 standard errors from zero), and the functional-status-by-widowhood interaction only slightly changes (cluster SE ratio relative to robust SEs: 0.88 for hypertension, 0.60 for sleep trouble - both below 1).

The widest confidence intervals under clustering occur, as expected, for coefficients on variables that vary systematically across states, such as urban residence and income quintile (SE ratios of 1.3 and 1.2 for hypertension, whereas for sleep trouble the clustered SEs are smaller than the robust ones, with ratios of 0.6 and 0.9). This serves as a reminder that state-level heterogeneity in urbanization and income, rather than the paper's central widowhood result, is what most requires the more conservative clustered standard errors.

The fact that observed controls only account for a portion of the true confounding and that unobserved factors may be responsible for the remainder is a common worry with any covariate-adjusted comparison.

This is formalized by Oster's (2019) method, which backs out how strong selection on unobservables would need to be in relation to the selection on observables the controls already capture in order to drive the true effect to zero. It does this by measuring how much a coefficient moves and how much R2 increases from an uncontrolled to a fully controlled regression.

Table 6 applies this to a linear-probability specification of the widowhood effect. The breakdown value for hypertension is $\delta^* = 5.6$, meaning that in order to fully explain away the association, unobservables would need to be more than five times as important as the entire set of observed controls (age, residence, functional status, HRQoL, income, disability, insurance) in determining who becomes widowed—far above the $\delta \geq 1$ threshold that Oster suggests as a general guideline for a robust result.

The breakdown value for sleep trouble is similar (δ* = 5.7), so it also passes the same threshold.

The inflated hypertension 2SLS estimate most likely reflects a violation of the exclusion restriction, according to the qualitative argument made in Section 5.4. It is possible to quantify this directly by allowing the instrument to directly affect the result to the extent of a fraction f of its total reduced-form relationship (f = 0 recovers the standard 2SLS estimate; f = 1 attributes the entire reduced-form relationship to a channel other than widowhood, which mechanically implies a zero widowhood effect). Figure 8 traces the implied widowhood effect as f varies from 0 to 1.

The 2SLS estimate for hypertension can be brought down to the OLS/full-control level with just f = 0.90, or 90% of the instrument's raw relationship with hypertension; the line reaches zero at f = 1.

A 90% direct/confounded share for a state-level health-diagnosis proxy is completely reasonable given how strongly healthcare access (proxied by urban residence, OR = 2.48 in Table 2) predicts hypertension diagnosis in this sample. This supports Section 5.4's conclusion that the hypertension 2SLS estimate is not credible.

In contrast, the implied effect for sleep trouble never reaches the OLS level anywhere in the plausible range (the breakeven fraction exceeds 100%) because the 2SLS and OLS estimates were already close in the first place, a formal confirmation of the comforting reading in Section 5.4.

When taken as a whole, the sensitivity analyzes in this section discipline rather than exaggerate the causal claims made in the paper. The hypertension moderation and mediation results (Sections 4.2 and 5.3) have a strong foundation against omitted-variable bias (Oster δ* = 5.6), but they are weak against the particular instrument used in Section 5.4, which the bounds indicate would be invalidated by a reasonable, not extreme, degree of exclusion-restriction violation.

The sleep-trouble results easily pass the instrumental-variables check, and they are about as resilient to omitted-variable bias in the Oster sense (δ* = 5.7). The most reliable conclusion a purely observational study of this type can provide is that no single result is confirmed by all methods at once.

	b unctrl	b ctrl	R2 unctrl	R2 ctrl	Rmax	b adj delta1	delta star
Hypertension	.0515	.0327	0.0028	.0699	.0908	.0268	5.5613
Sleep trouble	.0172	.0109	0.0003	.0513	.0667	.009	5.7148

