

Objective Measures of Sleep Quality and Associations with Cognition in Assisted Living Residents: Comparison with Community Dwelling Residents.

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Abstract

Study Objectives: Sleep and its associations with cognition have been examined in community dwelling and long-term care populations but remain poorly characterized in assisted living (AL) residents. The validity of common sleep measures in this group also warrants further investigation.

Methods: We assessed sleep and cognition in a prospective observational cohort of 26 AL residents and a retrospective cohort of 125 community dwelling residents. Sleep was measured with polysomnography (PSG), actigraphy, and subjective questionnaires. Agreement between sleep recording methods was evaluated with paired t-tests. Group differences were examined using t-tests and adjusted with linear and logistic regression. Associations between sleep and cognition were assessed using interaction models.

Results: AL residents were older, had less years of education, and lower Montreal Cognitive Assessment scores. After covariate adjustment, AL residents reported shorter total sleep time; exhibited greater wake after sleep onset (WASO), lower sleep efficiency, and a greater periodic limb movement index. Mean differences for WASO were 70.8 minutes among AL residents and 60.7 minutes among community dwelling residents while the mean difference in number of awakenings was 17.9 for AL residents vs. 13.5 in community dwelling residents. Actigraphy derived WASO demonstrated more negative associations with Hopkins Verbal Learning Test-Revised (HVLT-R) total recall ($\beta = -0.022$, $p = .045$) and delayed recall ($B = -0.024$, $p = .001$) among AL residents relative to community-dwelling participants. More actigraphy-derived awakenings were also associated with more negative associations with MoCA, HVLT-R total and delayed recall, and Brief Visuospatial Memory Test-Revised delayed recall ($\beta -0.092$ to -0.048 ; $p = .001-.042$).

Conclusions: AL residents experience shorter sleep duration and more sleep disruption than community dwelling residents. Large mean differences between recording techniques highlight challenges in applying common sleep measures to this population.

Key Points

- Assisted living residents demonstrated more sleep disturbances than community dwelling controls.
- Actigraphy underestimates wake after sleep onset and number of awakenings, while overestimating total sleep time and sleep efficiency in assisted living residents.

Introduction

Sleep disturbances are more common with advancing age and are prevalent among residents of continuing care facilities ^{1,2}. Individuals in long-term care subjectively report high rates and severity of sleep complaints and exhibit poorer objective sleep quality compared to community dwelling residents ³.

⁴. These disruptions have been associated with poorer cognitive performance and increased risk of cognitive decline in vulnerable populations ^{5, 6}.

The proportion of the population requiring facility-based continuing care is growing. It is projected that the number of people requiring continuing care in Canada will increase from 380,000 in 2019 to 605,000 by 2031 ⁷. Facility-based continuing care in Canada includes settings such as long-term care (nursing homes) and assisted living (AL) (retirement homes; lodges). AL residents can be characterized as a population who need assistance with some higher level activities of daily living but who are largely independent ⁸.

Despite the growth of the AL population, sleep in this population remains poorly characterized in this setting. Existing studies have largely relied on subjective questionnaires or actigraphy, limiting the assessment of sleep architecture and sleep disorders ^{2, 9, 10}. Furthermore, it remains unclear whether previously established relationships between sleep and cognition in community-dwelling and long-term care populations are relevant for AL residents.

Compared with long-term care residents, AL residents are less likely to have cognitive impairment, medical instability, and dependency for activities of daily living ¹¹. Interventions may be more effective if implemented at this stage of the care continuum, while residents possess greater cognitive reserve, physical capacity, and greater independence ¹². Sleep represents a non-pharmacological target for intervention that remains relevant across all levels of functional status.

Sleep in AL may be assessed using subjective questionnaires, actigraphy, or polysomnography. However, agreement among these methods has not been characterized in AL residents ¹³. Furthermore, actigraphy derived measures of sleep cannot capture specific sleep disorders such as periodic limb movement (PLM) disorder or sleep apnea, both of which have been associated with poorer cognitive performance ^{14, 15}.

Our primary objective was to characterize sleep in AL residents compared to community dwelling older adults. Secondary objectives included examining if relationships between sleep and cognitive performance differed by living status and finally to assess agreement between PSG, actigraphy, and subjective sleep questionnaires within AL residents. We hypothesized that AL residents would exhibit poorer subjective and objective sleep than community-dwelling older adults ^{2, 10, 16, 17}. We further hypothesized that relationships between sleep and cognitive performance would differ according to living status. Based on previous studies of different populations, we expected limited agreement among sleep measurement methods given that they capture different aspects of sleep ^{18, 19}.

Methods

Study design

Participants were recruited from The Brenda Strafford Foundation continuing care sites and adult day programs through flyers and presentations. The comparison sample was drawn from the Brain in Motion II (BIM-II) study, which enrolled middle-aged to older adults as part of an ongoing randomized controlled trial on the effects of exercise on cognition in older adults²⁰. All participants completed a level 2 at-home PSG, wrist-worn actigraphy, sleep questionnaires, and cognitive assessments. Recruitment occurred in Calgary and Okotoks, Alberta.

Eligibility criteria

Eligibility for the AL sample included adults at least 60 years old, who were residents or clients of the Brenda Strafford Foundation continuing care communities, residing in AL, or were adult day program clients receiving supportive home care (Calgary & Okotoks, AB). Exclusion criteria for the AL sample were (1) a developmental disability; (2) impaired communication and no decision-making capacity, defined as a Cognitive Performance Scale score > 3; (3) terminal illness with life expectancy < 1 year; (4) limited English fluency; (5) current enrollment in another trial; (6) medical or neurological conditions that would interfere with cognitive assessment or trial completion (as judged by the site investigator); or (7) contraindications for study testing. Eligibility for the community dwelling resident sample have been described previously²⁰.

