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RESEARCH ARTICLE

How does work impact daily sleep quality? A within-individual study using actigraphy and self-reports over the retirement transition

Johanna Garefelt | **Sara Gershagen** | **Göran Kecklund** | **Hugo Westerlund** | **Loretta. G. Platts**

Stress Research Institute, Department of Psychology, Stockholm University, Stockholm, Sweden

Correspondence
Johanna Garefelt, Stressforskningsinstitutet, Stockholms Universitet, SE-106 91 Stockholm, Sweden.
Email: johanna.garefelt@su.se

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Abstract

This study examined how the cessation of work at retirement affects daily measures of actigraphy-measured and self-rated sleep quality. Time in bed or asleep and stress at bedtime were examined as potential mechanisms. In total 117 employed participants who were aged 60–72 years and planned to retire soon were recruited to the Swedish Retirement Study. Sleep quality was measured in a baseline week using accelerometers, diaries, and questionnaires. Subjective sleep measures were sleep quality, restless sleep, restorative sleep, getting enough sleep, estimated wake after sleep onset, difficulties falling asleep, too early final awakening, and difficulties waking up. Actigraphy measures were sleep efficiency, wake after sleep onset, and average awakening length. After 1 and 2 years, the measurements were repeated for the now retired participants. Daily variations in sleep quality before and after retirement were analysed using multilevel modelling, with time in bed or asleep and stress at bedtime as potential mediators. We found that several self-reports of sleep improved (e.g., +0.2 standard deviations for sleep quality and +0.5 standard deviations for restorative sleep) while objective sleep quality remained unchanged or decreased slightly with retirement (e.g., −0.8% for sleep efficiency). Increased time in bed or asleep and stress at bedtime accounted partially for the improvements in self-rated sleep quality at retirement. In conclusion, actigraph-measured and self-reported sleep quality do not change in concert at retirement, highlighting the interest of studying both outcomes. The main effects of retirement from work concern subjective experiences of recovery more than sleep quality *per se*.

KEYWORDS
job, perseverative cognition, sleep duration, sleep initiating and maintenance disorders, sleep problems, stress

1 | INTRODUCTION

Despite the importance of sleep quality for health, well-being, daytime functioning, and reducing daytime sleepiness (Ohayon, 2002), the concept of sleep quality is poorly defined. The concept incorporates perceptions of sleep as refreshing and sufficient, as well as recollections of night time awakenings (Harvey et al., 2008). One perspective of sleep quality divides the concept into two components: one component is sleep continuity – lack of fragmented sleep – and the other is restorative sleep, defined as experiencing sufficiently refreshing sleep (Kecklund & Åkerstedt, 1997; Wilkinson & Shapiro, 2012).

Substantial research has explored factors that may impact sleep quality. One potentially important factor is paid work. Most evidence for the deleterious impact of paid work on sleep comes from studies comparing jobs with different work hours, or stressful jobs with jobs that are less stressful, especially in terms of job demands and effort–reward imbalance (Linton et al., 2015). Although work hours and stress are likely to be important mechanisms affecting sleep quality, paid work may affect sleep in other ways. A useful approach for examining the impact of paid work *per se* on sleep quality is to study, in a within-individual design, what happens when individuals retire from paid work. In such a quasi-experimental approach, individuals are compared with themselves before and after the removal of paid work. The use of this approach in several prospective studies is starting to generate a picture of the divergent ways in which sleep quality is changing at retirement and the potential mechanisms involved.

To date, sleep efficiency is the only aspect of actigraph-measured sleep that has been studied over the retirement transition; in those two studies, neither observed improvements in sleep efficiency at retirement (Garefelt et al., 2020; Myllyntausta et al., 2020). It is unknown how the retirement transition might affect specific aspects of sleep, including wake time once sleep onset has occurred or how fragmented sleep is. Consequently, our study incorporates several aspects of actigraph-measured sleep quality, including wake after sleep onset, the number of awakenings, and the mean length of awakenings.

Self-reported sleep quality has been investigated more thoroughly: improvements in sleep quality at retirement have been consistently reported in studies using composite sleep disturbance scales or reports of difficulties in sleeping (Myllyntausta et al., 2018; Peristera et al., 2021; Vahtera et al., 2009; van de Straat et al., 2019). Considering sleep in terms of its components: effect sizes for how refreshing sleep is tend to be relatively large, with studies consistently reporting declines in measures such as fatigue, daytime tiredness, and nonrestorative sleep (Myllyntausta et al., 2019; Peristera et al., 2021; Westerlund et al., 2010). In contrast, effect sizes for how measures of sleep continuity change at retirement are smaller or not always observed: Myllyntausta et al. (2019) did not observe changes in difficulties maintaining sleep or falling asleep; Peristera et al. (2021) observed only small reductions in these outcomes.

These studies offer preliminary evidence that sleep quality might change at retirement in divergent ways depending on the sleep quality components of interest and whether data come from self-reports or actigraphy. While these variations might be forming an emerging picture, they might have resulted from specificities of the various studies themselves. Consequently, in the current study, we examine changes in sleep over the retirement transition in a single sample using a wide range of self-reported and actigraph measures in order to test these emerging patterns in relation to the individual components of sleep quality in an independent dataset. We hypothesize that changes relating to how recuperative sleep is will be larger than changes relating to sleep continuity, whether continuity is self-reported or measured by actigraphy.

