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Influences of Social Disengagement and Depressive Symptom on Sleep Disturbance in Dementia Caregiving Dyads: A Nationally Representative Study

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Abstract:	Objectives To examine the influence of social disengagement and depressive symptoms on sleep disturbance among dementia caregiving dyads and the actor-partner interdependence nature of these influences. Design Actor-partner interdependence model through structural equation modeling for dyadic analyses. Setting and Participants 310 dyads of older adults with dementia and their care partners from two national representative studies in the United States, the National Health and Aging Trends Study (NHATS) and it's companion study, the National Study of Caregiving (NSOC). Methods Data from the NHATS Round 11 and NSOC IV were analyzed using descriptive statistics, Pearson correlation analysis, and the actor-partner interdependence model. Structural equation modeling was utilized to assess the mediation effects of depressive symptoms within the actor-partner interdependence models. Results In the actor model of caregivers, social disengagement had a direct impact on sleep disturbance (β=0.49, p<.001) and an indirect impact through depressive symptoms (β=0.25, p<.001). In the actor model of older adults with dementia, social disengagement only had an indirect effect on sleep disturbance through depressive symptoms. In partner models, caregivers' social disengagement directly influenced their care partners' depressive symptoms (β=0.20, p=.019), which subsequently affected caregiver's sleep disturbance (β=0.17, p<.001). Social disengagement (β=0.17, p=.001) and depressive symptoms (β=0.17, p<.001) in older adults with dementia directly impacted their caregivers' sleep disturbance. Depressive symptoms of older adults served as multiple mediators linking one member's social

	disengagement to both their own and partner’s sleep. Conclusions and Implications The sleep disturbance of caregivers may be directly influenced by the social disengagement and depressive symptoms exhibited by both members of the dyad, whereas the sleep disturbance experienced by older adults with dementia can only be indirectly influenced by the dyad’s social disengagement via their own depressive symptoms. Dyadic social activities targeting depressive symptoms could be designed to address sleep disturbances in dementia caregiving dyads.

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Running title

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Key words

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Influences of Social Disengagement and Depressive Symptom on Sleep Disturbance in Dementia Caregiving Dyads: A Nationally Representative Study

Abstract

Objectives: To examine the influence of social disengagement and depressive symptoms on sleep disturbance among dementia caregiving dyads and the actor-partner interdependence nature of these influences.

Design: Actor-partner interdependence model through structural equation modeling for dyadic analyses.

Setting and Participants: 310 dyads of older adults with dementia and their care partners from two national representative studies in the United States, the National Health and Aging Trends Study (NHATS) and its companion study, the National Study of Caregiving (NSOC).

Methods: Data from the NHATS Round 11 and NSOC IV were analyzed using descriptive statistics, Pearson correlation analysis, and the actor-partner interdependence model. Structural equation modeling was utilized to assess the mediation effects of depressive symptoms within the actor-partner interdependence models.

Results: In the model of caregivers, social disengagement had a direct impact on sleep disturbance (β=0.49, $p<.001$) and an indirect impact through depressive symptoms (β=0.25, $p<.001$). In the model of older adults with dementia, social disengagement only had an indirect effect on sleep disturbance through depressive symptoms. In models examining partner effects, caregivers' social disengagement directly influenced their care partners' depressive symptoms (β=0.20, $p=.019$), which subsequently affected caregiver's sleep disturbance (β=0.17, $p<.001$). Social disengagement (β=0.17, $p=.001$) and depressive

symptoms (β=0.17, p<.001) in older adults with dementia directly impacted their caregivers' sleep disturbance. Depressive symptoms of older adults with dementia served as multiple mediators linking one member's social disengagement to both their own and partner's sleep.

Conclusions and Implications: This study represents one of the first attempts to investigate the influencing mechanism of sleep disturbances among older adults with dementia and their informal caregivers through a dyadic perspective. The sleep disturbance of caregivers may be directly influenced by the social disengagement and depressive symptoms exhibited by both members of the dyad, whereas the sleep disturbance experienced by older adults with dementia can only be indirectly influenced by the dyad's social disengagement via their own depressive symptoms. Dyadic social activities targeting depressive symptoms could be designed to address sleep disturbances in dementia caregiving dyads.