Table 6. Oster (2019) coefficient-stability bounds for the widowhood effect

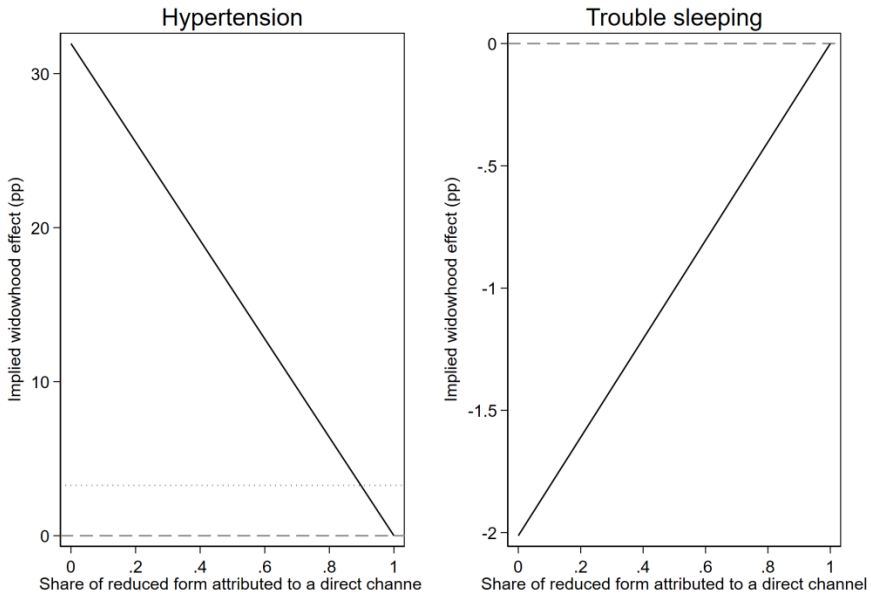


Figure 8. Plausibly-exogenous bounds: implied widowhood effect as the instrument is allowed a direct effect on the outcome

5.6 A Blinder-Oaxaca decomposition of the widowhood gap

This section asks whether widowhood contributes to the worsening of health. It explores a more descriptive, accessible question about the same gap:

The decomposition examines how much of the raw difference in hypertension and sleep-trouble prevalence between widowed and married women is attributable to differences in observed characteristics, such as age and functional status, versus differences in the association between these characteristics and health outcomes across the two groups.

I use the Blinder-Oaxaca decomposition approach (Blinder, 1973; Oaxaca, 1973) to decompose the observed gap between widowed and married women into an "explained" component, reflecting differences in observed characteristics and an "unexplained" component, reflecting differences in the associations between those characteristics and the outcome. Following (Neumark, 1988) and (Jann, 2008), I use pooled reference coefficients to avoid the reference-group ambiguity. The

decomposition includes the same covariates as the adjusted models in Table 2, with standard errors clustered on the primary sampling unit.

Table 7 and Figure 9 report the results, and they line up neatly with the moderation finding in Section 4.2. For hypertension, only 37% of the widowed-married gap is "explained" by widows having different characteristics; the remaining 63% is "unexplained" – the same characteristics (especially functional status and health-related quality of life) are associated with a larger hypertension gap for widows than the same values would predict for married women. For trouble sleeping, the split is similar: 37% of the gap is explained by different characteristics (again, mostly lower health-related quality of life and functional status among widows), and the remaining 63% is unexplained. This is broadly consistent with the interaction terms in Table 2, which are significant for both outcomes and of the same size (OR = 1.15 for both; p = .026 for hypertension and p = .020 for sleep trouble).

	Raw gap pp	Explained pp	Unexplained pp	Explained pct	Unexplained pct
Hypertension	5.15	1.88	3.27	36.52	63.48
Sleep trouble	1.72	.63	1.09	36.71	63.29

Table 7. Blinder–Oaxaca decomposition of the widowed–married gap in hypertension and sleep trouble

