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Mediation of pain in the association of sleep problems with falls among older adults in India

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Body pain, sleep problems and falls are commonly reported among the elderly population. This study aimed to explore the mediating role of pain in the association of sleep problems with fall-outcomes (falls, fall-injury, and multiple falls) among older adults. Cross-sectional data from the baseline survey of Longitudinal Aging Study in India (LASI), 2017–18 were used. The total sample size for the study was 28,285 older adults aged 60 years and above. Falls and fall-related injuries among older adults in the last two years were self-reported. The Jenkins Sleep Scale (JSS-4) was used to assess sleep problems while pain was assessed using questions on whether respondents reported that they were troubled by pain and they required some form of medication or treatment for the relief of pain. Multivariable logistic regression and mediation analyses were conducted to fulfill the study objectives. While 13% older adults suffered from sleep problems, 38.83% were troubled with pain. Additionally, 12.63%, 5.64% and 5.76% older adults reported falls, fall-injury and multiple falls respectively. Older adults who suffered from sleep problems had higher odds of falls [adjusted odds ratio (aOR): 1.43, confidence interval (CI): 1.30–1.58], fall-injuries, [aOR:1.50,CI:1.30–1.73] and multiple falls [aOR:1.41,CI:1.24–1.62]. Similarly, older adults who were troubled with pain were more likely to report falls [aOR:1.80, CI:1.67–1.95], fall-injuries [aOR:1.66, CI:1.48–1.87] and multiple falls [aOR:1.90,CI:1.69–2.12]. The percent of the mediated effect of pain when examining the association between sleep problems and fall outcomes were reported to be 17.10%, 13.56% and 18.78% in case of falls, fall-injuries and multiple falls respectively. The current study finds evidence that pain mediates the association of sleep problems and falls, fall-injuries, and multiple falls among older Indian adults. Both sleep problems and pain are modifiable risk factors that need attention for fall prevention strategies.

Age-related falls and resulting injuries are a major public health issue which can play a significant role in affecting older adults' morbidity and mortality[1,2]. Falls are among the leading causes of unintentional mortality worldwide[3]. Globally, based on the World Health Organization (WHO) report, a large proportion of older adults experience falls, with a disproportionate burden of falls-related injuries or mortality reported in low and middle-income countries[4].

At an individual level, age is a key risk factor for falls[5]. Women experience higher falls than men[6]. Studies also have showed a lower socioeconomic status to be a major risk factor for falls[7]. Health-related factors such as functional limitations, weak handgrip strength, chronic diseases such as diabetes or bone and joint diseases are also associated with a higher prevalence of falls[8–10]. Similarly, sleep problems are a major risk factor for falls. A study conducted among older adults in China found a significant positive association of sleep disturbance and short sleep duration with falls[11]. Another study conducted in six low and middle-income countries showed factors such as depression, sleep problems, multiple chronic conditions and poor cognition to be positively associated with falls-related injury[1]. Another study found similar findings wherein people with sleep problems and pain were more likely to experience falls[12], while a Finnish study among older adults found the number of chronic conditions to be closely associated with falls[13].

Falls and fall-related injuries pose major public health threats to an aging society[3,14] and are scrutinized as one of the 'Geriatric Giants'[15]. Recurrent falls are the leading cause of hospitalization, disability, and mortality[11,16]. The Indian population is aging rapidly with rising longevity[17]. One of the major challenges is to promote well-being

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and healthy aging of older adults[15,18]. Therefore, there is a growing need for advancing the evidence on the risk factors that contribute to increased morbidity and mortality along with the protective factors that can favor healthy aging, especially in resource-limited settings.

While pain and sleep problems are identified as risk factors for falls, the extent of their contribution to falls is unclear in the literature. To the best of our knowledge, no study has examined the mediating effect of pain on the relationship between sleep and falls or fall-related injuries or multiple falls among older adults in India. While falls and fall-related consequences are higher in low and middle-income countries, it is important to understand the role of sleep and pain and their effect on falls and fall-related injuries. In old age, pain and sleep problems are common risk factors leading to adverse health outcomes in India. A growing body of literature suggest that pain is associated with poor self-rated health[19], depression[20], and lower quality of life[19]. Through this study, any additional evidence of the role of pain in the association of sleep problems with fall outcomes that we find will be helpful in guiding policy-makers in developing interventions and policies to prevent falls and falls-related injuries among its elderly population.

Thus, the objectives of the current study are (1) to examine the association of pain and sleep problems with falls and falls-related injury (2) to study the direct and indirect effect of sleep problems on falls, falls-related injuries and multiple falls, and (3) to see the mediating role of pain, using a nationally representative dataset that comprises community-dwelling older adults in India.

Methods

Data. *Study participants.* The current study is based on the data from the baseline survey of the Longitudinal Aging Study in India (LASI), 2017–18. The LASI is a national-representative survey of 72,250 individuals aged 45 years and above and their spouses regardless of age across all states and union territories of the country. The survey provides important information on the physical, psychological, cognitive and social health of the older adult population in India. In the LASI, the sample selection is based on a multistage stratified cluster sample design, including a three-stage sampling design in rural areas and a four-stage sampling design in urban areas. The survey was administered face-to-face by an interviewer during household visits using computer-assisted personal interview (CAPI) technology in the local language. The total response rate at individual level was 95.6%. The details of sampling design, survey instruments, and data collection procedures are published elsewhere[21]. The Indian Council of Medical Research (ICMR) extended the necessary guidance and ethical approval for conducting the LASI. All the methods were carried out in accordance with those relevant guidelines and regulations. Prior informed consent from the respondents was taken before conducting the interviews. Our study sample is limited to eligible respondents aged 60 years and above. The missing cases for the outcome variable (n = 3179) were dropped from the analysis, resulting in a final sample size of 28,285 (13,836 males and 14,449 females) older adults aged 60 years and above. The sample selection procedure for this study is summarized in Fig. 1.