Keywords: dementia; dyad; social disengagement; depressive symptoms; sleep disturbance

Introduction

Sleep disturbances, characterized by difficulty falling asleep, interrupted sleep, and multiple nightly awakenings are frequently reported among dyads of individuals with dementia and their caregivers [1]. Specifically, caregivers of people with dementia were 2.8 times more likely to report poor sleep than non-dementia caregivers [2]. Sleep disturbance is associated with many negative outcomes, such as decreased daily activity and impaired nocturnal reduction of blood pressure in people with dementia [3], and exacerbated mental, physical and cognitive decline for dementia caregivers [1]. These disturbances are also associated with increased caregiver burden and a greater likelihood of nursing home placement for the care recipient [4]. Although it is commonly assumed that sleep problems of caregivers are associated with the care-recipient's nighttime behaviors, discrepancies in this assumption have been reported [5, 6]. A nationwide population-based study revealed that sleep disturbance may occur in both members of the dementia caregiving dyad, irrespective of their cohabitation status [7]. Therefore, an individual's sleep may not be the primary factor affecting the other's sleep within the caregiving dyad. Consequently, it is crucial to identify other influential factors to facilitate the development of effective interventions to enhance dyadic sleep quality.

Engaging in social activities, such as visiting friends and going out for enjoyment, is widely recognized for its stress-buffering effects, which are known to alleviate sleep disturbances [8]. The social participation model proposed by Douglas [9] posits that successful aging, including individuals with dementia and caregivers, can be indicated by social participation, which includes social connections, informal social participation, and volunteering. However, individuals with dementia and their informal caregivers often

experience social disengagement and isolation due to cognitive decline and societal stigma [10]. Social disengagement refers to the withdrawal from the roles and disengagement from social networks [11]. Specifically in this study, it means the reduction or absence of participation in valued social activities caused by health/caregiving responsibilities, such as visiting family and friends and; participating in group activities [12]. A longitudinal study involving 639 older adults revealed that reduced social engagement was associated with an increased risk of sleep disturbances [13]. Nevertheless, the mechanism through which social disengagement influences sleep disturbance remains incompletely understood, particularly within the context of dementia caregiving.

The Activity Restriction Model posits that depression is the probable underlying mechanism driving this association [14]. According to this model, the degree to which a significant life stressor limits one's everyday activities influences their psychological adjustment. Specifically in this study, the impact of dementia on depressive symptoms may be influenced by the extent of social engagement restriction. Given that depression can deplete somatic resources, it may consequently influence sleep. Evidence showed that depressive symptoms frequently co-occur with sleep disturbances in dementia caregiving dyads [15, 16], and there was a significant correlation between social engagement and both depression [17] and sleep disturbances [8]. A longitudinal study has indicated that social engagement mitigates the risk of depression [18]. Additionally, depressive symptoms have been found to strongly predict the occurrence of sleep disturbances [19]. However, it remains untested whether depressive symptoms mediate the relationship between social disengagement and sleep disturbance.

It is also noteworthy that throughout the extensive caregiving journey, the dyads function as cohesive units, wherein the well-being of each member is reciprocally influenced by their individual and partner factors within their shared psychosocial context [20]. Our systematic review revealed the interdependence of social, psychological and health variables within dementia caregiving dyads. Specifically, both depressive symptoms in people with dementia and caregivers are not only influenced by their own factors; but also those of their partners [21]. However, there remains a scarcity of empirical studies that comprehensively examine this interdependence. The Actor-Partner Interdependence Model (APIM) offers a valuable approach to understanding the reciprocal influences between dyad members; for instance, the experiences and behaviors of one member of the dyad (e.g., a caregiver) can influence, and be influenced by, member (e.g., a care recipient) [21]. APIM allows joint modeling of partner effects (from one member to another) and actor effects (within the member him/herself), thereby facilitating the validation and refinement of theories about inter-dyadic relationships. In terms of sleep, empirical evidence has demonstrated that one partner's sleep can be affected by the other's social engagement or depressive symptoms [22, 23]. However, there remains limited understanding regarding the interdependent relationship between actors and partners within dementia caregiving dyads. Preliminary exploration has indicated that both actor and partner effects exist for depressive symptoms about the dyad's sleep disturbance, such as trouble falling back to sleep and interrupted sleep [19]. Nevertheless, it remains untested whether social disengagement exhibits both actor and partner effects and whether depressive symptoms mediate the association between social disengagement and sleep disturbance with both actor and partner effects. To address these questions, this study employed a nationally representative

sample of older adults with dementia and their primary care partners to test these hypotheses using an actor-partner interdependence model.