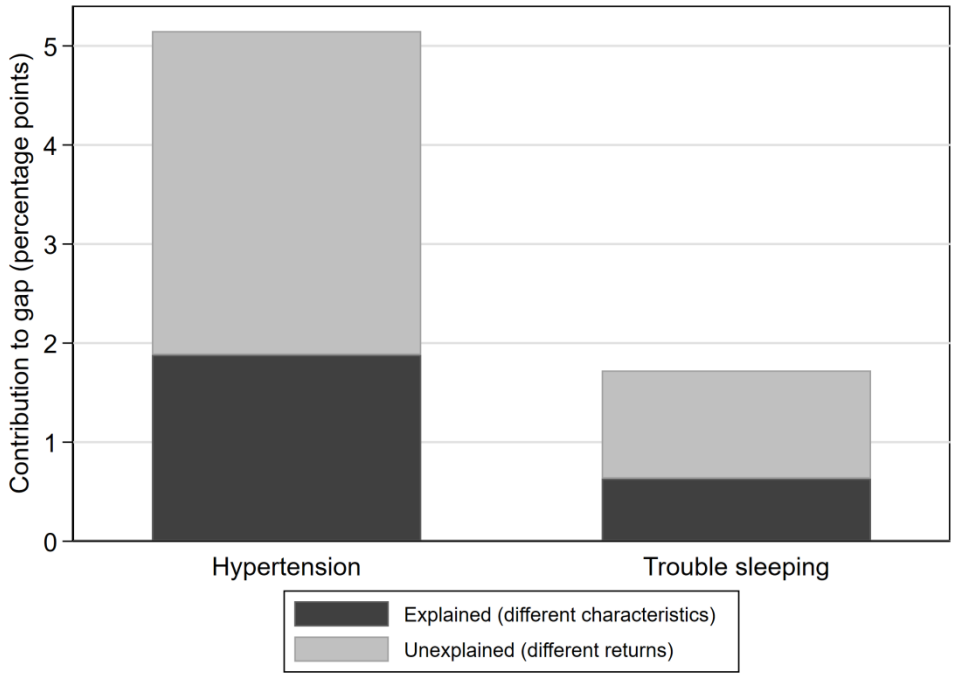


Figure 9. Blinder–Oaxaca decomposition: explained vs. unexplained components of the widowhood gap

A variable-by-variable breakdown of the explained component (not tabulated here for brevity) shows that health-related quality of life is among the largest contributors to the explained gap for both outcomes: for hypertension, urban residence (1.2 points, about 24% of the raw gap) and health-related quality of life (0.9 points, about 17%) contribute most, with functional status contributing little (0.2 points, not significant); for sleep trouble, health-related quality of life (2.0 points) and functional status (1.1 points, significant) contribute most, partly offset by age (-2.3 points). Income differences between widowed and married women work in the opposite direction, narrowing rather than widening the predicted gap, since widows in this sample are poorer and lower income is (perhaps counter intuitively, given screening and diagnosis patterns) associated with lower hypertension odds net of the other controls.

6. Discussion

This study aimed to investigate whether functional independence of older widowed or separated women in India is associated with lower hypertension and sleep problems to the same degree as it is in married women. For hypertension, the findings point to a different pattern: functional status is protective for all women, but its protective effect is significantly weaker among widows. One possible interpretation is the widowhood disrupts some of the channels through which functional status leads to better health. A married woman who can dress, bathe and move independently might more likely to have getting the support of a spouse who helps her stay on track with timely medication, meals and other physical activity. Such kind of regular support might her stay calm and maintain a low-level of blood pressures. In absence of such kind of support, a widow with the same physical capability may lack that reinforcement, so her functional independence does not translate into proper health advantage. This observation is consistent with evidence that widowhood in India raises cardiovascular risk independently of age, sex, and residence (Loganathan et al., 2023). It also fits with a broader research literature showing that the marital status of an older woman serves as a structural determinant of health behavior and monitoring.

The pattern for sleep trouble points in the same direction. The interaction is of similar size (OR = 1.15) and statistically significant at the 5% level in the main sample, although it is not significant in the smaller work-status sub-sample (OR = 1.15, 95% CI 0.97-1.37). This is insightful as the link

between the sleep and widowhood in the literature has significantly explored the channels of loneliness and grief, particularly in the period following bereavement (Monk et al. 2008; Yang & Gu (2021). This kind of observation is difficult to consider in LASI dataset where a woman who widowed twenty years ago is treated identically to the one widowed a few months ago, even though their sleep and loneliness trajectories are likely to differ substantially. This is the most crucial limitation of the present analysis and calls for a panel data analysis once more waves of LASI dataset becomes available.

The finding that widowed women have higher odds of hypertension across all levels of functional status, together with a weaker protective effect of functional independence, has an important policy implication. Functional-status screening, which is increasingly used in Indian geriatric and community health programmes as a quick way to identify those needing further support, may need to be interpreted differently for widowed and married women.

A widow who appears fully independent in a functional-status assessment should not automatically be considered at low cardio-metabolic risk. Marital status can provide important information about the social and caregiving support available to her, factors that a functional-status score alone may not capture.