Measurements

Body mass index and sex

Body mass index (BMI) was acquired during anthropometric assessments and was calculated using weight (kg)/height (m)². Sex was collected as self-reported biological sex assigned at birth.

Medication

Participants self-reported all medications and supplements. Medications were categorized into drug classifications of cardiovascular and nervous system categories, which are known to affect sleep or cognition^{21, 22}. Additionally, medications were subcategorized into the sub-classes of beta-blockers, diuretics, calcium channel blockers, anti-depressants, and benzodiazepines or non-benzodiazepine hypnotics due to their potential effects on sleep or memory task performance^{21, 22}.

Cognitive assessments

Cognitive assessments were conducted by a trained research assistant. Participants were administered the Montreal Cognitive Assessment (MoCA), Hopkins Verbal Learning Test–Revised (HVLT-R), and Brief Visuospatial Memory Test–Revised (BVM-T-R). The MoCA is a short (10-minute) screening tool for the

detection of mild cognitive impairment with a sensitivity of 90% and specificity of 87%²⁵. Scores range from 0 to 30, with higher scores indicating better global cognitive performance. Both the HVLT-R and BVMT-R tests are sensitive to cognitive impairment, show high correlations with longer cognitive tests like the Rey Auditory Verbal Learning Test and Benton Visual Retention Task, despite being shorter (5–10 minutes for HVLT-R vs. 20–30 minutes for Rey Auditory Verbal Learning Test), and have large normative data sets^{23,24}. HVLT-R and BVMT-R raw total recall and delayed recall raw scores were converted to age and sex adjusted z-scores. The HVLT-R scores were scaled based on age, sex, and education, whereas the BVMT-R was scaled based on age and sex^{26–28}.

Sleep assessments

AL residents were instrumented with the Prodigy 2 sleep system (Cerebra Medical, Winnipeg) by a trained research technician one hour before their self-reported typical bedtime. The sleep recording was stopped and collected in the morning at the participants' self-reported wake time by a research assistant. Data collected from the PSG studies include traditional sleep stages (stage 1, stage 2, stage 3 sleep), measures of sleep disordered breathing (apnea hypopnea index (AHI)), sleep macro-architecture (total sleep time, sleep efficiency, and sleep onset latency). All sleep studies were scored according to the American Academy of Sleep Medicine guideline by a validated autoscoring algorithm with subsequent minor researcher adjustment to lights-on lights-off or exclusion of poor peripheral oxygen saturation (S_pO_2) traces^{29–31}.

AL residents wore a wrist-based actigraphy watch (Phillips Actiwatch spectrum 2) for seven days. Actigraphy data were processed using Phillips Actiware 6 analysis software, which provides automated sleep wake scoring. Researchers reviewed the autoscored files and adjusted sleep and wake times based on participants' subjective sleep diaries³². Extracted actigraphy parameters included average bedtime, wake time, sleep onset latency, sleep efficiency, time spent awake after sleep onset, total sleep time, and number of nighttime awakenings.

The subjective sleep questionnaire utilized was the Pittsburgh sleep quality index (PSQI). This instrument has 19 self-related questions that assess seven sleep domains: sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction. These sub-components are summed to produce a score out of 21, with larger scores indicating worse sleep quality. A global PSQI score above five is commonly used to indicate poor sleep quality³⁴.

[Insert Fig. 1 around here]

Statistical analyses

All statistical analyses were conducted in SPSS (v29.0.1.1). To examine differences in sleep characteristics between the groups, independent samples t-tests were used. Differences in categorical variables were examined using Pearson's chi-squared tests. P-values were adjusted using linear regression where the variable of interest was included as the outcome with age, education, MoCA score, AHI, PLM, usage of a neurological medication, and cardiovascular medication as covariates. The p-value of the living status variable was used as the adjusted p-value. Within each living status group, paired samples t-tests were used to examine mean differences between PSG and actigraphy or PSQI derived measurements.

To examine whether associations between sleep variables and cognitive performance differed by living status, a series of linear regression models were conducted which included the sleep variable, living status, and their interaction term (sleep variable $\times$ living status). All models were adjusted for age, years of education, AHI, PLM, and use of nervous system medication. Analyses were conducted in the full sample. Statistical significance was set to $p < 0.05$ for all tests.

Results

Participants

Twenty-six AL residents were recruited. A comparison sample of 125 community-dwelling residents was also included. Baseline characteristics by living status are shown in Table 1.