Aim

To examine the influence of social disengagement and depressive symptoms on sleep disturbances in older adults with dementia and their care partners and the actor-partner interdependence nature of these influences.

Hypothesis

(1) Social disengagement is positively associated with depressive symptoms and sleep disturbances in older adults with dementia and their informal caregivers, and depressive symptoms act as a mediator in the models examining actor effects.

(2) Social disengagement in one member of the dementia caregiving dyad is also positively associated with the partner's depressive symptoms and sleep disturbance, and depressive symptoms serve as a mediator in the models examining partner effects.

Methods

Study design

This study adopts a cross-sectional design and applies the actor-partner interdependence model (APIM) for analyzing dyadic data.

Data source

Data from the National Health and Aging Trends Study [24] and its companion study, the National Study of Caregiving (NSOC), were used for the analysis. NHATS conducts annual

in-person interviews with a nationally representative sample of Medicare beneficiaries aged 65 or older. Simultaneously, NSOC is a periodic survey that focuses on selected caregivers assisting NHATS participants in self-care, mobility, medical tasks, household activities, transportation, or medically oriented duties [25]. This study used the latest round of the NHATS, Round 11 (2021) older adult data, and the NSOC IV (2021) caregiver data; these data were collected in 2021. IRB approval is exempted for this analysis.

Sample

The study sample was restricted to older adults with dementia and their primary informal caregivers. Older adults with dementia who reside in nursing homes were excluded because they were primarily cared for by nursing home staff. In the NHATS, each person was assigned a unique Sample Person ID (SPID) that could be matched year-to-year across all surveys. The updated dementia classification code was utilized to classify NHATS participants into probable, possible, and no dementia categories. Probable dementia served as a common criterion for identifying individuals with dementia in this dataset [26]. Specifically, three types of information from NHATS were used to identify persons with dementia: (a) self-report or proxy report of a doctor's diagnosis of dementia or Alzheimer's disease; (b) an Eight-item Informant Interview to Differentiate Aging and Dementia (AD8) score of 2 or higher based on proxy respondent answers; or (c) scores at least 1.5 standard deviations below the mean in at least two cognitive domains assessed by items evaluating memory, orientation, and executive function [27]. Individuals meeting any of these criteria were considered to have probable dementia [26]. The NHATS definition exhibits a fair sensitivity (65.7%) and high specificity (100.0%) [28]. Among the 3818 NHATS participants

in Round 11, 3085 reside in the community, with 722 meeting the criteria for dementia according to the NHATS definition.

According to NHATS, each NSOC participant was assigned an Other Person ID (OPID) linked to SPID. Since each NHATS participant can have up to five unpaid caregivers participate in NSOC, the SPID is connected to OPID through a one-to-many join. We selected the primary caregiver for our analysis to ensure one-to-one data usage. Our definition of primary caregiver is based on their longest caregiving relationship with the NHATS participant, explicitly referring to the caregiver who provided care for the longest duration in years. In cases where multiple caregivers provided equal years of caregiving, the one who provided the most hours of care per day was selected [29]. Among 13311 informal caregivers screened in the NSOC dataset, 1209 were identified as primary caregivers. Subsequently, we matched the 1209 primary caregivers, encompassing caregivers of all older adults, with the 722 individuals with dementia. Because not all primary caregivers of people with dementia completed the questionnaires in Wave IV, we ultimately identified 310 dementia caregiving dyads for analysis.

Variables

Social disengagement was measured by five items assessing whether health/caregiving responsibilities hindered older adults/caregivers from engaging in social activities such as visiting family and friends, attending religious services, participating in group activities, going out for enjoyment, and volunteering. Participants were asked to indicate yes (1) or no (2) for each activity. The total score of these five activities was used to represent social disengagement in this study, with higher scores indicating greater levels of social disengagement.

Symptoms of depression were evaluated using the 2-item Patient Health Questionnaire (PHQ-2) [30] in NHATS and NSOC. Participants responded to two questions on a 4-point scale, assessing how often they experienced little interest or pleasure in doing things and felt down, depressed, or hopeless over the past month. The total score was calculated by summing item scores, with higher scores indicating more severe depressive symptoms.