The instrumental-variables check in Section 5.4 adds an important value to the analysis. It evidently corroborates the sleep-trouble findings: the IV estimate is statistically indistinguishable from the OLS estimate, suggesting minimal bias from unobserved health-based selection into widowhood. However, it does not cleanly support the findings in hypertension where the IV point estimate is far larger than every other estimate in the paper. Therefore, the paper concludes that we argue, it more likely reflects a violated exclusion restriction (regional healthcare-access differences correlated with the instrument) than a true, much larger causal effect. Therefore, the moderation and mediation results for hypertension rest more heavily on the "selection on observables" assumption than the sleep-trouble results do.

7. Limitations

There are some limitations in this paper that should be highlighted. First, as the data are cross-sectional, the results reported in this paper should be interpreted with caution. Second, it should be noted that hypertension is based on self-reported diagnosis rather than measured blood pressure

through routine health check-ups. This may not reveal the true picture of women who have hypertension but remain undiagnosed, an issue also highlighted in relation to the LASI dataset (Geldsetzer et al. (2018). As Section 5.4 shows, this limitation may also compromise the exclusion restriction required for credible instrumental-variables estimation of this particular outcome. Third, the analysis does not account for the duration of widowhood, remarriage or living arrangements in detail, the indicators which are strong representative of health-related issues in bereavement literature. Fourth, the HRQoL score represents study-specific approximation of the SF-12 built from available LASI items rather than the validated instrument itself for the specific study. Therefore, it should not be interpreted as an internally consistent relative measure for this study. Fifth, the state-level instrument used in this paper in Section 5.4, while a strong predictor of individual widowhood, rests on an exclusion restriction that plausibly holds for sleep trouble but not for hypertension, and a within-state or spousal-age-gap-based instrument would be a meaningfully stronger design. Finally, disability and insurance coverage are rare in this sample, limiting statistical power to detect their associations with the outcomes.

8. Conclusion

Among India's older women, the higher performance on functional status score is associated with relatively lower levels of hypertension and sleeping problems. However, this association is weaker for women who are widowed and separated as compared to women who are married. It is evident that widowed women have higher odds of suffering from hypertension as compared to their counterparts in the same age group. This difference becomes is stronger for women with poor functional independence and weaker for women with better functional independence.

A causal analysis combining inverse-probability weighting with formal mediation analysis suggests that widowhood is associated with roughly two percentage points higher probabilities of both outcomes, although these estimates are imprecise and not statistically significant. However, declines in functional status explain only a small proportion of this difference, which is about 1% of the effect on hypertension and about 12% of the effect on sleep problems.

An independent instrumental-variables analysis supports this pattern for sleep problems, but the evidence is less convincing for hypertension. This could be because of the difference in the data

documentation approach, particularly the difference in regional healthcare access where it is recorded based on diagnosis data rather than measuring directly.

The findings highlight two important policy implications. First, functional independence provides less protection against poor health for widowed women than for married women. Second, much of the health burden associated with widowhood, particularly for sleep problems, and to an extent, for hypertension, is seem to extend beyond the loss of physical independence. This suggests that interventions should also address psychosocial stress, financial insecurity, and changes in caregiving and social support.

As the share of older widows in Indian population grows, the findings in this research suggest that while identifying the women at greater health risk, their health assessment should also account for the marital status along with the functional status.

Future research using longitudinal LASI data, particularly with directly measured blood pressure, information on the duration of widowhood, and a stronger instrumental variable, could help clarify how much of the hypertension gap can be attributed to widowhood.

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Appendix

Table S1. Construction of the 12-item HRQoL index from LASI Wave 1 items

HRQoL is the sum of 12 binary items (range 0-12; 1 = favourable). Items that were not asked or were missing score 0, so the index mixes health and questionnaire routing. It is a LASI-based proxy loosely modelled on the SF-12, not a validated SF-12 score. Survey-

weighted mean 7.85 (SD 2.12); Cronbach alpha 0.572 and correlation with functional status 0.433 (both unweighted); N = 16,512. Percentages favourable are survey-weighted.

