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Sleep-Wake Disturbances in Sedentary Community-Dwelling Elders With Functional Limitations

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Abstract

OBJECTIVES—To evaluate sleep-wake disturbances in sedentary community-dwelling elders with functional limitations.

DESIGN—Cross-sectional.

SETTING—Lifestyle Interventions and Independence in Elder (LIFE) Study.

PARTICIPANTS—1635 community-dwelling persons, mean age 78.9, who spent <20 minutes/week in the past month of regular physical activity and <125 minutes/week of moderate physical activity, and had a Short Physical Performance Battery (SPPB) score <10.

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MEASUREMENTS—Mobility was evaluated by the 400-meter walk time (slow gait speed defined as <0.8 m/s) and SPPB score (≤7 defined moderate-to-severe mobility impairment). Physical inactivity was defined by sedentary time, as percent of accelerometry wear time with activity <100 counts/min); top quartile established high sedentary time. Sleep-wake disturbances were evaluated by the Insomnia Severity Index (ISI) (range 0–28; ≥8 defined insomnia), Epworth Sleepiness Scale (ESS) (range 0–24; ≥10 defined daytime drowsiness), Pittsburgh Sleep Quality Index (PSQI) (range 0–21; >5 defined poor sleep quality), and Berlin Questionnaire (high risk of sleep apnea).

RESULTS—Prevalence rates were 43.5% for slow gait speed and 44.7% for moderate-to-severe mobility impairment, with 77.0% of accelerometry wear time spent as sedentary time. Prevalence rates were 33.0% for insomnia, 18.1% for daytime drowsiness, 47.8% for poor sleep quality, and 32.9% for high risk of sleep apnea. Participants with insomnia, daytime drowsiness, and poor sleep quality had mean values of 12.1 for ISI, 12.5 for ESS, and 9.2 for PSQI, respectively. In adjusted models, measures of mobility and physical inactivity were generally not associated with sleep-wake disturbances, using continuous or categorical variables.

CONCLUSION—In a large sample of sedentary community-dwelling elders with functional limitations, sleep-wake disturbances were prevalent but only mildly severe, and were generally not associated with mobility impairment or physical inactivity.

Keywords

mobility impairment; physical inactivity; sleep-wake disturbances

INTRODUCTION

Sleep-wake disturbances are prevalent among older persons and are associated with adverse outcomes. In two large studies of community-dwelling elders,[1,2] prevalence rates for insomnia symptoms and daytime napping ranged from 43%–50% and 25%–46%, respectively. The mechanisms underlying these high rates of sleep-wake disturbances likely include age-related increases in the prevalence of sleep apnea and multimorbidity, as well as age-related declines in sleep physiology.[3–8] Adverse outcomes associated with sleep-wake disturbances include reductions in driving capacity and cognition, cardiovascular disease, depression, falls, institutionalization, and death.[1,2,8,9]

Among older persons, risk factors for having sleep-wake disturbances may also include mobility impairment and physical inactivity.[2,4,10,11] In the Established Populations for Epidemiologic Studies of the Elderly (EPESE), for example, physical disability at follow-up (dependency in activities of daily living, or inability to walk up and down stairs or one half-mile without help) increased the likelihood of incident insomnia by 109%.[4] In the 2003 National Sleep Foundation poll, older persons who reported mobility disability (very difficult or unable to walk one-half mile or up and down a flight of stairs without help) had a 2-fold or greater prevalence of insomnia, daytime drowsiness, and history of sleep apnea, than those with normal mobility.[2] In the Wisconsin Sleep Cohort Study, decreased physical activity was cross-sectionally associated with increased severity of polysomnography-confirmed sleep apnea.[11] These prior studies, although based on population-derived

samples, had limitations because mobility and physical activity were evaluated by self-report and/or because insomnia and daytime drowsiness were established by single-item questions, rather than validated questionnaires such as the Insomnia Severity Index (ISI), Epworth Sleepiness Scale (ESS), and Pittsburgh Sleep Quality Index (PSQI).[12–14]