Our second aim is to explore two possible mechanisms for any changes in sleep quality over the retirement transition: increased time for sleep and relief from stress generated by working. Increased total sleep time and time in bed after retirement (Garefelt et al., 2020) are likely to improve ratings of having enough sleep and feeling rested. However, a longer time in bed after retirement and delayed sleep timing after retirement could decrease sleep pressure that in turn would reduce sleep efficiency (Garefelt et al., 2020; Hagen et al., 2016; Myllyntausta et al., 2017, 2020). In a similar vein, while people are still working, the earlier rise and partial sleep deprivation typically present during workdays (Garefelt et al., 2020) could affect sleep continuity and decrease the number of awakenings (Dijk, 2009), hence increasing sleep efficiency. These gains may be lost at retirement. The second possible mechanism that might explain changes in sleep quality after retirement is relief from stress generated by paid work. Work can impair sleep quality by generating worry and rumination that extend outside of working hours, termed perseverative cognition (Clancy et al., 2020; Harvey et al., 2005; Van Laethem et al., 2018); further, objective sleep quality has been found to be lower on nights before workdays that are expected to be stressful (Petersen et al., 2013). Relief from such stress at retirement may lie behind improvements in post-retirement sleep that are largest for people with high job demands (Vahtera et al., 2009; van de Straat et al., 2019). However, one recent study was unable to observe such effects, concluding that improvements in sleep after retirement are to be explained by mechanisms other than the stress release hypothesis (Myllyntausta et al., 2019).

2 | METHODS

2.1 | Study design and study population

The Swedish Retirement Study followed people between 60 and 72 years of age during their transition into retirement, with the first measurement week taking place approximately 6 months before planned retirement, the second week at 6 (±2) months after retirement, and the third week at 18 (±2) months after retirement. The 12-month gap between each measurement had the purpose of avoiding seasonal bias. During the measurement weeks, the participants wore accelerometers and filled in weekly and daily self-reports about their current life situation, engagement in paid work and other activities, health, and sleep. Data collection was approved by the regional ethical review board in Stockholm (2014/486-31/5, 2015/1536-32) and all participants provided written informed consent.

Full details about recruitment to the study are provided in an earlier study that examined sleep length and timing (Garefelt et al., 2020). In brief, the participants were recruited from two studies of working life – the Swedish Longitudinal Occupational Survey of Health, SLOSH, (Magnusson Hanson et al., 2018) and the Aging at Work study – if they were ≥60 years, planning to retire within 2 years, had not been on sick leave or unemployed for >3 months over the past year, and were not working night shifts (defined as working between 22:00 and 06:00 h). Of 193 people eligible to participate, 88 did not wish to participate or dropped out before completing the baseline measurement, and two people had too short working hours, leaving a study sample of 117 people.

2.2 | Analytical sample

Participants from the Swedish Retirement Study who had a baseline measure before retirement and worked more than 50% of full time at T1 (n = 117) were included. Follow-up measures at T2 and T3 were included for participants who did not work more than 25% of full time and had decreased their time in paid work by at least 50% of full time compared with T1 (n = 91 at T1 and n = 88 at T2). For participants who were working too much to be considered retired at T2 but below 25% at T3, their T2 data were coded as missing, while their T3 data were used in the analyses. When people were studied across the daylight-saving time transition, that specific night, (which also was the last night of the study week) was excluded from the sample (n = 10). Due to a small amount of missing information at the item level for some of the self-reported sleep measures, the final analytical sample consisted of 1852 nights with full information on these variables for the 117 individuals.

2.3 | Measures

2.3.1 | Socio-demographics

Age (in years) and sex (man/woman) were derived from register data; civil status was self-reported. Type of work was derived from the question "What is your main occupation?" asked in the questionnaire at T1 and classified according to SSYK-12, based on ISCO-08.

2.3.2 | Retirement

Being retired was defined as working less than 25% of full time. The retirement transition was defined as decreasing paid work by at least 50% of full time, resulting in no more than 25% of full-time paid work. This definition of retirement generates observable changes in sleep timing and length (Garefelt et al., 2020), while accommodating the Swedish context, which has a pension-age band rather than a fixed retirement age and where it is common to participate in some paid work while receiving a pension (Alecta, 2019).

2.3.3 | Sleep measures from actigraphy

We mailed out to participants triaxial accelerometers of type wActiSleep-BT or wGT3X-BT (ActiGraph Ltd). These are two models of the same watch-like activity monitor and the newer model wGT3X-BT is backwards compatible with the older model, generating fully comparable output. The participants were instructed to wear the accelerometer on the non-dominant wrist day and night during each study week.

Nocturnal sleep was scored with Actilife 6 software (ActiGraph Ltd) using 60 s epochs. Validation of wrist actigraphy with polysomnography has demonstrated good accuracy in discriminating sleep and wakefulness (Marino et al., 2013). A polysomnographic validation study using the same brand (but not model) of wrist accelerometer and the same software found that wrist actigraphy detected sleep well and had moderate capability to detect periods of wake during the sleep period (Slater et al., 2015). Sleep was scored with the Cole-Kripke algorithm, validated in the adult population (Cole et al., 1992), followed by ocular assessment of autoscored sleep periods by one of the authors.