Measures. *Outcome variables.* Falls among older adults in the last two years were self-reported and assessed using the question, '*In the past two years, have you fallen down?*' The responses were coded as 'no' and 'yes'. Further, fall-related injuries were assessed by the following survey question that '*In that fall, did you injure yourself seriously enough to need medical treatment?*' and the responses were similarly codes as 'no' and 'yes'. Ad-
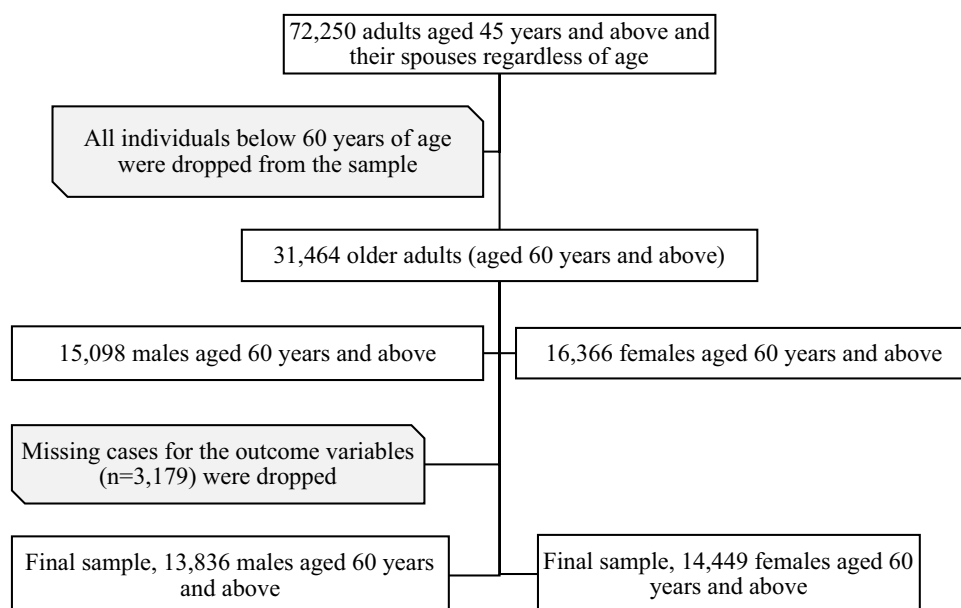
Figure 1. Sample selection criteria for this study.

ditionally, information on multiple falls was calculated from the question on number of falls in the last two years. Those who reported falls > 1 were classified as having multiple falls.

Main exposure variable. Sleep problems were assessed using the following four questions in the LASI survey, adapted from the Jenkins Sleep Scale (JSS-4)[22]: "*How often do you have trouble falling asleep?*" (1) "*How often do you have trouble with waking up during the night?*" (2) "*How often do you have trouble with waking up too early and not being able to fall asleep again?*" (3) "*How often did you feel unrested during the day regardless of the number of hours of sleep you had?*" These questions address the respondents' sleep during the past one month. Response options were "never, rarely (1–2 nights per week), occasionally (3–4 nights per week), and frequently (5 or more nights per week)" (item four was reverse coded). The presence of sleep problems was "coded as 1 if people responded 'frequently' to any of the four aforementioned questions[23]. The JSS-4 scale of assessing sleep problems has been used in clinical settings[24], epidemiological cohort studies[25,26] and observational studies on normal healthy people[27]. The scale has proven to have excellent reliability and demonstrated good construct validity[28]. Additionally, it has been validated in the Indian setting with local languages[29]. The internal consistency of JSS-4 (Chronbach's alpha) was 0.87 in our study.

Mediator variable. In this study, pain was the mediating variable in the association between sleep problems and falls, fall-injury and multiple falls. Pain was self-reported by older individuals, and assessed if respondents reported that they were troubled by pain and required some form of medication or treatment for the relief of pain, with the help of the following question '*Are you often troubled with pain?*', and coded as no and yes[20].

Other covariates. Socio-demographic variables included age (recoded as 60–69, 70–79 and 80+), sex (male and female), education (no education, primary education and secondary/higher education), marital status (married, widowed and others which included separated, divorced and never married), living arrangements (living alone, with spouse, with spouse and children and others) and work status (never worked, currently working, not working and retired). Self-rated health was recoded as good (Very good, good and fair) and poor (poor and very poor). The activities of daily living (ADL) is a term used to refer to normal daily self-care activities (such as movement in bed, changing position from sitting to standing, feeding, bathing, dressing, grooming, personal hygiene etc.) The ability or inability to perform ADLs is used to measure a person's functional status, especially in the case of people with disabilities and older adults[30,31]. Instrumental activities of daily living (IADL) that are not necessarily related to the fundamental functioning of a person, but letting an individual live independently in a community, are used as functional health indicator. In this study, difficulty in ADL and IADL were coded as binary variables (no and yes) representing the presence of at least one difficulty.

Further, the monthly per capita consumption expenditure (MPCE) quintile was assessed using household consumption data. Food expenditure was collected based on a reference period of seven days, and non-food expenditure was collected based on reference periods of 30 days and 365 days. Food and non-food expenditures have been standardized to the 30-day reference period. The MPCE is computed and used as the summary measure of consumption. The variable was then divided into five quintiles i.e., from poorest to richest. Religion was coded as Hindu, Muslim, Christian, and Others. Caste was recoded as Scheduled Caste/Scheduled Tribe (SC/ST), Other Backward Classes (OBC), and others. The SC refers to the population that is socially segregated and financially/economically weak by their lower status as per the caste hierarchy. Similarly, the ST refers to the indigenous populations who are amongst the most disadvantaged and discriminated socio-economic groups in the country. The OBC is the group of people identified as 'socioeconomically and educationally backward' while the 'other' caste category is identified as having higher social status, mostly those belonging to an upper caste group[32]. Place of residence was coded as urban and rural. Also, region of the country was coded as North, Central, East, Northeast, West, and South.

Statistical analysis. Descriptive statistics along with results of cross-tabulations are presented in the study. Additionally, multivariable logistic regression analysis[33] was conducted to find out the association between the outcome variables (falls, fall-injury and multiple falls) and sleep problems. The estimates were presented in the form of odds ratio (OR) along with a 95% confidence interval (CI). Additionally, the total effect in the observed association was divided into direct (the association of sleep problems with fall, fall-injury and multiple falls after controlling for all the covariates) and indirect or mediating effects (the association of sleep problems with fall variables through pain) using Karlson–Holm–Breen (KHB) method[34,35]. The KHB method is a recently developed method for assessing mediating effects that allow total effects to be divided into direct and indirect (i.e., mediation) effects for both discrete and continuous variables. The mediation percentage (the indirect effect divided by the total effect) is interpreted as the percentage of the association explained by the mediator variable. All statistical models were adjusted for covariates including age, sex, education, marital status, living arrangements, work status, self-rated health, ADL/IADL difficulty, MPCE quintiles, religion, caste, place of residence and region. The statistical analysis was performed using Stata 15.1. Individual weights were used to make the estimates nationally representative.