The Lifestyle Interventions and Independence for Elders (LIFE) Study is a randomized controlled trial designed to compare a physical activity program with a successful aging health education program in 1,635 community-dwelling older persons.[15,16] Participants were limited to persons aged 70–89 years who reported a sedentary status and had lower extremity functional limitations, but were otherwise non-disabled.[16] At the baseline evaluation, the study protocol included objective measures of mobility and physical activity, as well as sleep-wake questionnaires such as the ISI, ESS, and PSQI.[12–16] In addition, as a validated measure of the clinical risk of having sleep apnea, the Berlin Questionnaire (BQ) was administered.[17]

Because enrollment criteria included a sedentary status and lower extremity functional limitations, we postulated that sleep-wake disturbances would be prevalent in the LIFE Study. Moreover, we postulated that performance-based mobility and habitual physical inactivity would be cross-sectionally associated with sleep-wake disturbances, and that these associations were potentially modified by other known risk factors for sleep-wake disturbances (e.g., female sex, obesity, depressive symptoms, multimorbidity, medications, and health status).[1,2,4–8,18] The results of this work may further inform the importance of mobility impairment and sedentary behavior as potential risk factors for sleep-wake disturbances in older persons.

METHODS

Study Population

The LIFE Study is a multicenter randomized controlled trial comparing a moderate intensity physical activity program versus a successful aging health education program in 1635 non-disabled, community-dwelling persons aged 70–89 years.[15] The assembly of this cohort has been described in detail elsewhere.[16] In brief, eligibility criteria included: 1) low physical activity, defined as spending <20 minutes/week in the past month getting regular physical activity and reporting <125 minutes/week of moderate physical activity on the modified 18-item Community Healthy Activities Model Program for Seniors questionnaire;[19] and 2) lower extremity functional limitations, defined by a Short Physical Performance Battery (SPPB) score <10,[20,21] but able to complete a 400-meter walk test in 15 minutes without sitting, leaning, or the help of another person. The Institutional Review Boards of participating centers approved all study procedures. The present study reports on the baseline evaluation of LIFE participants.

Demographic and Clinical Characteristics

The baseline characteristics included age, sex, ethnicity, body mass index (BMI, in kg/meter^2), cognition, depressive symptoms, smoking status, medical conditions, medications, caffeine/energy drink use, and health status. Cognition was evaluated by the Modified Mini-

Mental State Examination (3MSE),[22] with scores <89 defining possible cognitive impairment.[15] Depressive symptoms were evaluated by the Center for Epidemiologic Studies Depression Scale (CES-D), with scores ≥ 16 defining high levels of depressive symptoms.[23] Medical conditions were self-reported, physician-diagnosed and were selected based on their known association with sleep-wake disturbances, including: hypertension, coronary artery disease, heart failure, stroke, chronic lung disease (asthma, chronic bronchitis, emphysema, or chronic obstructive pulmonary disease), diabetes mellitus, and symptomatic arthritis. [1,2,4,6–8] Medications were defined in two ways, as the total number of prescription medications and whether participants reported the use of a prescription medication with a potential central nervous system (CNS) effect (anticonvulsant, antidepressant, antihistamine, antipsychotic, barbiturate, benzodiazepine, muscle relaxant, or an opiate). Polypharmacy was defined by the use of four or more medications.[24] Caffeine/energy drink use was established by a daily consumption of at least two cups or cans of caffeinated beverages, such as soda, energy drinks, coffee, tea, iced coffee, or iced tea.[25] To assess health status, participants were asked, “Would you say your health in general is excellent, very good, good, fair, or poor?” Reduced health was defined as a rating of “poor.”