Pre-defined manual sleep scoring rules were used to adjust automatic scoring in light of participants' sleep timings which they recorded in a sleep diary (ActiGraph accelerometers do not have event markers). Specifically, the participants reported their bedtimes (lights off) just before going to sleep, and then in the morning their final awakening time and the time they got up (lights on). We used this information to adjust the autoscored sleep timings, e.g., distinguishing sedentary wake-time behaviour from the periods asleep. Specifically, where longer night time awakenings had led to the algorithm dividing night time sleep into several sleep periods, these were manually collapsed into one sleep period, resulting in increased wake after sleep onset compared with automatic scoring. Adjustments were also made if the start or end of the automatically scored sleep period occurred >20 min beyond the times reported in the sleep diary. Firstly, the minimum length of a sleep period detected by the algorithm was reduced from the default of ≥160 min to ≥20 min; any additional sleep periods occurring within ±20 min of diary-recorded sleep times were included in the total night time sleep. Secondly, if either sleep onset or final awakening were still not within 20 min of the sleep diary times, manual rescoring was carried out as follows: sleep onset (final awakening) was defined to have occurred following (prior to) the closest activity bout larger than 100 counts ±10 min from diary-recorded lights out (wake up) time. To keep manual scoring as close to the Cole-Kripke algorithm as possible, the first 5 min of inactivity from sleep onset and the last 2 min before sleep offset were excluded from each sleep period. Further detail is provided in Garefelt et al. (2020).

Sleep measures from the actigraphs analysed in this study were the covariates: total sleep time (hours spent asleep between sleep onset and final awakening), time in bed (hours between sleep onset and final awakening), and the outcomes: sleep efficiency (number of sleep minutes divided by the total number of minutes the subject was in bed, in percent), Wake After Sleep Onset, (WASO, minutes awake between sleep onset and final awakening), and the average length of awakenings (mean duration of the awakenings during sleep, in minutes).

2.3.4 | Self-reported sleep measures

Participants filled out daily sleep diaries regarding duration, timing, and quality every morning during the study. The sleep diary was a modified version of the Karolinska Sleep Diary, which has been validated in both laboratory and field studies, showing moderate to high correlation with standard objective indicators of sleep quality related to sleep continuity and the depth of sleep (Åkerstedt et al., 1994; Kecklund & Åkerstedt, 1997). Self-reported sleep measures analysed in this study were: Sleep quality "How did you sleep? (1) Very poor – (5) Very well", Restless sleep "Was your sleep restless? (1) Not at all – (5) Very", Restorative sleep "Did you feel rested at awakening (1) Not at all – (5) Very", Enough sleep: "Did you sleep enough? (1) No, definitely too short – (5) Yes, definitely enough", Estimated wake time during the night: "For about how long a time (in total) were you awake during the night? (1) Not at all – (5) 60+ min", Difficulties falling asleep "Did you have difficulties falling asleep? (1) Not at all – (5) Very", Too early awakening: "Did you wake up too early without being able to fall asleep again? (1) No not at all – (5) Much too early", and Difficulties waking up "Did you have difficulties waking up? (1) Not at all – (5) Very".

2.3.5 | Stress at bedtime

Participants reported in their sleep diaries the next morning whether they had experienced stress at bedtime to the question "Did you feel worried or stressed at bedtime?" with answers ranging between (1) Not at all – (5) Very".

2.4 | Statistical analysis

Data were analysed in Stata 16.1, using multilevel models with restricted maximum likelihood estimation. To enable within-individual analyses, the measurements per night/day (level 1) were nested within individuals (level 2), with participant identifier included as a factor with random intercept. In the main analysis, retirement status (T1, T2, and T3) was included as a factor in the fixed part of the separate models for each measure of sleep quality.

In the exploration of mediating factors, variables were analysed with adjustment for total sleep time or time in bed (depending on outcome) and stress at bedtime. The analyses of sleep efficiency, average length of awakenings, WASO, and the estimated wake time during the night were analysed in relation to time in bed, as time in bed is strongly related to sleep quality (Dijk, 2009) and differs with retirement between workdays and days off (Garefelt et al., 2020). The analyses of (self-rated) sleep quality, enough sleep, too early awakening, restorative sleep, too early final awakening, and difficulties waking up were instead analysed in relation to total sleep time, since longer time in bed does not necessarily reflect better sleep if the quality is low (e.g., high fragmentation and long WASO). The only sleep variable not controlled for time in bed or asleep was difficulties falling sleep, as this variable covers a state before sleeping takes place and hence is more related to time of rising and the previous night's sleep duration. To ease interpretation of the coefficients as well as the constant in the models, both total sleep time and time in bed were measured in hours and centred around the sample mean.