Sleep disturbance was measured by sleep-related items, which were selected by comparing the questionnaire items from the dataset with those of the Pittsburgh Sleep Quality Index [31]. Three items were used to measure the sleep of older adults with dementia: frequency of taking more than 30 minutes to fall asleep, difficulty in falling back to sleep, and frequency of medication usage for improving sleep quality. Two items were used to measure caregiver's sleep disturbance: trouble falling back to sleep and interrupted sleep. The older adult with dementia and caregiver were asked to rate their sleep quality on a 5-point scale ranging from 1 (every night) to 5 (never). Previous studies have also employed this rating system within the same dataset [32]. The sleep disturbance scores were reversed such that higher scores indicate more severe sleep disturbance. The total score of the items was calculated to represent the sleep disturbance.

Demographics: The demographics of older adults with dementia included age, gender, race, educational level, marital status, pain, number of chronic illnesses, and self-rated health. Caregiver factors encompassed age, gender, marital status, education level, working for payment, race, relationship with the older adult with dementia, pain, number of chronic illnesses, self-rated health, and caregiving intensity.

Data analysis

Demographic data were presented as mean (standard deviation) for continuous variables and count (percentage) for nominal variables for older adults with dementia and caregivers. Pearson correlations were used to evaluate the associations between dyads. In this study, the APIM with distinguishable dyads with structural equation modeling is employed so that the relationship between older adults with dementia and caregivers is distinguishable. Traditional statistical approaches assume that caregivers and care recipients are independent, which is not the case in dyadic data where two individuals are inherently linked. The APIM is a statistical model that examines dyadic data and analyzes the interdependence and interrelationships between dyads. Within the APIM, the actor effect refers to how an individual's characteristics or behaviors influence their own outcomes, while the partner effect refers to how an individual's partner's characteristics or behaviors affect their outcomes. Our objective in utilizing the APIM model is to determine how social disengagement and depressive symptoms of both older adults with dementia and caregivers impact their own sleep disturbance (actor effect) as well as their partner's sleep disturbance (partner effect). Additionally, we assessed potential mediation effects within our APIM by examining whether social disengagement affects sleep disturbance through depressive symptoms as a mediator variable in the models examining both actor and partner effects.

All data analyses were conducted using R version 4.2.2, with a two-tailed α level set at less than 0.05 indicating statistical significance throughout our analysis process. The lavaan library in R version 4.2 was utilized for fitting the APIM model, while standard error estimates and 95% confidence intervals of direct effects and mediation effects within our APIM were obtained via bootstrapping with a sample size of 5000 replications. Goodness

of fit of the model was evaluated by the comparative fit index (CFI) (acceptable fit ≥ 0.90), χ^2/df (acceptable fit < 3), and the root mean square error of approximation (RMSEA) (acceptable fit ≤ 0.08). To enhance the robustness of our research findings, we also adjusted for pain and number of chronic illnesses as covariates in the APIM to ensure that they did not confound the actor and partner effects estimates.

Results

Characteristics of the dyads

The descriptive statistics for the dyads are displayed in Table 1. The average age for older adults with dementia was 86.8 (SD, 5.8), while that for informal caregivers was 63.4 (SD, 14.1). A majority of both older adults with dementia (67.7%) and their informal caregivers (71%) were female. Daughters constituted the largest proportion of caregivers at 47.7%, followed by spouses (21.3%), other relatives (16.1%), and sons (14.8%). In addition, 67.4% of the informal caregivers and 58.1% of the older adults with dementia were White; in contrast, Black individuals accounted for 30.65% of caregivers and 30.3% of older adults with dementia. On average, the outcome variables indicated greater severity of social disengagement, depressive symptoms, and sleep disturbance among older adults with dementia than their care partners.

[Please insert Table 1 here]

Association between the study variables

Table 2 displays the correlations between dyadic members. The social disengagement of older adults with dementia exhibits a positive correlation with their own depressive symptoms and sleep disturbance, as well as the sleep disturbance of their care partner.

Additionally, the depressive symptoms of older adults with dementia are significantly associated with both their own and their care partner's sleep disturbance. Furthermore, caregivers' social disengagement is significantly associated with both their own and care partners' depressive symptoms and sleep disturbance. However, there is no significant association between the caregiver's depressive symptoms and their care partner's sleep disturbance.