Mobility Impairment and Physical Inactivity

Mobility measures included the 400-meter walk test (400MWT) and SPPB. The 400MWT was completed at the participant’s usual walking pace over a 40-meter course. A slow gait speed was defined as <0.8 m/s, a threshold that has been associated with adverse health outcomes,[26] including mortality.[27]

The SPPB is a summary performance measure consisting of time to walk 4 meters at usual pace, time to complete five chair stands, and three increasingly difficult standing balance maneuvers.[28] An SPPB ≤7 was selected to identify participants as having moderate-to-severe mobility impairment, relative to scores of 8 and 9 which were considered as representing mild mobility impairment.[15,20,21,28] Prior work has shown that SPPB scores of 7–9 and <7 were associated with a respective 80% and 390% increased risk of mobility-related disability, relative to SPPB ≥10.[20]

Physical inactivity was established by accelerometry, using the ActiGraph GT3X and ActiLife software (version 5) (ActiGraphTM LLC, Pensacola, FL), over a planned 7-day monitoring period. The on-line Appendix A provides a detailed description of our accelerometry data collection and processing. Briefly summarized, after dressing each morning, participants placed the accelerometer on their right hip (waistline belt), thereafter removing the monitor just prior to going to bed at night. Our measure of interest was sedentary time, defined as percent of accelerometry wear time with activity <100 counts/minute (approximated sitting time),[29] averaged across at least 5 days of monitoring, including 10 hours on each day (this amount of wear time correlates well with 3 weeks of wear time).[30] Participants who were in the top quartile were classified as having high sedentary time.

Of the 1635 LIFE participants, all completed the 400MWT and SPPB evaluation, whereas 1173 (71.7%) met the requisite accelerometer wear time definition.

Sleep-Wake Disturbances

Sleep-wake disturbances were defined by the Insomnia Severity Index (ISI), Epworth Sleepiness Scale (ESS), Pittsburgh Sleep Quality Index (PSQI), and Berlin Questionnaire (BQ).

The ISI is a 7-item questionnaire based on the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) criteria for insomnia.[12] The response to each item is scored on a 0–4 scale, yielding an ISI score ranging from 0–28, with higher scores signifying more severe symptoms. Based on prior work, an ISI ≥ 8 established a diagnosis of insomnia.[12]

The ESS measures the chance of dozing on a scale of 0–3, as experienced during eight different activities.[13] The ESS score ranges from 0–24, with higher scores signifying more severe symptoms. Two frequently cited thresholds for establishing daytime drowsiness include ESS scores of 10 and 11.[13,31–35] To establish clinically-meaningful daytime drowsiness, we opted for an ESS ≥10, because this has been used by the National Sleep Foundation (NSF) and, among older persons, is associated with other measures of daytime drowsiness, as well as hypertension, stroke, frailty, and driving capacity.[31–35]

The PSQI provides a comprehensive evaluation of sleep-wake disturbances over the prior month.[14] It includes seven subscales of subjective sleep quality, sleep latency, sleep duration, habitual sleep disturbances, use of sleep medications, and daytime dysfunction. Each subscale is weighted equally on a 0–3 scale, with the total PSQI score ranging from 0–21; the higher the score, the worse the sleep quality. Based on prior work, a PSQI >5 established poor sleep quality.[14]

The BQ consists of three categories that evaluate the clinical features of obstructive sleep apnea (OSA).[17] Category I includes five items related to snoring and witnessed apneas, with a maximum of six points available. Category II includes three items related to a history of fatigue and drowsiness, with a maximum of three points available. Category III includes a history of hypertension or BMI ≥30, with scoring based on a Yes/No response (no points assigned). A positive response for categories I and II is noted if either scores at least two points, whereas a positive response for category III requires a “Yes” response to a history of hypertension or BMI ≥30. Participants were then classified as having high risk of OSA if they had positive responses in at least two of the three categories, with all others classified as low risk.[17] Since category III does not have an assigned point score, the BQ was only evaluated as a categorical variable.