3 | RESULTS

Descriptive data of the sample are presented in Table 1. The sample consisted of 1852 nights from 117 individuals with a mean age of 64.8 years at T1 and of which 60% were women. A majority of the sample, 60%, worked in occupations requiring high levels of education; 19% worked with administration or service; 10% were managers; and 7% worked in mechanical manufacturing, transport, or elementary occupations. At T1, 74% worked full time (>35 h per week) with an average of 4.7 workdays across a mean of 6.3 measured days. The rest of the sample worked ≥50% of full time (defined as ≥20 h per week) with an average of 3.1 workdays across 6.7 measured days. After retirement, 16% (T2) and 14% (T3) were still working up to 25% of full time, which was the upper limit to be included in the sample as retired at T2/T3. Before retirement, 84% of the sample reported good or excellent health, which increased to 92% after retirement. Participants reported low levels of stress at bedtime at baseline (1.31; 95% CI 1.24–1.37), which decreased significantly (p < 0.001) to T2 and T3 (T2: 1.18, 95% CI 1.11–1.25; T3: 1.16, 95% CI 1.09–1.23).

Descriptive statistics of the sleep outcomes are presented in Table 2. Sleep quality measured with actigraphy was quite good at T1, as an example, sleep efficiency was about 92%. Self-reports also tended to be good, for example, sleep quality averaged around 4, which means "quite good" sleep.

3.1 | Results from multilevel models

Results from the multilevel analyses of retirement status on objective and self-reported sleep quality are shown in Figures 1 and 2 and Tables 3a and 3b. Bivariate findings are presented in the column "unadjusted".

TABLE 1 Sample characteristics, Swedish Retirement Study (1852 nights from 117 individuals)

Variable	T1	T2	T3
	n participants or mean (s.d.)		
Participants	117	91	88
Age at T1 (range 60–72 years)	64.8 (2.0)		
Gender at T1			
Men	47		
Women	70		
Civil status at T1			
Living together with a partner	95		
Living apart from partner	7		
Single	15		
Working hours			
Retired, not working at all	0	76	76
Working <20 h per week after retirement (inclusion criteria to be considered "retired")	0	15	12
Working 20–35 h per week	30	0	0
Working >35 h per week	87	0	0
	n measurements		
Measurements (number of measured nights/days)	698	565	589
Of which workdays	432	16	16
Of which days off	242	533	560
Of which not known if a workday or not	24	16	13

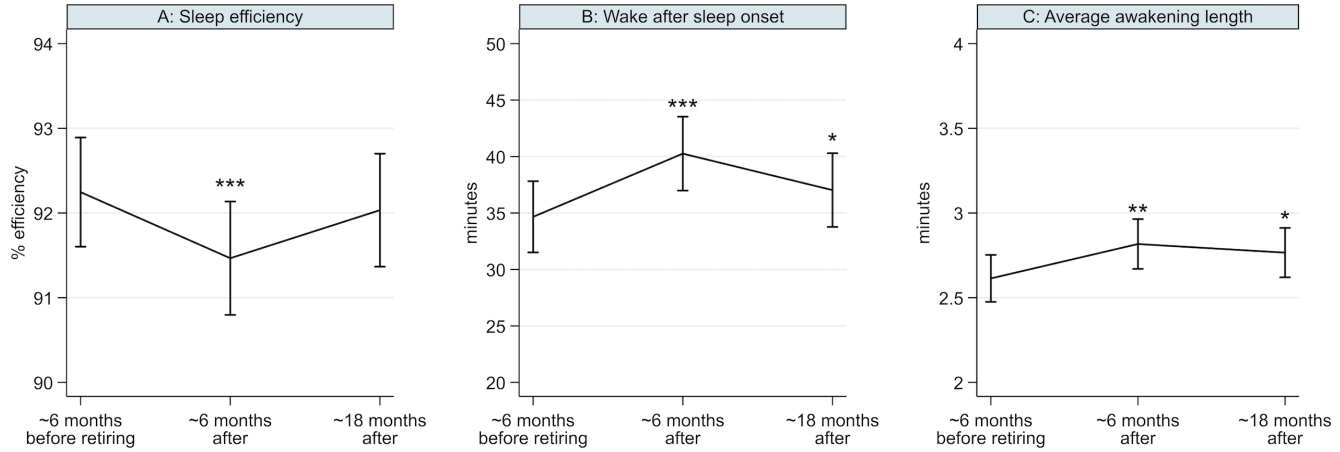
TABLE 2 Descriptive statistics of objective and self-rated sleep quality before retirement (T1), Swedish Retirement Study (1852 nights from 117 individuals)

	Mean	s.d.	Range
Objective sleep before retirement (T1)			
Sleep efficiency (%)	92.4	4.7	59.2–100.0
WASO (min)	34.1	22.7	0.0–191.0
Average awakening length (min)	2.6	1.2	0.0–13.6
Self-rated sleep before retirement (T1)			
Sleep quality	3.9	1.0	1–5
Restless sleep	1.7	1.0	1–5
Restorative sleep	3.4	1.1	1–5
Enough sleep	3.7	0.9	1–5
Too early final awakening	1.9	1.2	1–5
Difficulties waking up	1.6	0.9	1–5
Estimated WASO	2.4	1.1	1–5
Difficulties falling asleep	1.6	1.0	1–5
Other sleep-related measures before retirement (T1)			
Stress at bedtime	1.3	0.7	1–5