Table 1
Baseline Participant Characteristics by Living Status

Baseline Characteristics	Assisted Living Mean (SD) or Count (%)	Community Dwelling Mean (SD) or Count (%)	<i>p</i> - value	Adjusted <i>p</i> - value
Age (years)	80.1 (9.3)	63.5 (6.2)	< .001	< .001
Body Mass Index (kg/m ²)	27.2 (4.7)	28.7 (5.3)	.190	.287
Years of Education	14.12 (3.1)	17.0 (3.1)	< .001	.004
MoCA	22.3 (3.5)	27.0 (2.0)	< .001	.005
Pittsburgh Sleep Quality Index (PSQI) total	8.0 (3.5)	5.7 (3.5)	.001	.084
PSQI TST (minutes)	377.3 (73.6)	417.2 (66.4)	.007	.016
PSQI SE (%)	69.8 (13.3)	82.2 (14.9)	< .001	.054
PSQI SOL (minutes)	25.0 (26.5)	21.0 (26.6)	.484	.218
Sleep Study				
PSG				
TST (minutes)	328.4 (111.7)	344.0 (69.9)	.383	.910
Sleep Efficiency (%)	70.1 (10.4)	74.9 (10.9)	.061	.941
SOL (minutes)	16.6 (21.3)	32.0 (38.0)	.068	.818
WASO (minutes)	129.9 (68.4)	89.9 (55.8)	.003	.617
Awakenings	52.2 (22.3)	38.6 (17.6)	.002	.837
REM Latency (minutes)	187.6 (136.5)	111.2 (83.5)	< .001	.408
Stage 1 (%TST)	27.5 (14.7)	15.9 (9.7)	< .001	.888
Stage 2 (%TST)	52.2 (13.7)	55.9 (10.2)	.147	.675
Stage 3 (%TST)	13.8 (20.5)	11.7 (11.6)	.486	.173
Stage REM (%)	9.8 (8.0)	16.4 (7.4)	< .001	.686
AHI (events/hour)	37.1 (24.8)	24.0 (21.1)	.009	.098
PLM (events/hour)	34.7 (36.3)	10.8 (16.9)	< .001	.045
Average S_pO₂ (%)	89.5 (2.9)	92.0 (1.8)	< .001	.482
TST 90%	53.7 (32.0)	22.5 (25.2)	< .001	.519

Baseline Characteristics	Assisted Living Mean (SD) or Count (%)	Community Dwelling Mean (SD) or Count (%)	p- value	Adjusted p- value
<i>Actigraphy</i>				
TST (minutes)	428.2 (118.1)	432.5 (57.9)	.787	.025
SOL (minutes)	34.4 (39.2)	20.3 (14.5)	.002	.219
WASO (minutes)	63.1 (34.8)	29.2 (18.8)	< .001	.001
Sleep Efficiency (%)	77.2 (16.1)	86.7 (7.4)	< .001	< .001
Awakenings	34.4 (14.5)	25.2 (13.4)	.002	.430
Sex (% Female)	11 (42.3)	82 (65.6)	.026	.112
Cardiovascular medication (%)	18 (78.3)	60 (48.0)	.008	.706
Diuretic (%)	8 (34.8)	12 (9.6)	.001	.764
Beta-blocker (%)	4 (17.4)	4 (3.2)	.006	.682

Table 1
Continued.

Calcium channel blocker (%)	Assisted Living Mean (SD) or Count (%)	Community Dwelling Mean (SD) or Count (%)	p-value	Adjusted p- value
	5 (21.7)	10 (8.0)	.045	.239
Nervous system medication (%)	15 (65.2)	11 (8.8)	< .001	.006
<i>Benzodiazepine or Non- benzodiazepine (%)</i>	0 (0.0)	3 (2.4)	.453	.997
Antidepressant (%)	13 (56.5)	7 (5.6)	< .001	.251
Day program clients (%)	7 (27.0)			

Notes. Data are presented as mean (SD) or n (%). Unadjusted p-values for continuous variables were obtained using independent-samples Student's t-tests, and unadjusted p-values for categorical variables were obtained using Pearson's chi-square tests. Models adjusted for age, years of education, MoCA score, AHI, PLM index, cardiovascular medication use, and nervous system medication use. Medication data were unavailable for three supportive-living participants. MoCA scores range from 0–30 and PSQI scores range from 0–21. Bold values indicate $p < .05$. **Abbreviations:** AHI, apnea–hypopnea index; BMI, body mass index; MoCA, Montreal Cognitive Assessment; PLM, periodic limb movement index; PSG, polysomnography; PSQI, Pittsburgh Sleep Quality Index; REM, rapid eye movement; SOL, sleep-onset latency; SpO₂, peripheral oxygen saturation; TST, total sleep time; WASO, wake after sleep onset.

Table 2
Bias Between Sleep Measurements Separated by Living Status

Group	Outcome	Method	Mean (SD)	Mean Difference [95% CI]	p-value
Community Dwelling	TST	PSG	344.0 (69.8)		
		Actigraphy	432.5 (57.9)	-88.4 [-103.1, -73.7]	< .001
		PSQI	417.2 (66.4)	-73.2 [-91.1, -55.2]	< .001
	Sleep Efficiency	PSG	74.9 (10.9)		
		Actigraphy	86.7 (7.4)	-11.8 [-14.0, -9.6]	< .001
		PSQI	82.2 (14.9)	-7.3 [-10.8, -3.8]	< .001
	SOL	PSG	32.0 (38.0)		
		Actigraphy	20.1 (14.2)	11.9 [4.6, 19.1]	< .001
		PSQI	20.7 (26.5)	11.3 [2.8, 19.8]	.010
	WASO	PSG	89.9 (55.8)		
		Actigraphy	29.2 (18.8)	60.7 [50.8, 70.6]	< .001
	Awakenings	PSG	38.7 (17.6)		
		Actigraphy	25.2 (13.4)	13.5 [9.6, 17.3]	< .001
Assisted Living	TST	PSG	337.7 (105.4)		
		Actigraphy	429.2 (118.8)	-91.5 [-147.7, -35.3]	.003
		PSQI	373.6 (72.1)	-45.2 [-100.6, 10.1]	.104
	Sleep Efficiency	PSG	70.1 (10.7)		
		Actigraphy	77.0 (16.9)	-6.9 [-13.3, -0.5]	.036
		PSQI	70.9 (12.8)	-0.8 [-7.1, 5.6]	.805

Notes. Values are presented as mean (SD). In the community-dwelling group, analyses included n = 125 paired observations for TST, sleep efficiency, and wake after sleep onset, and n = 124 paired observations for SOL and awakenings. Assisted living data is from n = 21 participants with overlapping PSG and actigraphy data. Negative values indicate that actigraphy or PSQI overestimated compared to PSG. *p*-values were obtained from paired-samples t-tests comparing actigraphy and PSQI with PSG. Bold values indicate *p* < .05.