Of the 1635 LIFE participants, 1578 (96.5%) completed the ISI, 1589 (97.2%) completed the ESS, 1620 (99.1%) completed the PSQI, and 1611 (98.5%) completed the BQ. In addition, there were participants who partially completed their sleep-wake questionnaire but their scores nonetheless met criteria for a sleep-wake disturbance, including 32 participants with an ISI ≥8, 2 with an ESS ≥10, 9 with a PSQI >5, and 2 with a BQ that met criteria for high risk of OSA. Participants who met criteria for a sleep-wake disturbance based on a partially completed sleep-wake questionnaires were included in the analysis of categorical

variables but were excluded from the analysis of continuous variables, including calculation of mean values.

Statistical Analysis

The baseline demographic and clinical characteristics of study participants were first summarized as means accompanied by standard deviations or as counts accompanied by percentages. Similarly, using both continuous and categorical variables, measures of mobility, physical inactivity, and sleep-wake disturbances were also summarized. For the measures of physical inactivity and mobility impairment, their degree of correlation was additionally evaluated.

Next, in unadjusted and adjusted models, continuous measures of mobility and physical inactivity were regressed on continuous measures of sleep-wake disturbances, yielding coefficients of determination (R-squared percent values). The R-squared percent values quantified the total variability in sleep-wake disturbances that was explained by measures of mobility and sedentary time. P values for each predictor were also calculated for the explained variation of the predictor as the last variable in the model.

Similarly, but using categorical variables, the associations of slow gait speed, moderate-to-severe mobility impairment, and high sedentary time with sleep-wake disturbances (insomnia, daytime drowsiness, poor sleep quality, and high risk of sleep apnea) were evaluated by calculating odds ratios, in unadjusted and adjusted logistic regression models.

Covariates in the adjusted models included age, sex, non-white, BMI, 3MSE, high level of depressive symptoms (CES-D ≥16), number of medical conditions, polypharmacy, CNS-based medication, use of caffeine/energy drinks, and reduced health status. Because the amount of missing data was quite small for those covariates that we adjusted for in these models (see Table 1), analyses were fit to the subset of cases with complete data.

Lastly, the potential effect modification of the associations of mobility and physical inactivity with poor sleep quality was also assessed in a series of exploratory analyses. In particular, using logistic regression models, interactions were evaluated by crossing known risk factors for sleep-wake disturbances, including female sex, obesity (BMI ≥ 30), high level of depressive symptoms (CES-D ≥16), multimorbidity (≥2 medical conditions), polypharmacy (≥4 medications), use of a CNS-based medication, and reduced health status, [1,2,4,6–8,18] with slow gait speed, moderate-to-severe mobility impairment, and high sedentary time. In these analyses, the selected outcome was poor sleep quality, because it is based on the PSQI which provided a broad assessment of sleep-wake disturbances (i.e., the PSQI evaluates insomnia symptoms, daytime drowsiness, and risk factors for sleep apnea).[14] In the logistic regression models, the covariates included age, sex, non-white, BMI, 3MSE, high level of depressive symptoms (CES-D ≥16), number of medical conditions, polypharmacy, CNS-based medication, use of caffeine/energy drinks, and reduced health status, except when the covariate was the effect modifier of interest.

All statistical analyses were performed using SAS v9.3 (SAS Institute; Cary, NC), and assuming a Type I error rate of 0.05.

RESULTS

Table 1 summarizes demographics and clinical characteristics. The mean age was 78.9; 67.2% were female and 23.9% were non-white. The mean BMI was 30.2 kg/m^2, with obesity (BMI ≥30) established in 46.0% of participants. A smoking history was reported by 48.1% (former and current smokers). Possible cognitive impairment (3MSE <89) and high levels of depressive symptoms (CES-D ≥16) were identified in 26.9% and 19.6% of participants, respectively. The mean number of medical conditions (known to be associated with sleep-wake disturbances) was 1.5, with the five most prevalent being hypertension (71.0%), diabetes (25.4%), symptomatic arthritis (19.6%), chronic lung disease (15.6%), and coronary artery disease (7.9%). Participants used on average 5.4 medications, with 70.3% identified as having polypharmacy and 40.1% as using a CNS-based medication. Caffeine/energy drink use was also prevalent, reported by 79.6% of participants. A reduced health status was reported, however, by only 16.6%.