Item	LASI variable(s)	Coding rule	Closest SF-12 item	Fit	% all	% married	% wid./sep.
overall_health	HT001a/b	1 if rated excellent/very good/good (codes 1-3)	SF-12 Q1 general health	Close	75.4	79.4	72.2
physical_strength	HT309, HT310, HT311	1 if no difficulty with any one of the three	SF-12 Q2 moderate activities	Partial	89.7	92.2	87.7
stairs_climbing	HT306	1 if no difficulty	SF-12 Q3 climbing several flights	Close	37.1	42.1	33.1
physical_issue_accomplish	FS609a, FS609b	1 if agree codes 4-7 (a) or 4-5 (b)	SF-12 Q4a accomplished less	Weak	81.7	85.8	78.5
physical_issue_limitations	HT303, HT304, HT308	1 if no difficulty with any one of the three	SF-12 Q4b limited in kind of work	Partial	83.9	87.1	81.5
emotional_issue_accomplish	WE007	1 if never stopped (code 2); ever-workers only	SF-12 Q5a emotional: accomplished less	Weak (proxy)	46.2	44.2	47.7
emotional_issue_limitations	MH214	1 if no episode (code 2)	SF-12 Q5b emotional: less careful	Weak (proxy)	82.6	83.6	81.8
pain	EV001	1 if none/mild/moderate (codes 1-3); asked of a subsample	SF-12 Q6 pain interference	Close	21.6	22.2	21.1
peace	FS611a, FS611b	1 if either is anything other than "never"	SF-12 Q7 calm and peaceful	Partial	78.7	81.7	76.2
energy	FS703	1 if rarely or never	SF-12 Q7b energy	Close	35.2	36.2	34.4
downhearted	MH201	1 if no episode (code 2)	SF-12 Q7c downhearted	Close	75.5	77.8	73.7
bothered	FS710	1 if not "rarely or never" (codes 2-4)	SF-12 Q8 social activities interference	Weak (proxy)	77.1	79.6	75.2

Note: wid./sep. = widowed/separated. Reference periods vary (current, past week, past 12 months, lifetime); see the Online Resource for item wording.

Table S2. Variable definitions

Variable	Definition
Functional status	Sum of ADL items HT401-HT406 (difficulty with basic activities; walking across a room replaces continence); higher = better; z-

	scored in models.
Widowed/separated	1 if not currently married (widowed 95%; divorced, separated, deserted, living-in or never married 5%); 0 if currently married.
Hypertension	Self-reported physician diagnosis of hypertension (1 = yes).
Trouble sleeping	1 if sleeping problems reported at any frequency above "never".
Income group	Monthly per capita consumption expenditure (MPCE) quintile, 1 = poorest.
Insurance	Employer-linked social insurance (WE316 c, e-i); asked only of ever-workers; not general health insurance.
Disability	1 if disaster-related permanent disability (HT108a) or family intellectual disability (FM312a); not a measure of the respondent's own functional impairment.
Urban	1 if urban residence.
Age (centred)	Age in years minus 60.
HRQoL	See Table S1; z-scored in models.

Table S3. Robustness of the main results to the HRQoL specification (survey-weighted odds ratios, 95% CI)

Specification	Hyp.: FS	Hyp.: widowed/sep.	Hyp.: FS x wid./sep.	Sleep: FS	Sleep: widowed/sep.	Sleep: FS x wid./sep.
A. 12-item HRQoL (main)	0.88 (0.79-0.98)	1.16 (0.99-1.35)	1.15 (1.02-1.31)	0.73 (0.66-0.81)	1.03 (0.92-1.15)	1.15 (1.02-1.29)
B. 10 items (drop WE007- and EV001-based)	0.86 (0.78-0.96)	1.15 (0.99-1.35)	1.16 (1.02-1.31)	0.74 (0.67-0.82)	1.01 (0.91-1.14)	1.14 (1.02-1.28)
C. 6 SF-12-proximate items	0.90 (0.81-1.00)	1.16 (0.99-1.35)	1.14 (1.00-1.30)	0.81 (0.73-0.90)	1.02 (0.91-1.14)	1.12 (1.00-1.25)
D. No HRQoL covariate	0.82 (0.74-0.91)	1.17 (1.00-1.36)	1.16 (1.03-1.31)	0.63 (0.57-0.70)	1.05 (0.94-1.18)	1.17 (1.04-1.31)
E. Without insurance and disability	0.88 (0.79-0.98)	1.16 (0.99-1.35)	1.15 (1.02-1.31)	0.73 (0.66-0.81)	1.03 (0.92-1.15)	1.15 (1.02-1.29)

Note: Hyp. = hypertension; FS = functional status (z-score). Survey-weighted logistic regressions with the same covariates except as stated.