Group	Outcome	Method	Mean (SD)	Mean Difference [95% CI]	p-value
	SOL	PSG	17.2 (21.7)		
		Actigraphy	35.6 (41.9)	-18.5 [-40.6, 3.6]	.096
		PSQI	23.2 (23.8)	-6.6 [-22.9, 9.7]	.411
	WASO	PSG	133.7 (67.6)		
		Actigraphy	62.9 (34.0)	70.8 [40.9, 100.7]	< .001
	Awakenings	PSG	53.1 (22.4)		
		Actigraphy	35.2 (14.8)	17.9 [6.7, 29.0]	.003
<i>Notes.</i> Values are presented as mean (SD). In the community-dwelling group, analyses included n = 125 paired observations for TST, sleep efficiency, and wake after sleep onset, and n = 124 paired observations for SOL and awakenings. Assisted living data is from n = 21 participants with overlapping PSG and actigraphy data. Negative values indicate that actigraphy or PSQI overestimated compared to PSG. <i>p</i>-values were obtained from paired-samples t-tests comparing actigraphy and PSQI with PSG. Bold values indicate <i>p</i> < .05.					

Abbreviations: CI, confidence interval; PSG, polysomnography; PSQI, Pittsburgh Sleep Quality Index; SD, standard deviation; SOL, sleep-onset latency; TST, total sleep time; WASO, wake after sleep onset.

AL residents were older (mean $\pm$ SD; 80.1 ± 9.3 vs. 63.5 ± 6.2 years), had fewer years of education (14.1 ± 3.1 vs. 17.0 ± 3.1 years), and had lower MoCA scores (22.3 ± 3.5 vs. 27.0 ± 2.0). These results remained significant after adjusting for age, years of education, AHI, PLM index, use of neurological medications, and cardiovascular medication (*p* < .05).

Self-reported sleep data indicated that AL residents had higher global PSQI scores (8.0 ± 3.5 vs. 5.7 ± 3.5), shorter total sleep time (377.3 ± 73.6 vs. 417.2 ± 66.4 minutes), and lower sleep efficiency (69.8 ± 13.3 vs. $82.2 \pm 14.9\%$). After adjustment, only PSQI total sleep time remained significantly different between groups.

Actigraphy-derived measures showed that AL residents had longer sleep onset latency (34.4 ± 39.2 vs. 20.3 ± 14.5 minutes), greater wake after sleep onset (63.1 ± 34.8 vs. 29.2 ± 18.8 minutes), lower sleep efficiency (77.2 ± 16.1 vs. $86.7 \pm 7.4\%$), and more awakenings (34.4 ± 14.5 vs. 25.2 ± 13.4). After adjustment, wake after sleep onset was significantly higher in AL residents, while sleep efficiency and total sleep time were significantly lower (428.2 ± 118.1 vs. 432.5 ± 57.9 minutes).

AL residents had more awakenings (52.2 ± 22.3 vs. 38.6 ± 17.6), longer rapid eye movement sleep latency (187.6 ± 136.5 vs. 111.2 ± 83.5 minutes), a higher proportion of stage 1 sleep ($27.5 \pm 14.7\%$ vs. $15.9 \pm 9.7\%$), and lower proportion of time spent in rapid eye movement sleep ($9.8 \pm 8.0\%$ vs. $16.4 \pm 7.4\%$). AL residents also had higher AHI (37.1 ± 24.8 vs. 24.0 ± 21.1 events/hour), more PLMs ($34.7 \pm$

36.3 vs. 10.8 ± 16.9 events/hour), lower average SpO₂ ($89.5 \pm 2.9\%$ vs. $92.0 \pm 1.8\%$), and more time spent below 90% oxygen saturation (53.7 ± 32.0 vs. $22.5 \pm 25.2\%$). After adjustment, only PLM index remained significantly different between groups.

AL residents were more likely to report use of nervous system medications (65.2% vs. 8.8%) including antidepressants (56.5% vs. 5.6%), and cardiovascular medications (78.3% vs. 48.0%), including diuretics (34.8% vs. 9.6%), beta-blockers (17.4% vs. 3.2%), and calcium channel blockers (21.7% vs. 8.0%). After adjustment only the difference between neurological medication remained statistically significant.

Comparison of sleep recording techniques

Among community-dwelling residents, actigraphy overestimated total sleep time (mean difference [95% CI] = -88.4 minutes [-103.1, -73.7]) and sleep efficiency (-11.8% [-14.0, -9.6]), and underestimated wake after sleep onset (60.7 minutes [50.8, 70.6]), sleep onset latency (11.9 minutes [4.6, 19.1]), and awakenings (13.5 [9.6, 17.3]). Similarly, PSQI-derived estimates differed from PSG for total sleep time (-73.2 minutes [-91.1, -55.2]), sleep efficiency (-7.3% [-10.8, -3.8]), and sleep onset latency (11.3 minutes [2.8, 19.8]).