First, we examined retirement effects. After retirement, objective sleep quality was similar or deteriorated slightly. Sleep efficiency decreased by 0.8%, WASO increased by 5.6 min and average awakening length by 0.2 min. In contrast, several self-reported sleep measures, scaled between 1–5, improved. Changes at T2 were particularly pronounced for restorative sleep, which increased by 0.46 points, and enough sleep, which increased by 0.42 points. These were mostly maintained into T3, 18 months after retirement. The ratings of sleep quality increased more moderately at T2, by 0.21 points, and difficulty waking up decreased by 0.20 points and restless sleep decreased by 0.13 points; these changes were not so accentuated but still significant at the 5% level at T3 for all but restless sleep. However, changes after retirement at the 5% significance level were not observed for too early final awakening, estimated time awake during the night, or difficulties falling asleep.

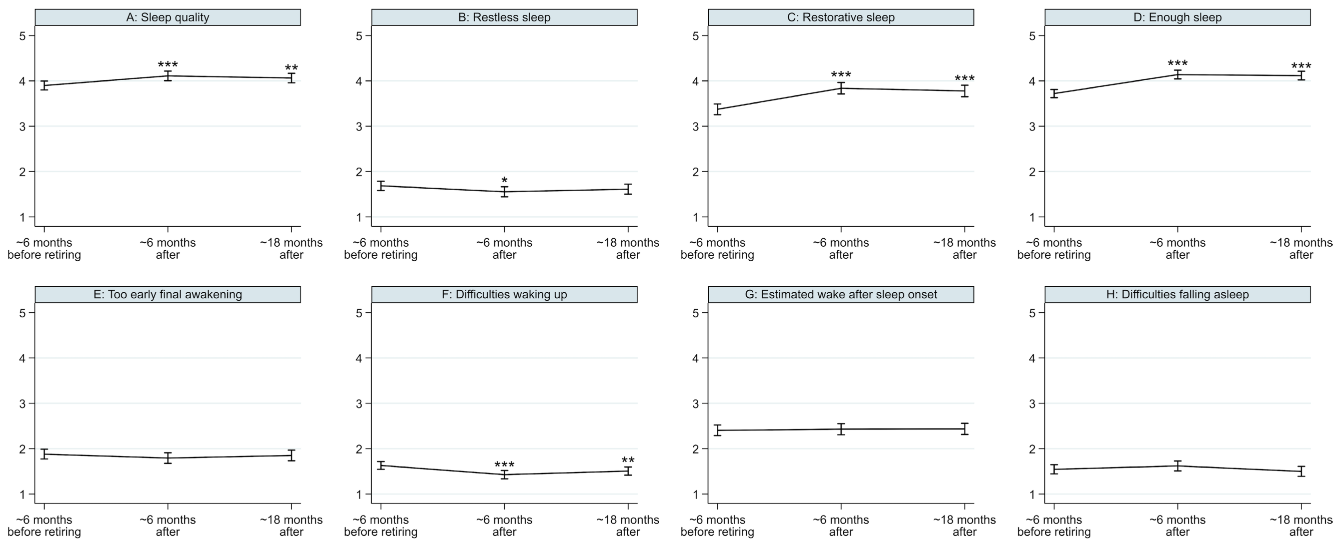
Second, we examined associations between the sleep quality outcomes and time in bed or asleep. The total sleep time was associated with improved levels and time in bed with deteriorating levels of all measured sleep outcomes. Lastly, stress at bedtime was associated with worsened levels of all self-reported sleep quality measures, but was not associated with any of the objective sleep measures.

The final set of models in Tables 3a and 3b presents sleep quality outcomes in models fully adjusted for retirement, time in bed/asleep and stress at bedtime. In these models, the associations of retirement with the objective sleep outcomes were similar to in the unadjusted models. This was also the case for most self-rated sleep measures, specifically sleep quality, restless sleep, estimated WASO, difficulties falling asleep, too early final awakening and difficulties waking up. However, for the self-reported sleep measure getting



Asterisks indicate level of significance of any difference compared to 6 months before retiring, * p<0.05, ** p<0.01, *** p<0.001.

FIGURE 1 Changes in objective sleep after retirement. The Swedish Retirement study (1852 nights from 117 individuals)



Asterisks indicate level of significance of any difference compared to 6 months before retiring, * p<0.05, ** p<0.01, *** p<0.001.

FIGURE 2 Changes in self-rated sleep after retirement. The Swedish Retirement study (1852 nights from 117 individuals)

enough sleep, the size of the estimates at T2 after adjustment for total sleep time and stress at bedtime decreased to 0.26, suggesting that the impact of retirement is partially mediated by these factors. More details of the individual effects of the variables time in bed/asleep and stress at bedtime are presented in Tables S1 and S2 in the Appendix S1.