Ethical approval. The Indian Council of Medical Research (ICMR) extended the necessary guidance, guidelines and ethical approval for conducting the LASI survey. All methods were carried out in accordance with those relevant guidelines and regulations. The survey agencies that conducted the field survey for the data collection have collected prior consent (signed and oral) for both the interviews and biomarker tests from the eligible respondents in accordance with the Human Subjects Protection.

Results

Sample characteristics. Table 1 presents the socioeconomic and health profile of older adults in the current study. A proportion of 13.12% older adults suffered from sleep problems and 38.83% older adults were troubled with pain in the study. More than 10% of the participants were aged 80 years and above and the sample included 51.08% female respondents. A proportion of 33.25% older adults were widowed in the study, while 5.06% older adults were living alone. More than half of the participants had no formal education and 29.08% were currently working. Furthermore, 21.70% older adults had poor self-rated health, 20.11% and 42.96% had ADL and IADL difficulty respectively. Besides, 65.42% of the sample lived in rural areas of the country.

Prevalence of falls, fall-related injury and multiple falls is estimated to be 12.63%, 5.64% and 5.76% respectively. Older adults who suffered from sleep problems had a higher prevalence (19.12% vs. 11.58%) of falls than those did not suffer from sleep problems. Similarly, higher prevalence of a fall-related injury (8.95% vs. 5.11%) and multiple falls (9.04% vs. 5.22%) were reported among those who had sleep problems. Besides, 18.08% of older adults who were troubled with pain reported falls in comparison to those who had no pain (9.32%). Consistently, fall-related injury (8.19% vs. 4.09) and multiple falls (8.66% vs. 3.99%) were observed to be higher among those who reported pain.

Table 2 presents the state-wise prevalence of falls, fall-related injury and multiple falls. The higher prevalence was observed in the states of Odisha (23.13%), Punjab (20.83%) and Kerala (18.70%). The higher prevalence of fall-related injuries was observed in the states of Punjab (9.94%), Gujarat (8.70%) and Odisha (7.80%). Besides, higher prevalence of multiple falls was found in the states of Kerala (12.24%), Punjab (11.44%) and Odisha (10.62%).

Table 3 presents the results of multivariable logistic regression. Older adults who suffered from sleep problems had significantly higher odds of falls [aOR: 1.43, CI: 1.30–1.58], fall-related injury [aOR: 1.50, CI: 1.30–1.73] and multiple falls [aOR: 1.41, CI: 1.24–1.62]. Similarly, older adults who were troubled with pain were more likely to report falls [aOR: 1.80, CI: 1.67–1.95], fall-related injury [aOR: 1.66, CI: 1.48–1.87] and multiple falls [aOR: 1.90, CI: 1.69–2.12].

Table 4 presents the results from the mediation analysis. Older adults who suffered from sleep problems had higher odds of falls [aOR: 1.54, CI: 1.40–1.70], fall-related injury [aOR: 1.60, CI: 1.39–1.84] and multiple falls [aOR: 1.53, CI: 1.34–1.75]. The associations of sleep problems with fall outcomes were mediated by pain. The percent of mediated effects were reported to be 17.10%, 13.56% and 18.78% in case of falls, fall-related injuries and multiple falls respectively.

Discussion

Although sleep problems have been identified as a risk factor for falls, whether this association is mediated by pain is unclear in the current literature. Our study found that a large number of older Indian adults are suffering from sleep problems that can potentially have serious consequences on their health and overall wellbeing[36–38]. This study further unfolds the role of pain in the relationship between sleep problems and falls, fall-related injuries, and multiple falls. It demonstrates the mediator effect of pain in the relationship between sleep problems and falls and related injuries. In line with previous studies, the association of sleep problems and pain with falls in the geriatric population was found to be positive and statistically significant[39–42].

A significant proportion of older people (12.63%) reported falls in the past two years, which appears to be lower than estimates reported in studies in other countries[43–47]. A systematic review from India reported that a pooled prevalence of falls was 31% among older people[48]. Similarly, Pichai et al. (2019) found one-fourth of their study participants to have a history of falling[46]. However, the prevalence of falls, related-injuries and multiple falls in our study was similar to previous evidence from India[18,47]. One plausible explanation for the dissimilarity in prevalence in other studies could be that reporting of falls and related injuries was associated with hospitalization[46]. Older adults who experienced hospitalization with falls and were institutionalized will be more likely to recall falls and the LASI survey did not collect information from older adults who were institutionalized. Therefore, given that multiple falls and injuries are an indication of poor physical and cognitive health of elderly people[42,44], preventing falls among its rising older adult population remains a major public health concern in India.

Sleep problems in late life are common among older people and are associated with declining physical activity, functional impairment, and decreased quality of life[14,39,49]. Our study found 13.12 percent of the geriatric population to have reported any sleep problems. This percent is lower than the estimates obtained by other hospital-based studies among older adults that reported an insomnia prevalence to range between 11.8% and 32%[50]. While our study is a population-based study representative of the older adult population in the whole country, the lower prevalence might also have been on account of older people in the community-dwellings cognizing sleep problems as a natural part of aging, thus leading to its under-estimation[43,49,51]. Our study also found that older people with reported sleep problems had a significant increase in the risk of falls, fall-related injuries and multiple falls, which was consistent with other studies[39,52,53]. Older people with reduced psychomotor performance, sleep problems, short sleep duration in night and naps are at higher risk of falls and related injuries[54]. This possible delineation by which sleep problems affect falls occurrence is due to daytime sleepiness, cognitive disorder, impaired standing balance and walking ability[53,55]. In particular, Morelhão et al.[39] endorsed that sleep deprivation causes detrimental damage in an organism disrupting the systems of balance and coordination, difficulty in sustaining attention and concentration, leading to falls, related injuries, and multiple falls in old age[39]. These results emphasized the importance of sleep problems in the obviation of falls and related injuries among older people. However, the relationship between sleep problems and falls was significantly attenuated when pain was controlled. Thus, our study indicated that the presence of pain might be a pathway in the association between self-reported sleep problems and falls among older people.