[Please insert Table 2 here]

The actor-partner interdependence model

The APIM analysis was examined to investigate the dyadic mediated effects of social disengagement and depressive symptoms on sleep disturbance. The model demonstrated an acceptable fit (RMSEA=0.06, CFI=0.98 and χ^2/df=2.07) (Figure 1). In the models examining actor effects, the direct effect of social disengagement on sleep disturbance in caregivers was found to be statistically significant (β=0.49, p<.001). Additionally, the mediation effects of depressive symptoms between social disengagement and sleep disturbance in both caregivers (β=0.20, p=.001 and β =0.25, p<.001) and older adults with dementia (β =0.28, p<.01 and β =0.50, p<.001) were also significant. In the models examining partner effects, a statistically significant direct effect was observed between the social disengagement of older adults with dementia and sleep disturbance in caregivers (β=0.17, p=.001). Additionally, depressive symptoms of older adults with dementia mediated the relationship between social disengagement of older adults with dementia and caregiver sleep disturbance (β=0.28, p<.001 and β=0.17, p<.001). Furthermore, depressive symptoms of older adult with dementia mediated the relationship between caregiver's social disengagement and sleep disturbance (β=0.20, p=.019 and β=0.17, p<.001), as well

as the relationship between caregiver's social disengagement and the sleep disturbance of older adults with dementia (β=0.20, p=.019 and β=0.50, p<.001). Table 3 presents the path coefficients of the APIM model. Adjusting for pain and the number of chronic illnesses of both members of the dyad as covariates did not alter the significance of these paths in the APIM (Supplementary Figure 1, Supplementary Table 1).

[Please insert Figure 1, Table 3 here]

Discussion

Utilizing a nationally representative sample, this study represents one of the pioneering attempts to investigate the psychosocial factors associated with sleep disturbance in dementia caregiving dyads. Our findings illuminate the intricate interplay between older adults with dementia and their informal caregivers regarding how social disengagement and depressive symptoms influence the dyad's sleep. This comprehension is pivotal for developing efficacious interventions for ameliorating sleep disturbances in these dyads.

The findings demonstrate the actor effects of social disengagement and depressive symptoms on sleep disturbance, in line with the Activity Restriction Model [14]. Moreover, the results reveal that depressive symptoms act as a significant mediator through which social disengagement affects one's sleep disturbance. This may be attributed to the emotional processes of the human brain, whereby social disengagement can trigger a stress response in the body, increasing vulnerability to depression and disrupting sleep patterns [33]. Another possible explanation is that depression alters sleep architecture by exacerbating feelings of sadness and hopelessness associated with social disengagement [34].

The partner effects underscore the interdependence of well-being within dyads. The findings suggest that caregiver social engagement plays a pivotal role, exerting a profound

impact on the depressive symptoms of older adult with dementia and consequently influencing both partners' sleep disturbance. This may be attributed to the fact that socially disengaged informal caregivers often face limited access to emotional and practical support from family, friends, and community resources. Consequently, feelings of isolation and helplessness are exacerbated, leading to more severe depressive symptoms and poorer sleep quality [35]. Furthermore, caregiver social disengagement can trigger depressive symptoms in their care partners due to its potential consequences such as reduced respite for caregivers, heightened stress levels, increased burden, compromised caregiving abilities, ultimately exacerbating depressive symptoms among individuals with dementia [36].

Conversely, social disengagement in older adults with dementia can directly impact their partner's sleep disturbance. This may be due to the fact that socially disengaged older adults with dementia tend to nap more during the day, which disrupts their sleep-wake cycle and increases confusion and disorientation at night, ultimately affecting both individuals' sleep quality [37]. However, it is important to note that social disengagement does not significantly influence caregivers' depressive symptoms. It may be because these are primarily influenced by care recipient dependency levels and behavioral disturbances rather than social engagement [22].

Another noteworthy and innovative finding in this study is the multiple mediation role of depressive symptoms in older adults with dementia, suggesting that their depressive symptoms serve as a fundamental mechanism through which social disengagement influences both their own and their partner's sleep quality. This discovery underscores the significance of addressing depressive symptoms in interventions aimed at enhancing the

sleep quality of older adults with dementia, thereby potentially alleviating the detrimental impact of social disengagement on both partners' sleep quality.