4 | DISCUSSION

This paper shows that actigraph-measured and self-reported measures of sleep quality do not change in concert at retirement. While self-reported sleep quality tended to improve, sleep quality measured by actigraphy remained unchanged or even slightly deteriorated, findings which emphasise the complex relation between objective and self-rated measures of sleep (Bianchi et al., 2013). Our findings are in line with prior research using actigraphy or self-reports (Garefelt et al., 2020; Myllyntausta et al., 2018, 2020; Vahtera et al., 2009; van de Straat et al., 2019), but we studied these outcomes in the same study sample and design. In this way, we provide additional evidence strengthening the case for considering actigraphy and self-reports as separate and complementary sleep quality outcomes (Clancy et al., 2020). Disagreement between subjective and actigraphy-based indictors of sleep quality is commonly observed (Aili et al., 2017; Jackowska et al., 2011). While reasons for the discrepancy are not fully understood, it has been shown

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TABLE 3(A) Mediating factors in the change of objective sleep quality across the retirement transition: time in bed, feeling stressed before the night. The Swedish Retirement Study (1852 nights from 117 individuals)

	Unadjusted	95% CI	Adjusted	95% CI
Sleep efficiency (%)				
T1, work	Ref.	–	Ref.	–
T2, retired	−0.78***	−1.21; −0.35	−0.59**	−1.02; −0.16
T3, retired	−0.21	−0.64; 0.21	−0.08	−0.50; 0.35
Time in bed (h)	−0.56***	−0.73; −0.38	−0.55***	−0.72; −0.37
Stress at bedtime	−0.16	−0.48; 0.16	−0.34*	−0.66; −0.02
Constant	–	–	92.56	–
Wake after sleep onset (min)				
T1, work	Ref.	–	Ref.	–
T2, retired	5.59***	3.51; 7.68	2.70**	0.74; 4.66
T3, retired	2.36*	0.29; 4.44	0.09	−1.85; 2.04
Time in bed (h)	7.32***	6.54; 8.10	7.29***	6.49; 8.09
Stress at bedtime	−0.66	−2.22; 0.91	1.49*	0.03; 2.95
Constant	–	–	34.50	–
Average awakening length (min)				
T1, work	Ref.	–	Ref.	–
T2, retired	0.20**	0.08; 0.32	0.17**	0.05; 0.29
T3, retired	0.15*	0.03; 0.27	0.12*	0.00; 0.24
Time in bed (h)	0.10***	0.06; 0.15	0.09***	0.05; 0.14
Stress at bedtime	−0.02	−0.10; 0.07	0.02	−0.06; 0.11
Constant	–	–	2.61	–

Ref., reference; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. T1, measurement ≈6 months before retirement, T2 and T3 are measurements ≈6 and ≈18 months after retirement. CI, = 95% confidence interval. Time in bed is the number of hours spent in bed that night. Stress at bedtime is a question with answers ranging between 1 (low/no stress) to 5 (high stress). The adjusted models show the distinguished effects of retirement, time in bed as well as feeling stressed or worried before the night on each outcome.

that subjective sleep quality reports are often related to measures of well-being, mental health and stress (Jackowska et al., 2011). Further, it should be noted that insomniacs often overestimate their sleep disturbances relative to objective measures of sleep (Harvey & Tang, 2012). Thus, the discrepancy between the subjective and objective sleep quality measures is not surprising and fits well with the literature.

Although deterioration in actigraph-measured sleep quality was observable in this study, it must be borne in mind that the effect sizes are small and take place against a background of a baseline of very high sleep efficiency of 92% and a low WASO of 35 min (Conley et al., 2019, Fig. 1.4). Observed effects were small: −0.8% for sleep efficiency and 6 min for WASO. As points of comparison, a WASO of >60 min predicted worsening depressive symptoms in a sample of older women and, in another study, reports of sleep quality tended to be rated as high when sleep efficiency was above 87% (Åkerstedt et al., 1994; Maglione et al., 2014).

While most prior work has used broad measures of sleep disturbances – a single question about the presence of sleep disturbance (Vahtera et al., 2009) or a scale of sleep disturbance symptoms (van de Straat et al., 2019) – we observed diversity between the individual measures of self-rated sleep. Myllyntausta et al. (2018) and Peristera et al. (2021), who also studied individual outcomes, found as we did large improvements after retirement for (non-)restorative sleep and smaller or no effects for difficulties falling asleep or in difficulties maintaining sleep; findings that are in line with the smaller and less consistent results we observed for the outcomes difficulties falling asleep, estimated WASO, restless sleep, and too early final awakening. The effect of retirement upon subjective sleep quality appears to be specific, mostly concerning outcomes that relate to fatigue and recovery rather than sleep continuity, a fact that highlights the interest of distinguishing individual measures of self-rated sleep.

We examined the role of two potential mediators in the retirement–sleep relationship: experiencing stress at bedtime and having a longer period in bed or asleep. For those outcomes where large retirement effects were observed, these were somewhat diminished after inclusion of these covariates; for some other outcomes with smaller retirement effects, these were no longer significant at the 5% level. We interpret these findings as there might be some support for the stress release hypothesis – that reduced stress after retirement improves sleep quality – as one potential mechanism behind the increases in subjective sleep quality after retirement. These conclusions are partly in line with three previous studies in which sleep disturbance at retirement reduced more for people with high

TABLE 3(B) Mediating factors in the change in self-rated sleep quality across the retirement transition: total sleep time/time in bed, feeling stressed before the night. The Swedish Retirement Study (1852 nights from 117 individuals)