Table S4. Unweighted versus survey-weighted logistic regressions (odds ratios, 95% CI)

Variable	Hypertension, unweighted	Hypertension, weighted (M2)	Sleep trouble, unweighted	Sleep trouble, weighted (M4)
Functional status (z)	0.89*** [0.84,0.94]	0.88* [0.79,0.98]	0.82*** [0.77,0.88]	0.73*** [0.66,0.81]
Widowed/separated	1.13*** [1.05,1.21]	1.16 [0.99,1.35]	1.04 [0.97,1.11]	1.03 [0.92,1.15]
FS x widowed/separated	1.10** [1.03,1.18]	1.15* [1.02,1.31]	1.09* [1.00,1.17]	1.15* [1.02,1.29]
HRQoL (z)	0.82*** [0.79,0.85]	0.84*** [0.78,0.91]	0.67*** [0.65,0.70]	0.69*** [0.64,0.75]
Income quintile	1.22*** [1.19,1.25]	1.25*** [1.17,1.32]	1.02* [1.00,1.05]	1.03 [0.99,1.08]
Disability	1.04 [0.81,1.34]	0.81 [0.56,1.17]	0.98 [0.77,1.27]	1.07 [0.72,1.58]
Insurance	1.00 [0.68,1.46]	0.92 [0.49,1.72]	1.25 [0.87,1.79]	1.38 [0.74,2.57]
Urban residence	2.10*** [1.96,2.24]	2.48*** [1.96,3.14]	0.90** [0.84,0.96]	0.95 [0.83,1.09]

Age (centred at 60)	1.00 [0.99,1.00]	1.00 [0.99,1.01]	1.00 [0.99,1.00]	0.98*** [0.97,0.99]
N	16,512	16,512	16,512	16,512

Note: Unweighted models use robust (HC1) standard errors; weighted models are Table 2, M2 and M4. *p<.05, **p<.01, ***p<.001. Conclusions are unchanged in direction: the weighted interaction ORs are similar to the unweighted ones, while the widowhood main effect on hypertension is smaller and only marginally significant (p = .065) once weighted, and the urban-residence association is stronger for hypertension.

Table S5. Supporting numbers cited in the text (survey-weighted; from the replication output)

Item	Column 1	Column 2
Panel A. Covariate balance (survey-weighted SMD, widowed/separated vs married)	**Before IPTW**	**After IPTW**
Age	0.774	0.099
Urban residence	0.128	0.009
Panel B. Widowhood effect on probability (percentage points)	**Hypertension**	**Sleep trouble**
Naive survey-weighted difference (SE)	5.15 (1.92)	1.72 (1.31)
IPTW-adjusted difference (SE)	2.14 (1.59), p = .177	1.45 (1.55), p = .348
Doubly robust (AIPW) estimate (SE)	1.71 (1.54)	1.65 (1.77)
Panel C. State-clustered vs robust standard errors (logit)	**Hypertension**	**Sleep trouble**
Widowed/separated coefficient (log-odds)	0.145	0.029
SE, robust / state-clustered	0.0758 / 0.0605	0.0736 / 0.0657
z (clustered)	2.40	0.45
SE ratio clustered/robust: interaction	0.88	0.60
SE ratio clustered/robust: urban residence	1.29	0.61
SE ratio clustered/robust: income	1.23	0.85
Panel D. Blinder-Oaxaca explained gap by variable (percentage points)	**Hypertension**	**Sleep trouble**
Age	0.30	−2.31
Urban residence	1.23	−0.07
Functional status	0.16	1.08
HRQoL	0.88	2.03
Income quintile	−0.70	−0.11
Disability	0.01	0.00
Insurance	0.00	0.03
Total explained (raw gap)	1.88 (5.15)	0.63 (1.72)
Panel E. Sensitivity (Oster, IV)	**Hypertension**	**Sleep trouble**
Oster breakdown δ*	5.56	5.71
IV first-stage coefficient (F robust / clustered)	0.942 (119.8 / 129.1)	0.942 (119.8 / 129.1)
Control-function test p-value	0.001	0.751
Breakeven exclusion-violation f (2SLS reaches OLS)	0.898	1.542

Note: IPTW weights are stabilised and trimmed at the 1st/99th percentiles and multiplied by the survey weight. The doubly robust estimate is computed by hand because Stata's teffects does not accept survey weights. Oaxaca contributions use the pooled model with a group indicator, with SEs clustered on PSU; the total explained gaps are 36.5% (hypertension) and 36.7% (sleep trouble) of the raw gaps. Oster δ is the proportional selection needed to drive the effect to zero (R-max = 1.3 × the controlled R^2).