Limitations and implications

Despite the significant findings identified in this study, several limitations warrant attention. Firstly, the use of cross-sectional data hinders the assumption of a time sequence and limits the ability to make causal inferences; Longitudinal studies are recommended to establish causality. Second, given that our sample mainly comprised Whites, generalizability to other ethnic/racial populations may be limited. More diverse samples are suggested for future research. Third, due to the complexity of selecting dyadic data and limited dyadic sample size, it is not applicable to use weights, stratification, or clustering variables to maintain the sample's representativeness, particularly in the context of dyadic studies. Hence, the sample may have been limited in its representativeness. In addition, the measure of sleep disturbance used in this study is a composite of self-reported items rather than objective measures, and there is a lack of information regarding daily sleeping hours. However, evidence suggests that self-reported questions can provide reliable measurements of sleep and closely align with objective assessments using actigraphy [38]; potential recall bias and measurement error cannot be ignored. Furthermore, this study's sleep disturbance measures were unable to differentiate between subtypes such as sleep-disordered breathing or insomnia; therefore, it is recommended for future research to employ more sophisticated measurements. Besides, due to the unavailability of living arrangement data, we could not explore the influence of living arrangements on the dyad's sleep disturbances. Since the modelling of actor, partner, direct and indirect effects and covariances constitutes to many parameters (~40) in the APIM but the sample size of black

subsamples is small (<120). We have tried to fit the APIM model only to the black subsamples. The model is nearly saturated and unreliable, with a zero RMSEA and CFI equal to 1. Therefore, the small sample size of black subsamples did not allow us to compare models with different subsamples. Another limitation is that the dementia stage was not measured in this study, which may have influenced social disengagement.

These findings have significant implications for research and practice in promoting social engagement among dementia caregiving dyads. Addressing depressive symptoms is crucial to enhance the effects of social engagement intervention on sleep disturbances. Group-based dyadic social activities, such as art interventions and interactive reading, have been shown to improve depressive symptoms significantly, and can be implemented to enhance sleep quality in dyads [39, 40]. Given the potential challenge of engaging both members in dyadic interventions, tailored activities are commended to enhance the engagement between individuals with dementia and their informal caregivers, thereby optimizing intervention effects [41].

Conclusions and Implications

The results confirm the association between social disengagement, depressive symptoms, and sleep disturbance in older adults with dementia and their caregivers. Depressive symptoms act as mediators between social disengagement and sleep disturbance in both members of the dyad. Furthermore, social disengagement and depressive symptoms in older adults with dementia can influence caregiver sleep disturbance, while social disengagement in caregivers can influence depressive symptoms in older adults with dementia. Additionally, the APIM model highlights that the depressive symptom of older adults with dementia plays a crucial role as a mediator through which one member's social

disengagement affects their own and their partner's sleep. Dyadic social activities targeting depressive symptoms could be designed to address sleep disturbances in dementia caregiving dyads.

Acknowledgments

Conflicts of interest

None declared.

Author contributions

SW and SHIL contributed to the study design and data acquisition. SHIL conducted the analysis, while SW, SHIL, XX, and ML interpreted the data. SW and XX acquired funding for this research. The initial draft of the manuscript was written by SW. ML, PW, WZ, and WM contributed to reviewing and editing the manuscript. All authors provided comments and approved the final submission of this manuscript.

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Table 1 Characteristics of informal caregivers and older adults with dementia

	Informal caregivers (n=310) Mean(±SD) or n (%)	Older adults with dementia (n=310) Mean(±SD) or n (%)
Age in years	63.4±14.1	86.8±5.8
Gender		
Male	90 (29.0%)	100 (32.3%)
Female	220 (71.0%)	210 (67.7%)
Marital status		
Married	199 (64.2%)	86 (27.7%)
Live with a partner	5 (1.6%)	7 (2.3%)
Separated	11 (3.5%)	2 (0.6%)
Divorce	36 (11.6%)	31 (10%)
Widowed	19 (6.3%)	172 (55.5%)
Never married	40 (12.9%)	12 (3.9%)
Education		
High school below	24 (7.7%)	103 (33.2%)
High school graduate	72 (23.2%)	86 (27.7%)
Vocational or associate	107 (34.5%)	57 (18.4%)
Bachelor’s degree or above	107 (34.5%)	64 (20.6%)
Working		
Yes	92 (30.0%)	
No	218 (70.0%)	
Race		
White	209 (67.4%)	180 (58.1%)
Black	95 (30.65%)	94 (30.3%)
Others	6 (1.94%)	36 (11.6%)
Relationship with people with dementia		
Spouse	66 (21.3%)	
Daughter	148 (47.7%)	