	Sleep quality				Restless sleep			
	Unadjusted	95% CI	Adjusted	95% CI	Unadjusted	95% CI	Adjusted	95% CI
T1, work	Ref.	–	Ref.	–	Ref.	–	Ref.	–
T2, retired	0.21***	0.11; 0.31	0.11*	0.01; 0.21	−0.13*	−0.23; −0.03	−0.06	−0.16; 0.03
T3, retired	0.16**	0.07; 0.26	0.06	−0.03; 0.16	−0.07	−0.17; 0.03	−0.00	−0.10; 0.09
Total sleep time (h)	0.20***	0.16; 0.24	0.16***	0.12; 0.20	−0.09***	−0.14; −0.05	−0.06**	−0.10; −0.02
Stress at bedtime	−0.42***	−0.49; −0.35	−0.37***	−0.44; −0.30	0.38***	0.31; 0.45	0.36***	0.29; 0.43
Constant	–	–	4.41		–	–	1.20	
	Restorative sleep				**Enough sleep**			
	Unadjusted	95% CI	Adjusted	95% CI	Unadjusted	95% CI	Adjusted	95% CI
T1, work	Ref.	–	Ref.	–	Ref.	–	Ref.	–
T2, retired	0.46***	0.36; 0.57	0.30***	0.20; 0.40	0.42***	0.33; 0.51	0.26***	0.18; 0.34
T3, retired	0.40***	0.30; 0.51	0.25***	0.15; 0.34	0.40***	0.30; 0.49	0.24***	0.16; 0.32
Total sleep time (h)	0.43***	0.39; 0.47	0.38***	0.34; 0.42	0.42***	0.38; 0.45	0.37***	0.34; 0.41
Stress at bedtime	−0.45***	−0.53; −0.37	−0.32***	−0.39; −0.25	−0.41***	−0.47; −0.34	−0.29***	−0.35; −0.23
Constant	–	–	3.87		–	–	4.17	
	Too early final awakening				**Difficulties waking up**			
	Unadjusted	95% CI	Adjusted	95% CI	Unadjusted	95% CI	Adjusted	95% CI
T1, work	Ref.	–	Ref.	–	Ref.	–	Ref.	–
T2, retired	−0.09	−0.20; 0.03	0.02	−0.09; 0.13	−0.20***	−0.28; −0.12	−0.15***	−0.23; −0.07
T3, retired	−0.03	−0.14; 0.08	0.07	−0.04; 0.18	−0.12**	−0.20; −0.04	−0.07	−0.15; 0.01
Total sleep time (h)	−0.29***	−0.33; −0.24	−0.28***	−0.33; −0.23	−0.13***	−0.17; −0.10	−0.11***	−0.14; −0.07
Stress at bedtime	0.17***	0.09; 0.25	0.10**	0.02; 0.18	0.19***	0.13; 0.24	0.15***	0.09; 0.20
Constant	–	–	1.69		–	–	1.42	
	Estimated wake after sleep onset				**Difficulties falling asleep**			
	Unadjusted	95% CI	Adjusted	95% CI	Unadjusted	95% CI	Adjusted	95% CI
T1, work	Ref.	–	Ref.	–	Ref.	–	Ref.	–
T2, retired	0.02	−0.08; 0.13	0.00	−0.10; 0.10	0.07	−0.03; 0.18	0.14**	0.04; 0.24
T3, retired	0.03	−0.07; 0.13	0.02	−0.08; 0.12	−0.05	−0.15; 0.06	0.03	−0.07; 0.13
Time in bed (h)	0.11***	0.07; 0.15	0.13***	0.08; 0.17	–	–	–	–
Stress at bedtime	0.19***	0.11; 0.27	0.22***	0.15; 0.30	0.52***	0.45; 0.59	0.53***	0.45; 0.60
Constant	–	–	2.14		–	–	0.85	

Ref., reference; *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. T1, measurement ≈6 months before retirement, T2 and T3 are measurements ≈6 and ≈18 months after retirement. Time in bed is the number of hours spent in bed that night and total sleep time the number of minutes spent asleep during time in bed, both centred around the mean for easier interpretation of the constant in the models. Stress at bedtime is a question with answers ranging between 1 (low/no stress) to 5 (high stress). The fully adjusted models show the distinguished effects of retirement, time in bed/total sleep time as well as feeling stressed before the night on each outcome.

levels of work demands or job strain than for people with low levels (Myllyntausta et al., 2018; Vahtera et al., 2009; van de Straat et al., 2019) and with findings from Myllyntausta et al. (2019) that sleep loss due to worry decreased at retirement, even if in this last paper the authors were not able to observe larger decreases in sleep disturbances for people with a higher number of work stressors. Our findings are also in line with the findings of Clancy et al. (2020) who observed that sleep is affected when perseverative cognition concerns the future, e.g., work the next day.

Turning to time in bed or asleep, prior research on the same data (Garefelt et al., 2020) has demonstrated that total sleep time at retirement increases by about 30 min on weekdays, reducing chronic weekly partial sleep debt by about 2.5 h. In the current study, we found that a longer total sleep time was associated with higher subjective sleep quality, which is in line with the idea that sleep length is an important element of quality sleep (Mallon et al., 2014). However, since actigraphy-measured sleep quality is based largely on sleep continuity, decreased sleep pressure from longer sleep duration after retirement can increase night time awakenings and decrease efficiency, something we observed in our results based on actigraphy.