Variables	Distribution		Fall		Fall-injury		Multiple falls	
	Frequency	w col %	w%	p-value	w%	p-value	w%	p-value
Sleep problems				< 0.001		< 0.001		< 0.001
No	24,567	86.88	11.58		5.11		5.22	
Yes	3709	13.12	19.12		8.95		9.04	
Pain				< 0.001		< 0.001		< 0.001
No	17,293	61.17	9.32		4.09		3.99	
Yes	10,977	38.83	18.08		8.19		8.66	
Age (in years)				0.047		0.679		< 0.001
60–69	17,179	60.74	12.42		5.76		5.33	
70–79	8172	28.89	12.52		5.03		6.08	
80 +	2934	10.37	14.12		6.68		7.21	
Sex				< 0.001		< 0.001		< 0.001
Male	13,836	48.92	11.69		5.28		4.91	
Female	14,449	51.08	13.52		5.98		6.56	
Marital status				< 0.001		0.001		< 0.001
Currently in union	18,110	64.03	12.04		5.37		5.21	
Widowed	9404	33.25	13.87		6.22		6.87	
Others	771	2.73	9.96		4.33		3.58	
Living arrangement				< 0.001		0.001		< 0.001
Alone	1431	5.06	14.78		5.76		8.31	
With spouse	5627	19.89	12.62		5.82		5.34	
With spouse and children	12,259	43.34	11.62		5.06		5.08	
Others	8968	31.71	13.56		6.26		6.44	
Educational status				< 0.001		< 0.001		< 0.001
None	15,036	53.16	13.16		5.91		6.47	
Primary	5218	18.45	13.9		6.40		5.80	
Secondary/higher	8031	28.39	10.63		4.55		4.18	
Work status				< 0.001		0.001		< 0.001
Never worked	7777	27.50	11.3		4.84		5.31	
Not working	9769	34.54	13.43		5.80		6.56	
Working	8225	29.08	13.41		6.31		5.56	
Retired	2514	8.89	10.11		4.88		4.23	
Self-rated health				< 0.001		< 0.001		< 0.001
Good	21,753	78.30	11.36		5.16		4.76	
Poor	6030	21.70	16.86		7.29		8.78lePara>	
ADL difficulty				< 0.001		< 0.001		< 0.001
No	22,570	79.89	11.78		5.22		5.18	
Yes	5682	20.11	15.6		7.12		7.73	
IADL difficulty				< 0.001		< 0.001		< 0.001
No	16,095	57.04	11.16		4.95		4.78	
Yes	12,121	42.96	14.3		6.43		6.83	
MPCE quintile				0.031		0.031		0.741
Poorest	5876	20.77	11.5		4.44		5.38	
Poorer	5834	20.63	13.64		5.88		6.17	
Middle	5746	20.31	11.86		5.53		5.59	
Richer	5524	19.53	12.72		5.52		6.00	
Richest	5305	18.76	13.67		7.24		5.62	
Caste				0.001		0.160		< 0.001
SC/ST	9371	33.13	13.26		6.34		5.61	
OBC	10,621	37.55	11.71		4.89		5.83	
Others	8,293	29.32	13.5		6.18		5.78	
Religion				< 0.001		< 0.001		0.217
Hindu	20,567	72.71	12.59		5.66		5.70	
Muslim	3350	11.84	12.28		5.65		5.42	
Others	4368	15.44	13.67		5.41		7.01	
Place of residence				< 0.001		< 0.001		< 0.001
Continued								

Variables	Distribution		Fall		Fall-injury		Multiple falls	
	Frequency	w col %	w%	p-value	w%	p-value	w%	p-value
Urban	9781	34.58	10.35		4.62		4.77	
Rural	18,504	65.42	13.57		6.06		6.16	
Region				< 0.001		< 0.001		< 0.001
North	5318	18.80	10.25		4.65		4.62	
Central	3829	13.54	13.79		6.01		7.09	
East	4860	17.18	15.47		7.12		6.50	
Northeast	3469	12.26	9.89		4.57		4.15	
South	6905	24.41	8.44		2.80		4.43	
West	3904	13.80	15.16		7.83		5.98	
Total	28,285	100	12.63		5.64		5.76	

Table 1. Sample distribution and rates of fall, fall-injury and multiple falls by background characteristics among older adults. Notes: w col %: Weighted column percentage; w%: weighted percentage prevalence to account for survey design and provide national population estimates; ADL: Activities of daily living; IADL: Instrumental activities of daily living; MPCE: Monthly per capita consumption expenditure.

Consistent with prior evidence[16,40,41,56], our findings indicate that older adults with pain experienced more falls, related injuries and multiple falls than those without pain. A meta-analysis study conducted by Stubbs et al. (2014) revealed that older people who reported pain were 56% at higher risk of falls compared to those with no pain. Furthermore, they also demonstrated that half of the study participants with pain reported one or more falls[16]. A 4-year follow-up study among community-dwelling older adults aged 70 years and above revealed that pain interference and pain distribution independently predicted injurious falls[57]. Another 1-year follow-up study found that self-reported back pain was associated with recurrent falls among older persons[58]. The mechanism behind this significant association could be multifaceted, namely, local joint pathology, the neuromuscular effect of pain and central mechanisms, through which pain mediates with cognitive function as age advances[41]. Additionally, factors such as fear of falling, history of falls and fall efficiency are related to falling, increase the risk of falls, and are associated with pain[59,60]. Future studies are warranted to examine these aspects.

Both sleep problems and pain serve as a common array of physical and mental health comorbidities[56,61]. However, no studies have shed light on the mediation effect of pain in the relationship between sleep problems and falls, falls-related injuries and multiple falls among Indian older adults. The studies based on medical interventions demonstrated that the onset of pain appears as a side effect that coexists with the development of sleep disturbances or the other way round[61,62]. Our findings also indicated that 17.10% of falls, 13.56% of falls injuries, and 18.78% of recurrent falls were mediated by pain among older people who had sleep problems. One mechanism behind this association is that sleep problems expand the risk for the genesis of pain among older people, which eventually worsens the long term prognosis of existing pain[61] and influences mobility and functionality in day to day life resulting in a higher incidence of falls among older adults[14,48]. Studies also propound that sleep problems can lead to systemic inflammation in the body that escalate pain[59] which further prognosticate poorer physical and psychological functioning eventuating in falls and injuries[59,60]. Another possible explanation could be that older adults with sleep problems will amplify chronic back pain. Also, sleep deficiency disrupts the body's immune response and body's cognitive functions. Sleeping difficulty hampers the pain and pain makes sleeping more difficult[63]. Therefore, the bidirectional relationship can cause problems in concentration and attention, thereby increasing the risk of falling and multiple falls[55].