In AL residents, actigraphy overestimated sleep efficiency (-6.9% [-13.3, -0.5]), and total sleep time (-91.5 minutes [-147.7, -35.3]). However, actigraphy underestimated wake after sleep onset (70.8 minutes [40.9, 100.7]), and number of awakenings (17.9 awakenings [6.7, 29.0]).

[Insert Fig. 2 around here]

Interaction analysis

To examine whether associations between sleep variables and cognitive performance differed by living status, a series of linear regression interaction models were conducted. Models were adjusted for age, years of education, AHI, PLM index, and presence of nervous system medication as covariates. Only significant interaction terms are reported below, all interaction results are presented in **Supplemental Table S1**.

For PSQI-derived measures, living status moderated the association between sleep-onset latency and HVLT-R total recall ($\beta = 0.031$, $p = .035$).

For PSG-derived measures, significant interactions were observed between total sleep time and HVLT-R delayed recall ($\beta = 0.006$, $p = .004$); sleep-onset latency and both BVMT-R total recall ($\beta = 0.028$, $p = .019$) and delayed recall ($\beta = 0.021$, $p = .047$); and awakenings and MoCA scores ($\beta = 0.063$, $p = .022$).

For actigraphy-derived measures, living status moderated the associations between sleep efficiency and HVLT-R delayed recall ($\beta = 0.034$, $p = .027$); wake after sleep onset and both HVLT-R total recall ($\beta = -0.022$, $p = .045$) and delayed recall ($\beta = -0.024$, $p = .001$); and awakenings and MoCA scores ($\beta =$

-0.092, $p = .042$), HVLT-R total recall ($\beta = -0.053$, $p = .041$), HVLT-R delayed recall ($\beta = -0.048$, $p = .005$), and BVMT-R delayed recall ($\beta = -0.067$, $p = .001$).

[Insert Fig. 3 around here]

Discussion

Main findings

This study compared sleep characteristics between AL residents and community-dwelling residents. Using PSG, subjective questionnaires, and actigraphy, we report three major findings. First, AL residents demonstrated more disrupted sleep than community-dwelling residents, with lower sleep efficiency, greater wake after sleep onset, and increased PLM index. Second, Bland-Altman analyses indicated systematic differences among measurement tools. Third, exploratory interaction models indicated that relationships between sleep and cognitive function differ between AL residents and those residing in the community. It should be noted that many unadjusted group differences were attenuated following covariate adjustment, suggesting that differences in age, sleep disordered breathing, PLM index, and underlying medical conditions may have contributed to the observed differences between groups.

Sleep characteristics

Compared with community-dwelling older adults, AL residents demonstrated poorer sleep across subjective and objective measures. AL residents reported worse sleep quality and exhibited greater sleep fragmentation, including increased wake after sleep onset and more frequent nocturnal awakenings in unadjusted analyses. PSG findings further suggested more sleep fragmentation, characterized by a greater proportion of stage 1 sleep, greater indices of sleep disruption, and poorer nocturnal oxygenation in unadjusted analyses. Together, these findings indicate that sleep disturbances are prevalent among AL residents.

There are many factors that can contribute to the differences in sleep characteristics we observed. Namely, AL residents were older and have the potential for more complex underlying medical conditions than the community dwelling population. The attenuation of many group differences following adjustment suggests that these characteristics may contribute to the observed differences¹¹.

Following statistical adjustment for age, MoCA, education, and usage of neurological or cardiovascular medications only the PLM index remained statistically significantly among PSG derived measures between groups. Specifically, AL residents demonstrated a greater PLM index than community-dwelling older residents. Given the established connection between PLM index, sleep fragmentation, and poorer sleep quality, the PLM index may represent an underrecognized contributor to sleep disruption in AL residents³⁵.

Associations between sleep and cognitive performance by living status

Although interaction analyses demonstrated that the associations between sleep and cognitive performance differed according to living status, these findings should be interpreted cautiously. Despite adjustment for age and other relevant covariates, the demographic and clinical differences between these populations may have contributed to these observed relationships.

Among the sleep variables examined, the number of awakenings demonstrated the most consistent interactions with cognitive performance across actigraphy and polysomnography. Previous studies have linked sleep fragmentation and awakenings to poorer cognitive performance³⁶. Repeated awakenings and fragmentation of sleep continuity may impair or hinder sleep-dependant memory consolidation, particularly during slow-wave sleep and rapid eye movement sleep^{5, 37}. The present findings extend this literature by suggesting that these previously reported relationships may not be uniform across older adult populations and strength or presence of these relationships may vary according to the characteristics of the population being studied.

Comparisons between objective, semi-objective and subjective measurements.

Relative to polysomnography, actigraphy underestimated wake after sleep onset and awakenings in both groups, with larger mean differences among AL residents. Actigraphy-derived sleep-onset latency differed from polysomnography among community-dwelling participants but not among AL participants. PSQI derived estimates differed from polysomnography only in the community-dwelling group. Prior studies report similarly wide actigraphy-PSG agreement in healthy adults, with reduced correlations in poor sleepers (PSQI > 5) and those with lower PSG sleep efficiency^{18, 19, 39}. In our study, the AL sample had a higher PSQI score, which may explain the weaker agreement observed in this group. These findings suggest that actigraphy and the PSQI may provide useful insights but should not be viewed as substitutes for gold-standard sleep measures in AL residents. The pattern observed in the present study is consistent with actigraphy's reliance on movement to infer sleep and wake states. Periods of motionless wakefulness may be classified as sleep, resulting in overestimation of total sleep time and sleep efficiency and underestimation of wake after sleep onset and awakenings. This limitation may be particularly relevant in populations with fragmented sleep.