Son	46 (14.8%)	
Other relatives	50 (16.1%)	
Self-rated health		
Excellent	35 (11.3%)	13 (4.2%)
Very good	111 (35.8%)	59 (19.0%)
Good	96 (31.0%)	97 (31.3%)
Fair	52 (16.8%)	85 (27.4%)
Poor	16 (5.2%)	56 (18.1%)
No of hours of care to people with dementia (per day)	5.3±5.9	
Social disengagement	0.7±1.3	1.5±1.6
Symptoms of depression	3.2±1.4	4.0±2.0
Sleep disturbance	2.4±1.7	3.8±3.2
Suffering Pain (Last month)	174(56.1%)	167(53.8%)
Number of chronic illnesses	1.82±1.50	4.10±1.69

Table 2 Correlations between the total variable scores (n=310 dyads)

Variable	Social disengagement (oa)	Depressive symptoms (oa)	Sleep disturbance (oa)	Social disengagement (cg)	Depressive symptoms (cg)	Sleep disturbance (cg)
Social disengagement (oa)	1 (NA)	**0.27 (<.001)**	**0.17 (<.001)**	**0.23 (<.001)**	0.05 (.341)	**0.30 (<.001)**
Depressive symptoms (oa)	**0.27 (<.001)**	1 (NA)	**0.33 (<.001)**	**0.18 (<.001)**	**0.11 (.049)**	**0.34 (<.001)**
Sleep disturbance (oa)	**017 (<.001)**	**0.33 (<.001)**	1 (NA)	**0.20 (<.001)**	0.08 (.162)	**0.28 (<.001)**
Social disengagement (cg)	**0.23 (<.001)**	**0.18 (<.001)**	**0.20 (<.001)**	1 (NA)	**0.20 (<.001)**	**0.51 (<.001)**
Depressive symptoms (cg)	0.05 (.341)	**0.11 (.049)**	0.08 (.162)	**0.20 (<.001)**	1 (NA)	**0.31 (<.001)**
Sleep disturbance (cg)	**0.30 (<.001)**	**0.34 (<.001)**	**0.28 (<.001)**	**0.51 (<.001)**	**0.31 (<.001)**	1 (NA)

Note: The correlation is displayed as "r(p-value)", significant correlations (p-value < 0.05) are bolded. "oa": older adults with dementia, "cg": caregivers

Table 3 Path model of APIM for social disengagement, depressive symptoms and sleep disturbance

Path	*Beta*	*SE*	*z*	*p-value*	*Partial r*
From Disengagement (cg) to					
Depressive symptoms (cg)	0.20	0.06	3.42	.001	0.20
Sleep disturbance (cg)	0.49	0.06	8.12	<.001	0.40
Depressive symptoms (oa)	0.20	0.08	2.35	.019	0.14
From Disengagement (oa) to					
Sleep disturbance (cg)	0.17	0.05	3.37	.001	0.16
Depressive symptoms (oa)	0.28	0.07	4.08	<.001	0.23
From Depressive symptoms (cg) to					
Sleep disturbance (cg)	0.25	0.06	4.36	<.001	0.20
From Depressive symptoms (oa) to					
Sleep disturbance (cg)	0.17	0.04	4.06	<.001	0.20
Sleep disturbance (oa)	0.50	0.09	5.58	<.001	0.31

Note: "oa": older adults with dementia, "cg": caregivers, "Partial r": Partial Corr. (Effect size)

Descriptive figure legends

- **Figure 1** Path diagram of APIM between disengagement, depressive symptoms and sleep disturbance

Notes: "oa": older adults with dementia, "cg": caregivers, RMSEA = 0.06, CFI = 0.98, χ^2/df = 2.07. The solid line indicates a significant effect; the dotted line indicates an insignificant effect.

Descriptive legends for all supplemental material

- **Supplementary Figure 1** Path diagram of APIM between disengagement, depressive symptoms and sleep disturbance controlling for pain and number of chronic illnesses

Notes: "oa": older adults with dementia, "cg": caregivers, RMSEA = 0.04, CFI = 0.97, χ^2/df = 1.50. The solid line indicates a significant effect; the dotted line indicates an insignificant effect.

- **Supplementary Table 1** Path model of APIM for social disengagement, depressive symptoms and sleep disturbance controlling for pain and number of chronic illnesses

Figure