The present study also found that falls, falls-related injury and multiple falls were associated with other factors, including socio-demographic and physiological characteristics of individuals. These factors can either relate to falls independently or act in conjunction with other potential risk factors to impact on the prevalence of falls among older adults. Furthermore, the female gender was at higher risk of falls which was also identified in previous studies[15,18]. This may be partially explained by genetic factors, lifestyle demands and differences in bone density between men and women[10,18]. Older people having difficulties in ADL and IADL were at a higher risk of falls and injuries in our study. Consistently, ADL and IADL related difficulties significantly predicted falls in previous studies[15,59]. Thus, enhancing physical activity and improving functional ability can probably reduce the risk of falls among older people[47,64].

Strengths and limitations

The major strength of the study is the large nationally-representative survey data with comprehensive information on socioeconomic and health characteristics of older population. The study included a large number of potential confounders that strengthen the current findings. Although the present study provides evidence on the role of pain in sleep problems and associated falls, related injuries, and multiple falls, it has several limitations. The study deals with self-reported information resulting in recall bias and under-reporting. While falls are typically reported using a single-year time-frame or less, the 2-year time-frame used in LASI might be associated with some recall bias on the part of the respondents. However, LASI follows other longitudinal aging studies in using the timeframe for fall outcomes such as the English Longitudinal Study of Ageing (ELSA)[65]. Also, there was no definition in the questionnaire of what constituted a fall. Studies have differed in how a fall is defined and this

State/UT	Fall %	Fall-injury %	Multiple falls %
Jammu & Kashmir	3.41	1.17	0.29
Himachal Pradesh	12.13	3.69	6.70
Punjab	20.83	9.94	11.44
Chandigarh	9.93	5.36	1.83
Uttarakhand	12.51	3.74	5.79
Haryana	12.79	5.76	5.03
Delhi	8.71	5.02	5.03
Rajasthan	6.23	3.05	2.22
Uttar Pradesh	16.03	6.92	8.46
Bihar	14.77	7.54	7.44
Arunachal Pradesh	10.11	0.45	5.17
Nagaland	4.15	0.10	3.03
Manipur	4.02	2.22	0.86
Mizoram	1.61	0.95	0.07
Tripura	11.22	4.08	5.47
Meghalaya	3.20	0.92	1.89
Assam	12.24	6.25	4.96
West Bengal	11.97	6.24	3.75
Jharkhand	16.87	7.37	5.44
Odisha	23.13	7.80	10.62
Chhattisgarh	11.85	4.20	6.03
Madhya Pradesh	10.36	4.87	4.97
Gujarat	17.04	8.70	7.07
Daman & Diu	13.25	7.15	5.02
Dadra & Nagar Haveli	17.49	8.12	6.88
Maharashtra	14.37	7.49	5.51
Andhra Pradesh	6.03	3.15	3.29
Karnataka	7.02	2.65	3.32
Goa	10.79	3.34	6.07
Lakshadweep	2.65	1.42	2.20
Kerala	18.70	3.33	12.24
Tamil Nadu	9.35	2.61	4.88
Puducherry	6.33	2.64	3.51
Andaman & Nicobar Islands	4.67	2.56	2.78
Telangana	5.08	2.74	1.48
India	12.63	5.64	5.76

Table 2. State-wise prevalence (%) of falls, fall-injury and multiple falls among older adults (60 + years), India, LASI Wave 1, 2017–18.

diversity may not facilitate a direct comparison of findings[66]. The data were cross-sectional in nature, thus limiting the interpretation of causal association. Sleep problems was assessed through many questions, but there is great diversity in sleep patterns depending on cultural, contextual, and structural factors. For instance, some people take quality sleep in less time and others getting regular sleep hours have sleep problems. Therefore, sleep quality and duration are also necessary to explore the relationship between sleep and falls.

Conclusion

The current study comes up with evidence that pain mediates the association of sleep problems and falls, related injuries, and multiple falls among older Indian adults. Both sleep problems and pain are modifiable risk factors that need attention for fall prevention strategies. From an economic standpoint, falls are costly to treat and due to lack of health insurance, non-affordability is a common cause for not seeking any medical treatment among older adults[67]. Therefore, policy-makers can consider development of falls prevention programs. These programs include education, exercises for balance and strength training, medication review, home safety modifications, correction of refractive errors etc. and several have shown to be effective in improving balance and mobility in the Indian context[68–71]. Encouraging physical exercise and social participation should be prioritized to prevent or reduce the incidence of falls and injuries related to falling among older people. Measures to improve sleep health and reducing pain through nutritional intervention such as vitamin-D supplementation will be useful.