Strengths & limitations

A strength of this study is the use of PSG, the gold standard for the assessment of sleep, alongside actigraphy and subjective sleep questionnaires. This multimethod approach allowed sleep to be characterized from multiple perspectives. However, this study also has limitations that should be considered when interpreting the findings. First, our AL sample was recruited through convenience sampling; these participants may have been more likely to experience sleep problems and thus may differ from the general population. Moreover, a small number of participants were drawn from adult day

programs; individuals in adult day programs spend one or more days at the AL facility and many adult day program clients are on the waitlist for AL accommodations and receive supportive care at home. Secondly, participants from the BIM-II study likely represent a predominately Caucasian, healthier, and economically advantaged section of the population⁴⁰. Third, our PSG data were derived from single night recordings, raising the possibility of a first night effect⁴¹. However, the usage of portable at-home PSG can reduce the effect of the first night effect by reducing observer effects and through the comfortability of the equipment and benefits of sleeping in a familiar environment⁴².

This study highlights the challenges of accurately assessing sleep in AL residents and underscores the limitations of relying solely on actigraphy or subjective questionnaires in this population. The observed discrepancies between actigraphy, PSG, and self-reported measures emphasize the need for careful selection of assessment tools when evaluating sleep in older adults living with greater frailty or potential cognitive impairment.

Conclusion

AL residents exhibited greater sleep disruption than community-dwelling older adults across several subjective, semi-objective, and objective sleep measures. However, after adjustment for demographic and clinical covariates, only the PLM index, actigraphy derived sleep efficiency, wake after sleep onset, and total sleep time as well as PSQI derived total sleep time remained significantly different between groups. Relationships between sleep and various domains of cognitive performance differed by living status, suggesting that these associations may not be uniform across populations of older adults, especially those with differing clinical and demographic differences. Future longitudinal studies are needed to clarify the potential mechanisms underlying these findings.

Declarations

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Ethics approval and consent to participate

Our study conformed to the standards set by the Declaration of Helsinki, except for registration in a database. All participants gave informed consent to participate in the study. All studies were approved by the University of Calgary Conjoint Health Research Ethics Board (CHREB) of the University of Calgary (Ethics Committee Reference # REB16-1199 and # REB19-1939).

Consent for Publication

All individuals who contributed significantly to this work have been acknowledged.

Availability of Data and Material

Data can be made available upon a reasonable request.

Conflicts of Interest

Shane Magnison-Benoit has no personal or financial conflicts of interest; Erin Bates has no personal or financial conflicts of interest; Jenna Naylor has no personal or financial conflicts of interest; Stewart Longman has no personal or financial conflicts of interest; Jayna-Holroyd-Leduc has no personal or financial conflicts of interest; Willis H. Tsai has no personal or financial conflicts of interest; Marc J. Poulin has no personal or financial conflicts of interest.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Shane Magnison-Benoit. The first draft of the manuscript was written by Shane Magnison-Benoit and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Sponsors Role

The funding organizations had no role in the study design, methods, data analysis, interpretation of the findings, preparation of the manuscript, or decision to submit the manuscript for publication. The Brenda Strafford Foundation provided access to recruitment sites and matching funding for the Mitacs Accelerate Fellowship but had no role in data analysis, interpretation, or manuscript preparation.

Why does this paper matter:

By using gold-standard polysomnographic recordings, we demonstrate that assisted living residents have more fragmented and disrupted sleep than community dwelling older adults.