Table 2 summarizes mobility, physical inactivity, and sleep-wake disturbances, using continuous and categorical variables. A slow gait speed and moderate-to-severe mobility impairment were present in 43.5% and 44.7% of participants, respectively, with accelerometer-based activity averaging 77.0% as sedentary time. Importantly, the correlation of sedentary time with gait speed and SPPB score was only −0.26 and −0.17, respectively, indicating that sedentary time and measures of mobility are different constructs. Sleep-wake disturbances were also common, with 33.0% of participants having insomnia, 18.1% having daytime drowsiness, 47.8% having poor sleep quality, and 32.9% having high risk of sleep apnea. However, as a group, LIFE participants had mean values for the ISI (5.8), ESS (6.1), and PSQI (5.9) that were less than one-third of maximum available scores (28, 24, and 21, respectively). Moreover, among LIFE participants who met criteria for insomnia, daytime drowsiness, and poor sleep quality, the respective mean scores for the ISI (12.1), ESS (12.5), and PSQI (9.2) were only mildly abnormal.

Tables 3 and 4 show the cross-sectional associations of mobility and physical inactivity with sleep-wake disturbances, using continuous and categorical variables. As shown in Table 3, the continuous measures of mobility and sedentary time explained less than 1% of the total variability in continuous measures of sleep-wake disturbances. Similarly, but using categorical variables, Table 4 showed that the adjusted odds ratios for associations of impaired mobility and physical inactivity with sleep-wake disturbances were generally close to 1.0 and not significant.

Table 5 presents exploratory results for the cross-sectional associations of mobility impairment and high sedentary time with poor sleep quality according to several potential effect modifiers. In adjusted models, the most significant interaction was between slow gait speed and multimorbidity — adjusted OR of an association between slow gait speed and poor sleep quality of 1.29 (0.94, 1.78) and 0.71 (0.53, 0.96), for ≥2 and <2 medical conditions, respectively (interaction: $p<0.01$). A significant interaction was also seen between obesity and poor sleep quality — adjusted OR of 1.24 (0.81, 1.91) and 0.62 (0.41, 0.93), for BMI ≥30 (obesity) and <30, respectively (interaction: $p=0.02$). Because of the

large number of exploratory analyses conducted, however, these results should be interpreted with caution.

DISCUSSION

In a large sample of sedentary community-dwelling elders with functional limitations (LIFE Study), we found that slow gait speed and moderate-to-severe mobility impairment were prevalent (43.5% and 44.7%, respectively), and that a high proportion of accelerometer-based activity (77.0%) was spent as sedentary time. Similarly, sleep-wake disturbances were prevalent, including insomnia (33.0%), daytime drowsiness (18.1%), poor sleep quality (47.8%), and having a high risk of sleep apnea (32.9%). Nonetheless, using either continuous or categorical variables, mobility and physical inactivity were not associated with sleep-wake disturbances.

LIFE participants had prevalent risk factors for sleep-wake disturbances, including female sex, obesity, smoking history, depressive symptoms, polypharmacy, and use of caffeine/energy drinks.[1,2,4,8,18,25] These risk factors may have contributed to the high prevalence of sleep-wake disturbances in the LIFE Study. However, LIFE participants as a group only had mild sleep-wake disturbances, as reflected by the mean scores for ISI (5.8), ESS (6.1), and PSQI (5.9), which are less than one-third of the maximum available scores (28, 24, and 21, respectively).[12–14] Moreover, among LIFE participants who met criteria for insomnia, daytime drowsiness, and poor sleep quality, the respective mean scores for ISI (12.1), ESS (12.5), and PSQI (9.2) were only mildly abnormal. For example, mild, moderate, and severe insomnia are defined by an ISI of 8–14, 15–21, and 22–28, respectively,[12] whereas an ESS ≥16 signifies high levels of daytime drowsiness.[13] Although the PSQI has not been previously described by level of severity, an abnormal score ranges from 6 to 21, with higher scores signifying a worse sleep quality.[14]