Variables	Fall aOR (95% CI)	Fall-injury aOR (95% CI)	Multiple falls aOR (95% CI)
Sleep problems			
No	Ref.	Ref.	Ref.
Yes	1.43*** (1.30–1.58)	1.50*** (1.30–1.73)	1.41*** (1.24–1.62)
Pain			
No	Ref.	Ref.	Ref.
Yes	1.80*** (1.67–1.95)	1.66*** (1.48–1.87)	1.90*** (1.69–2.12)
Age (in years)	1.00 (0.99–1.00)	0.99 (0.99–1.00)	1.00 (1.00–1.01)
Sex			
Male	Ref.	Ref.	Ref.
Female	1.31*** (1.18–1.44)	1.26** (1.09–1.46)	1.45*** (1.26–1.67)
Marital status			
Currently in union	Ref.	Ref.	Ref.
Widowed	0.85 (0.57–1.26)	0.69 (0.41–1.15)	0.80 (0.47–1.37)
Others	0.71 (0.45–1.13)	0.62 (0.33–1.16)	0.51* (0.26–1.00)
Living arrangement			
Alone	Ref.	Ref.	Ref.
With spouse	0.79 (0.52–1.20)	0.62 (0.35–1.08)	0.68 (0.38–1.21)
With spouse and children	0.83 (0.55–1.26)	0.68 (0.39–1.17)	0.75 (0.43–1.33)
Others	1.08 (0.91–1.28)	1.15 (0.89–1.49)	0.94 (0.75–1.18)
Education (in years)	1.00 (0.99–1.01)	1.00 (0.98–1.01)	0.99 (0.98–1.01)
Work status			
Never worked	Ref.	Ref.	Ref.
Not working	1.30*** (1.17–1.45)	1.28** (1.09–1.50)	1.35*** (1.17–1.56)
Working	1.43*** (1.27–1.61)	1.46*** (1.22–1.74)	1.46*** (1.23–1.73)
Retired	0.98 (0.81–1.18)	1.09 (0.83–1.42)	1.04 (0.79–1.37)
Self-rated health			
Good	Ref.	Ref.	Ref.
Poor	1.26*** (1.15–1.38)	1.11 (0.97–1.27)	1.49*** (1.32–1.68)
ADL difficulty			
No	Ref.	Ref.	Ref.
Yes	1.18** (1.07–1.30)	1.18* (1.03–1.37)	1.27*** (1.11–1.45)
IADL difficulty			
No	Ref.	Ref.	Ref.
Yes	1.16*** (1.07–1.27)	1.21** (1.06–1.37)	1.14* (1.00–1.28)
MPCE quintile			
Poorest	Ref.	Ref.	Ref.
Poorer	1.20** (1.07–1.35)	1.25* (1.04–1.50)	1.10 (0.93–1.30)
Middle	1.10 (0.97–1.24)	1.27* (1.05–1.52)	1.10 (0.93–1.31)
Richer	1.30*** (1.15–1.47)	1.53*** (1.27–1.84)	1.25* (1.05–1.49)
Richest	1.29*** (1.13–1.46)	1.67*** (1.37–2.02)	1.22* (1.02–1.46)
Religion			
Hindu	Ref.	Ref.	Ref.
Muslim	0.84** (0.74–0.96)	0.92 (0.76–1.10)	0.92 (0.77–1.10)
Others	1.18** (1.04–1.34)	0.91 (0.75–1.11)	1.47*** (1.24–1.74)
Caste			
SC/ST	Ref.	Ref.	Ref.
OBC	1.19*** (1.07–1.31)	1.05 (0.91–1.22)	1.31*** (1.14–1.51)
Others	1.16** (1.04–1.30)	1.06 (0.90–1.24)	1.22* (1.04–1.42)
Place of residence			
Urban	Ref.	Ref.	Ref.
Rural	1.22*** (1.11–1.33)	1.13 (0.99–1.30)	1.28*** (1.12–1.46)
Region			
North	Ref.	Ref.	Ref.
Central	1.24** (1.08–1.42)	1.26* (1.03–1.55)	1.39*** (1.15–1.69)
East	1.55*** (1.37–1.75)	1.64*** (1.37–1.97)	1.42*** (1.18–1.70)
Continued			

Variables	Fall aOR (95% CI)	Fall-injury aOR (95% CI)	Multiple falls aOR (95% CI)
Northeast	0.64*** (0.54–0.75)	0.61*** (0.46–0.79)	0.66*** (0.52–0.85)
West	0.82** (0.72–0.93)	0.69*** (0.56–0.84)	1.01 (0.84–1.21)
South	1.37*** (1.20–1.57)	1.55*** (1.29–1.88)	1.28* (1.05–1.55)

Table 3. Multivariable logistic regression estimates of fall, fall-injury and multiple falls by socioeconomic and health characteristics among older adults. Notes: *if p-value < 0.05, ** if p-value < 0.005, *** if p-value < 0.001; aOR: adjusted Odds Ratio; ADL: Activities of daily living; IADL: Instrumental activities of daily living; MPCE: Monthly per capita consumption expenditure.

	Fall aOR (95% CI)	Fall-injury aOR (95% CI)	Multiple falls aOR (95% CI)
Sleep problems			
Total effect	1.54*** (1.40–1.70)	1.60*** (1.39–1.84)	1.53*** (1.34–1.75)
Direct effect	1.43*** (1.30–1.58)	1.50*** (1.30–1.73)	1.41*** (1.24–1.62)
Indirect effect via pain	1.08*** (1.06–1.09)	1.07*** (1.05–1.08)	1.08*** (1.06–1.10)
PEM (in %)	17.10	13.56	18.78

Table 4. Direct and indirect effects of sleep problems on falls, fall-related injuries, and multiple falls. Notes: aOR: OR adjusted for age, sex, education, marital status, living arrangements, self-rated health, ADL/IADL difficulty, MPCE quintiles, religion, caste, place of residence and regions; PEM: Percent of effect mediated.

Lastly, developing educational programs and providing appropriate facilities such as several forms of care-giving assistance for disabled senior citizens in the neighbourhood might be some cost-effective interventions to also consider implementing.

Data availability

The study uses secondary data which is available on reasonable request through https://www.iipsindia.ac.in/content/lasi-wave-i. The data are also available at The Gateway to Global Aging Data https://www.g2aging.org/