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Figures

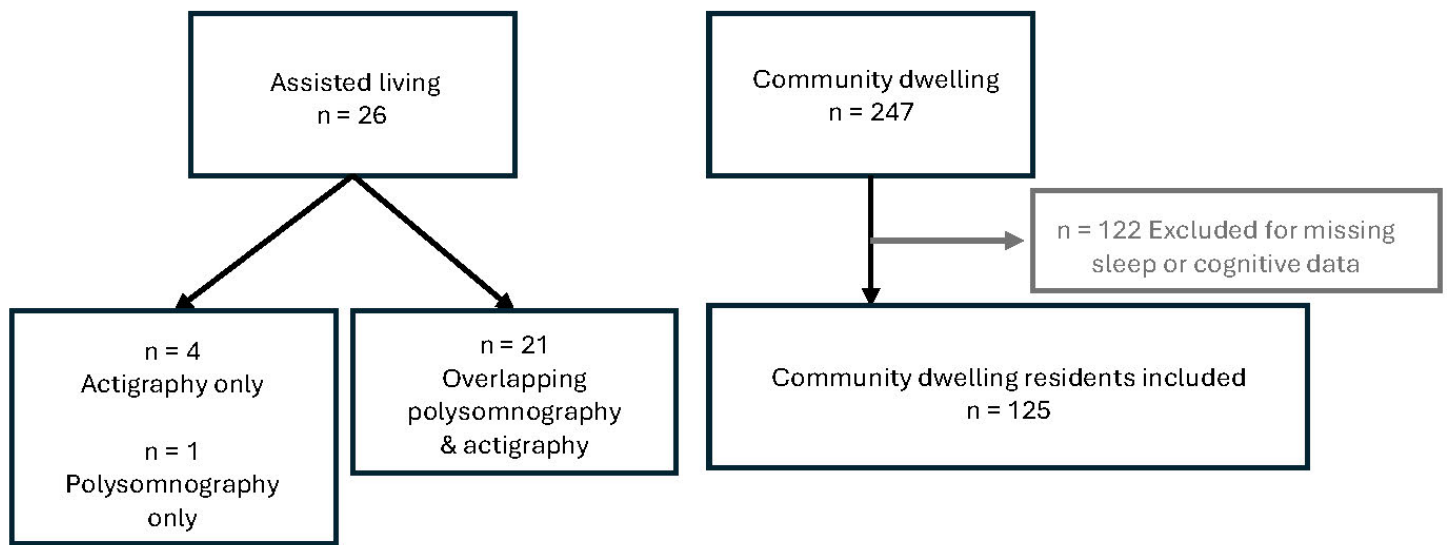


Figure 1

Sample size distribution. Among 26 assisted-living participants, 21 had overlapping polysomnography and actigraphy data, four had actigraphy data only, and one had polysomnography data only. After excluding 122 of the available 247 community-dwelling participants assessed due to missing or incomplete sleep or cognitive data 125 participants in the community-dwelling sample remained.

Abbreviations: n, number of participants.

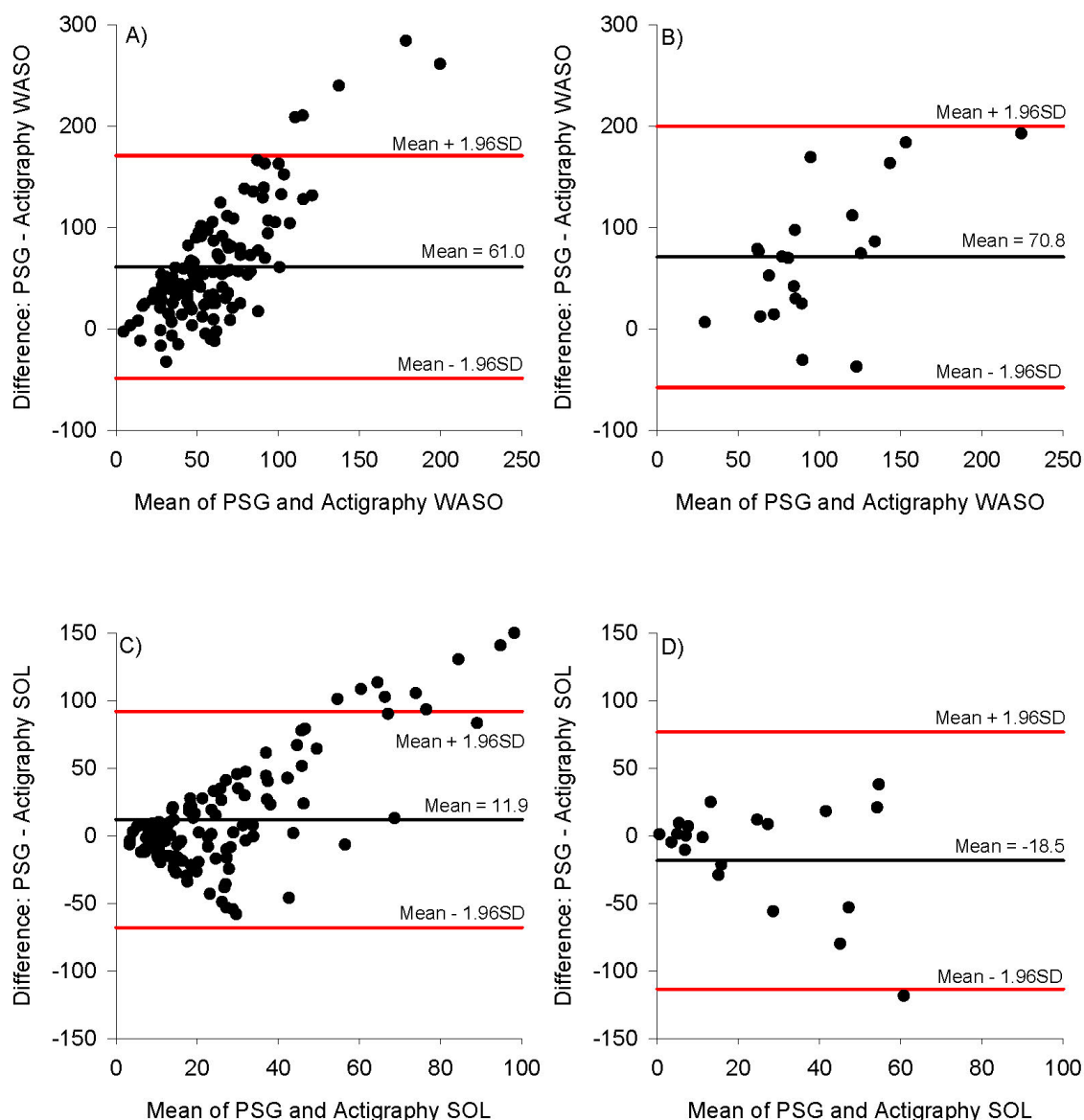


Figure 2

Bland–Altman plots comparing polysomnography and actigraphy-derived sleep measures by living status. (A) wake after sleep onset among community-dwelling participants, (B) wake after sleep onset among supportive-living participants, (C) sleep onset latency among community-dwelling participants, (D) sleep onset latency among supportive-living participants. Differences were calculated as polysomnography minus actigraphy; therefore, positive values indicate that actigraphy underestimated

polysomnography. Black horizontal lines indicate the mean difference, and red horizontal lines indicate the 95% limits of agreement, calculated as mean $\pm 1.96SD$. The x-axis represents the average of the polysomnography and actigraphy measurements.