Even after controlling for stress at bedtime and time in bed or asleep, most retirement effects remained, and may therefore be explained by other mechanisms. A potential explanation for worsened actigraph-measured sleep after retirement is postponement of sleep timing on weekdays (Garefelt et al., 2020). On those days, the time spent in bed is increased during early mornings when the circadian system is increasing cortisol levels, thereby reducing sleep continuity (Akerstedt et al., 1997). Another potential mechanism is daytime napping, which may reduce sleep pressure and thereby also sleep continuity the following night. Turning to the subjective measures, the remaining retirement effects concerned improvements in having enough sleep, sleep being restorative, and reductions in difficulties waking up. There are several potential mechanisms for these, which future investigators may wish to explore. Stabilization of weekly rhythms at retirement reducing social jet lag (Garefelt et al., 2020), may reduce morning tiredness as well as fatigue in general. Work-related arousal may generate sleep disturbance, even if involving neutral thoughts about work that do not generate perceptions of worry or stress (Brosschot et al., 2010). Increased napping after retirement may reduce fatigue and worries about getting enough sleep that before retirement could be self-realized due to the arousal such thoughts might cause. Lastly, mood, which is known to affect subjective sleep ratings, may improve after retirement (Baillet et al., 2016).

While not possible in this study due to limitations among others of sample size, future research could focus on potential mechanisms linking retirement to subjective and actigraph-measured sleep, including naps, implicit stress, social jet lag, postponing sleep timing, and diminished fatigue. Participation in paid work provides mental and physical stimulation, which may generate fatigue before going to sleep, hasten sleep initiation, raise sleep continuity, and increase sleep depth (Banno et al., 2018; Horne & Minard, 1985; Naylor et al., 2000). Mechanisms connecting retirement and sleep could be explored more closely than was possible in the current study: An implication of the findings is that subjective sleep quality may not improve as much if stress at bedtime continues to be high after retirement or if sleep length does not increase, for example, as a result of illnesses or pain.

4.1 | Strengths and limitations

Strengths include the wide range of sleep measures from both accelerometery and self-reports, and a prospective within-individual study design that includes a large number of nights measured over several years. The use of nightly data reduces recall bias compared with retrospective questions about sleep the preceding months or even year (Sato & Kawahara, 2011). However, the study has certain limitations. First, the study only included people working up to at least 50% of full-time up to statutory retirement age without being on sick leave, which provides a healthy sample that has limited generalizability to the whole population. Generalizability of the effects to younger age groups is limited by the sample being aged ≥60 years. Since nonrestorative sleep is more common among younger age groups, the actual effects of work on nonrestorative sleep are likely to be larger than the effects observed in this age-group. Second, actigraphy is less accurate than the gold standard of polysomnographic sleep recording and does not provide information about sleep stages. Third, the retirement definition used in this paper enables “retired” participants to have limited participation in the labour market, a decision which might have influenced all of the results in a conservative direction. However, the findings reported here are broadly in line with papers using contrasting definitions, highlighting the robustness of this literature to how retirement is defined. Fourth, adopting a retirement lifestyle involves more than the removal of work, and may be accompanied for instance by changes in finances as well as by taking up new activities such as grandparenting. Such confounding factors – with consequences for potential mechanisms such as stress, mental stimulation and physical activity – may have implications for the quality of sleep. An alternative approach for understanding the role of work in affecting sleep might be provided by studying how sleep changes following removal of work during a lengthy holiday (such as that taken in summer in Nordic countries), an approach which would also be suitable for younger age groups.

5 | CONCLUSIONS

Retirement has contrasting effects on self-rated and actigraph sleep measures, demonstrating the need to assess both. The main effects of retirement from work concern subjective experiences of recovery more than sleep quality *per se*. Retirement–sleep quality relationships appeared to be affected to some degree by decreased stress at bedtime and a longer period in bed or asleep. Future research could explore these and other potential mechanisms affecting sleep in relation to retirement, such as reduced social jet lag, postponed sleep timing and less sleep deprivation.

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AUTHOR CONTRIBUTIONS

JG performed the analyses and drafted the paper in collaboration with the other authors. All authors contributed to the study design, interpretation of data, critical revision of the work, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work.

DATA AVAILABILITY STATEMENT

Given restrictions from the ethical review board and considering that sensitive personal data are handled, it is not possible to make the data freely available. Access to the data may be provided to other researchers in line with Swedish law and after consultation with the Stockholm University legal department. Requests for data, stored at the Stress Research Institute, Department of Psychology, should be sent to registrator@su.se with reference to The Swedish Retirement Study or directly to the corresponding author.

ORCID

Johanna Garefelt https://orcid.org/0000-0003-3658-6448
Sara Gershagen https://orcid.org/0000-0002-3467-2900
Göran Kecklund https://orcid.org/0000-0001-7457-7302
Hugo Westerlund https://orcid.org/0000-0002-8806-5698
Loretta. G. Platts https://orcid.org/0000-0002-3243-0262

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