References

1. Williams, J. S. *et al.* Prevalence, risk factors and disability associated with fall-related injury in older adults in low-and middle-income countries: Results from the WHO Study on global AGEing and adult health (SAGE). *BMC Med.* **13**, 1–12 (2015).
2. Hartholt, K. A. *et al.* Mortality from falls among US adults aged 75 years or older, 2000–2016. *JAMA* **321**, 2131–2133 (2019).
3. James, S. L. *et al.* The global burden of falls: Global, regional and national estimates of morbidity and mortality from the Global Burden of Disease Study. *Inj. Prev.* **2019**, 3–11 (2017).
4. Mathers, C. *The global burden of disease: 2004 update.* World Health Organization, 2008.
5. Fuller, G. F. Falls in the elderly. *Am. Fam. Physician* **61**, 2159 (2000).
6. Stevens, J. A. & Sogolow, E. D. Gender differences for non-fatal unintentional fall related injuries among older adults. *Inj. Prev.* **11**, 115–119 (2005).
7. Kim, T., Choi, S. D. & Xiong, S. Epidemiology of fall and its socioeconomic risk factors in community-dwelling Korean elderly. *PLoS ONE* **15**, e0234787 (2020).
8. Yeung, S. S. *et al.* Sarcopenia and its association with falls and fractures in older adults: A systematic review and meta-analysis. *J. Cachexia Sarcopenia Muscle* **10**, 485–500 (2019).
9. Wen, Y. *et al.* Risk of falls in 4 years of follow-up among Chinese adults with diabetes: Findings from the China Health and Retirement Longitudinal Study. *BMJ Open* **11**, e043349 (2021).
10. Muhammad, T., Maurya, P. & Sharma, P. Prevalence and correlates of bone and joint diseases and its association with falls among older adults in India: Evidence from LASI, 2017–18. *Geriatr. Nur. (Lond)* **42**, 1143–1150 (2021).
11. Essien, S. K. *et al.* Sleep duration and sleep disturbances in association with falls among the middle-aged and older adults in China: A population-based nationwide study. *BMC Geriatr.* **18**, 1–14 (2018).
12. Hill, E. L. *et al.* Sleep disturbances and falls in older people. *J. Gerontol. A Biol. Sci. Med. Sci.* **62**, 62–66 (2007).
13. Immonen, M. *et al.* Association between chronic diseases and falls among a sample of older people in Finland. *BMC Geriatr.* **20**, 1–12 (2020).
14. Min, Y. & Slattum, P. W. Poor sleep and risk of falls in community-dwelling older adults: A systematic Review. *J. Appl. Gerontol.* **37**, 1–26 (2018).
15. Krishnaswamy, B., and Gnanasambandam Usha. Falls in older people: national/regional review India. *Chennai: Madras Medical College and Government.* 1-9 (2006).
16. Stubbs, B. *et al.* Pain and the risk for falls in community-dwelling older adults: Systematic review and meta-analysis. *Arch. Phys. Med. Rehabil.* **95**, 175–187 (2014).
17. Chakravorty, S., Goli, S. & James, K. S. Family demography in India: Emerging patterns and its challenges. *SAGE Open* https://doi.org/10.1177/21582440211008178 (2021).

18. Williams, J.-S. *et al.* Prevalence, risk factors and disability associated with fall-related injury in older adults in low- and middle-incomecountries: Results from the WHO Study on global AGEing and adult health (SAGE). *BMC Med.* **13**, 1–12 (2015).
19. Chaudhary, M., & Selvamani, Y. Association between back pain and subjective health, wellbeing and sleep problems among older adults in six middle-income countries: A cross-sectional study. *J Public Health* 1–10 (2021).
20. Muhammad, T., & Rashid, M. Prevalence and correlates of pain and associated depression among community-dwelling older adults: Cross-sectional findings from LASI, 2017–2018. *Depress Anxiety*.
21. Bloom, D. E., Sekher, T. V. & Lee, J. Longitudinal Aging Study in India (LASI): New data resources for addressing aging in India. *Nat. Aging* **1**, 1070–1072 (2021).
22. Jenkins, C. D. *et al.* A scale for the estimation of sleep problems in clinical research. *J. Clin. Epidemiol.* **41**, 313–321 (1988).
23. Cho, E. & Chen, T.-Y. The bidirectional relationships between effort-reward imbalance and sleep problems among older workers. *Sleep Health* **6**, 299–305 (2020).
24. Jenkins, C. D., Stanton, B.-A. & Jono, R. T. Quantifying and predicting recovery after heart surgery. *Psychosom. Med.* **56**, 203–212 (1994).
25. Kumari, M. *et al.* Self-reported sleep duration and sleep disturbance are independently associated with cortisol secretion in the Whitehall II study. *J. Clin. Endocrinol. Metab.* **94**, 4801–4809 (2009).
26. Lallukka, T., Dregan, A. & Armstrong, D. Comparison of a sleep item from the general health questionnaire-12 with the Jenkins sleep questionnaire as measures of sleep disturbance. *J. Epidemiol.* **21**, 474–480 (2011).
27. Kudielka, B. M. *et al.* Effort-reward imbalance, overcommitment and sleep in a working population. *Work Stress* **18**, 167–178 (2004).
28. Fabbri, M. *et al.* Measuring subjective sleep quality: A review. *Int. J. Environ. Res. Public Health* **18**, 1082 (2021).
29. Salman, M., Khan, A. H., Sulaiman, S. A. S. *et al.* Psychometric validation of the Urdu version of the Jenkins sleep evaluation questionnaire. *J. Pharm. Pract. Community Med.* **4**(1), 4–6 (2018).
30. Srivastava, S. & Muhammad, T. Violence and associated health outcomes among older adults in India: A gendered perspective. *SSM Popul. Health* **12**, 100702 (2020).
31. Muhammad, T. & Srivastava, S. Why rotational living is bad for older adults? Evidence from a cross- sectional study in India. *J. Popul. Ageing* https://doi.org/10.1007/s12062-020-09312-4 (2020).
32. Zacharias, A. & Vakulabharanam, V. Caste stratification and wealth inequality in India. *World Dev.* https://doi.org/10.1016/j.worlddev.2011.04.026 (2011).
33. Aiken, L. S., West, S. G., & Pitts, S. C. Multiple linear regression. *Handb. Psychol.* 2003; 481–507.
34. Karlson, K. B. & Holm, A. Decomposing primary and secondary effects: A new decomposition method. *Res. Soc. Stratif. Mobil.* **29**, 221–237 (2011).
35. Karlson, K. B., Holm, A. & Breen, R. Comparing regression coefficients between same-sample nested models using logit and probit: A new method. *Sociol. Methodol.* **42**, 286–313 (2012).
36. Selvamani, Y., Arokiasamy, P. & Chaudhary, M. Association of sleep problems and sleep duration with self-rated health and grip strength among older adults in India and China: Results from the study on global aging and adult health (SAGE). *J. Public Health* **26**, 697–707 (2018).
37. Muhammad, T., Gharge, S. & Meher, T. The associations of BMI, chronic conditions and lifestyle factors with insomnia symptoms among older adults in India. *PLoS ONE* **17**, e0274684 (2022).
38. Koyanagi, A. *et al.* Chronic conditions and sleep problems among adults aged 50 years or over in nine countries: A multi-country study. *PLoS ONE* **9**, 1–17 (2014).
39. Morelhão, P. K. *et al.* Can sleep problems have a negative impact on falls in older people?. *J. Clin. Sleep Med.* **14**, 1821 (2018).
40. Welsh, V. K. *et al.* Multisite pain and self-reported falls in older people: Systematic review and meta-analysis. *Arthritis Res. Ther.* **21**, 1–8 (2019).
41. Leveille, S. G. *et al.* Chronic musculoskeletal pain and the occurrence of falls in an older population. *JAMA J. Am. Med. Assoc.* **302**, 2214–2221 (2009).
42. Stubbs, B. *et al.* Pain is associated with recurrent falls in community-dwelling older adults: Evidence from a systematic review and meta-analysis. *Pain Med.* **15**, 1115–1128 (2014).
43. Altintas, H.-K. & Aslan, G.-K. Incidence of falls among community-dwelling older adults in Turkey and its relationship with pain and insomnia. *Int. J. Nurs. Pract.* **25**, 1–9 (2019).
44. Jehu, D. A. *et al.* Risk factors for recurrent falls in older adults: A systematic review with meta-analysis. *Maturitas* **144**, 23–28 (2021).
45. Kabeshova, A. *et al.* Falling in the elderly: Do statistical models matter for performance criteria of fall prediction? Results from two large population-based studies. *Eur. J. Intern. Med.* **27**, 48–56 (2016).
46. Pitchai, P. *et al.* Prevalence, risk factors, circumstances for falls and level of functional independence among geriatric population—A descriptive study. *Indian J. Public Health* **63**, 21–26 (2019).
47. Sasidharan, D. K. *et al.* Incidence and risk factors for falls among community-dwelling elderly subjects on a 1-year follow-up: A prospective cohort study from Ernakulam, Kerala, India. *BMJ Open* **10**, 1–9 (2020).
48. Kaur, R. *et al.* Burden of falls among elderly persons in India: A systematic review and meta-analysis. *Natl. Med. J. India* **33**, 195–200 (2020).
49. Crowley, K. Sleep and sleep disorders in older adults. *Neuropsychol. Rev.* **21**, 41–53 (2011).
50. Gambhir, I. S. *et al.* Insomnia in the elderly—A hospital-based study from North India. *J. Clin. Gerontol. Geriatr.* **5**, 117–121 (2014).
51. Dahale, A. B. *et al.* Insomnia Among Elderly Primary Care Patients in India. *Prim. Care Companion CNS Disord.* https://doi.org/10.4088/PCC.19m02581 (2020).
52. Hill, E. L. *et al.* Sleep disturbances and falls in older people. *J. Gerontol. Ser. Biol. Sci. Med. Sci.* **62**, 62–66 (2007).
53. Min, Y., Nadpara, P. A. & Slattum, P. W. The association between sleep problems, sleep medication use, and falls in community-dwelling older adults: Results from the health and retirement study 2010. *J. Aging Res.* **2016**, 1–10 (2016).
54. Stone, K. L. *et al.* Sleep disturbances and risk of falls in older community-dwelling men: The outcomes of Sleep Disorders in Older Men (MrOS Sleep) Study. *J. Am. Geriatr. Soc.* **62**, 299–305 (2014).
55. Noh, J. W. *et al.* Association between sleep duration and injury from falling among older adults: A cross-sectional analysis of Korean community health survey data. *Yonsei Med. J.* **58**, 1222–1228 (2017).
56. Li, Y. *et al.* Independent and synergistic effects of pain, insomnia, and depression on falls among older adults: A longitudinal study. *BMC Geriatr.* **20**, 1–9 (2020).
57. Cai, Y. *et al.* chronic pain and risk of injurious falls in community-dwelling older adults. *J. Gerontol. Ser. A* **76**, e179–e186 (2021).
58. Marshall, L. M. *et al.* A prospective study of back pain and risk of falls among older community-dwelling men. *J. Gerontol. Ser. A* **72**, 1264–1269 (2017).
59. Byun, M., Kim, J. & Kim, M. Physical and psychological factors affecting falls in older patients with arthritis. *Int. J. Environ. Res. Public Health* https://doi.org/10.3390/ijerph17031098 (2020).
60. Park, J. II., Yang, J. C. & Chung, S. Risk factors associated with the fear of falling in community-living elderly people in Korea: Role of psychological factors. *Psychiatry Investig.* **14**, 894–899 (2017).
61. Finan, P. H., Goodin, B. R. & Smith, M. T. The association of sleep and pain: An update and a path forward. *J. Pain* **14**, 1–24 (2013).