Abbreviations: SD, standard deviation; PSG, polysomnography, WASO, wake after sleep onset; SOL, sleep onset latency.

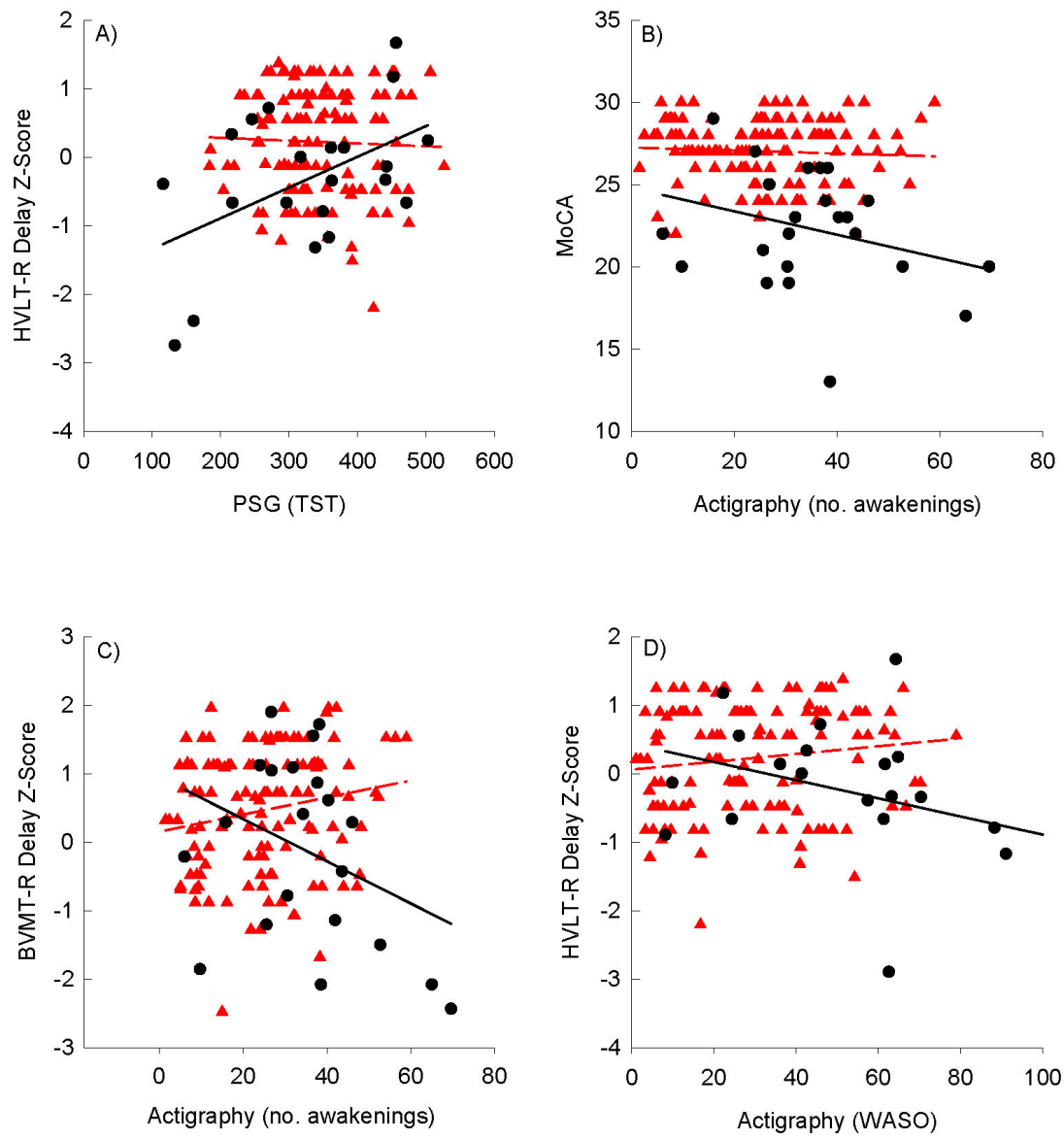


Figure 3

Selected sleep–cognition associations moderated by living status. (A) PSG derived total sleep time and HVLT-R delayed recall (B) actigraphy-derived number of awakenings and MoCA (C) actigraphy-derived number of awakenings and BVMT-R, and (D) actigraphy-derived wake after sleep onset and HVLT-R delayed recall. Red triangles and dashed red lines represent community-dwelling participants; black circles and solid black lines represent AL residents. Total sleep time and wake after sleep onset are reported in minutes, and awakenings are reported as counts. MoCA scores range from 0-30. The HVLT-R scores were scaled to z-scores based on age, sex, and education, whereas the BVMT-R was scaled based on age and sex alone.

Abbreviations: AL, Assisted Living; BVMT-R, Brief Visuospatial Memory Test–Revised; HVLT-R, Hopkins Verbal Learning Test–Revised; MoCA, Montreal Cognitive Assessment; no., number; PSG, polysomnography; TST, total sleep time; WASO, wake after sleep onset.

Supplementary Files

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- [MagnisonBenoitSBsubmissionSupplementalTable1.pdf](#)