62. Drewes, A. M. *et al.* A longitudinal study of clinical symptoms and sleep parameters in rheumatoid arthritis. *Rheumatology* **39**, 1287–1289 (2000).
63. Schrimpf, M. *et al.* The effect of sleep deprivation on pain perception in healthy subjects: A meta-analysis. *Sleep Med.* **16**, 1313–1320 (2015).
64. Yokoya, T., Demura, S. & Sato, S. Relationships between physical activity, ADL capability and fall risk in community-dwelling Japanese elderly population. *Environ. Health Prev. Med.* **12**, 25–32 (2007).
65. Gale, C. R., Cooper, C. & Aihie, S. A. Prevalence and risk factors for falls in older men and women: The English Longitudinal Study of Ageing. *Age Ageing* **45**, 789–794 (2016).
66. Masud, T. & Morris, R. O. Epidemiology of falls. *Age Ageing* **30**, 3–7 (2001).
67. Goswami, A. *et al.* Health problems and health seeking behaviour of the rural aged. *Indian J. Gerontol.* **19**, 163–180 (2005).
68. Gillespie, L. D., Robertson, M. C., & Gillespie, W. J., *et al.* Interventions for preventing falls in older people living in the community. *Cochrane Database Syst. Rev.* **9** (2012).
69. Bhat, P. & Walia, S. Effects of task oriented balance training program with or without altered sensory input on balance and functional performance in community dwelling older adults. *Indian J. Physiother. Occup. Ther.* **4**, 112 (2010).
70. Jahagirdar, S. S., & Kenkre, I. R. Training elderly for mobility and strength using EMG-biofeedback and SWISS ball/peanut ball exercises. *Indian J. Occup. Ther. Indian J. Occup. Ther.* **42**, 1 (2010).
71. Choudhary, N. & Mohammad, S. Effect of joint mobilization, strengthening and stretching of ankle on balance in elderly. *J. Indian Acad. Geriatr.* **7**, 150–153 (2011).

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Author contributions

Conceived and designed the research paper: T.M. and Y.S.; analyzed the data: T.M.; Wrote the manuscript: T.M., U.K., P.M. and Y.S.; Refined the manuscript: U.K., T.M., P.M. and Y.S. All authors reviewed the manuscript. All authors have read and approved the manuscript.

Competing interests

The authors declare no competing interests.

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