Prior work has shown that increased multimorbidity, reduced health status, and physical disability (including mobility disability) are associated with sleep-wake disturbances.[2,4,8,36,37] Furthermore, in the LIFE Study, our results suggested a potential interaction between multimorbidity and decreased mobility for the outcome of poor sleep quality (≥2 medical conditions increased significantly the association between slow gait speed and a PSQI >5). Consequently, the mild severity of sleep-wake disturbances in the LIFE Study may be explained by low levels of symptomatic multimorbidity. In particular, LIFE participants had on average <2 medical conditions that are known to be associated with sleep-wake disturbances, [1,2,4,6–8,18] and had a health status that was poor in only 16.6% of participants. In addition, a key exclusion criterion in the LIFE Study was mobility disability, either self-reported inability to walk across a room or could not complete a 400MWT.[15,16]

The mild severity of sleep-wake disturbances in LIFE participants may also reflect their advanced age. In particular, although aging is associated with reductions in sleep physiology (e.g., reduced slow wave and rapid eye movement sleep),[5] the phenotype of sleep-wake disturbances may be milder with advancing age, in at least three ways. First, chronic sleep loss and the consequent reduction in performance across wakefulness is more prevalent and

severe in younger than older persons.[31,38–40] Second, the importance of obstructive sleep apnea (OSA) may diminish with age. For example, OSA is associated with more severe nocturnal hypoxemia and daytime drowsiness in younger than older persons, and OSA is associated with incident coronary heart disease in middle-age but not in old-age.[3,6,41] Third, by adjusting daytime activity patterns, older persons may alter the phenotype of sleep-wake disturbances. To illustrate, rates of drowsy-driving were substantially higher in a national survey of younger drivers aged 18–29 years than in a cohort of active older drivers aged ≥70 years (19.4% vs. 5.1%, respectively).[31] The different rates of drowsy-driving likely reflected age-related driving patterns, with younger persons driving longer distances than older persons (42.3 vs. 13.8 miles/day, respectively).[42] Driving a shorter distance attenuates the adverse effect of sleep-wake disturbances on driver alertness (i.e., two of the 8 items of the ESS relate to drowsiness while in a motor vehicle).[13,42]

In light of the above discussion, the lack of associations of mobility and physical inactivity with sleep-wake disturbances at the baseline visit of the LIFE Study may have been due in part to the sleep-wake outcomes being only mild in severity. Despite these results, the longitudinal component of the LIFE Study may provide important insights into the associations of mobility and physical inactivity with sleep-wake disturbances, including the importance of effect modifiers. In particular, over an average course of 2.7 years, we hypothesize that the LIFE physical activity program, relative to the successful aging (SA) education program,[15] may reduce the incidence of sleep-wake disturbances by improving mobility and physical inactivity, and that this effect is modified by health status and depressive symptoms (among other factors).[4,8,43–47]

The longitudinal component of the LIFE Study may also help clarify whether reduced mobility and physical inactivity have bidirectional associations with sleep-wake disturbances. Prior work, for example, has shown that depression and heart disease have bidirectional associations with sleep-wake disturbances.[47–49] Similarly, either because of shared risk factors (e.g. depression or heart disease) or as a direct effect, we hypothesize that insomnia and daytime drowsiness may lead to physical inactivity and deconditioning (reduced mobility), whereas physical inactivity and reduced mobility may adversely affect the homeostatic and circadian regulation of the sleep-wake cycle, thus increasing the risk of sleep-wake disturbances.[8] We plan to test this and the earlier stated hypothesis when the longitudinal data in the LIFE Study become available.

We acknowledge three limitations that may have impacted the present study. First, because the LIFE Study only enrolled sedentary individuals with functional limitations, the range of scores on measures of mobility and physical inactivity was constrained, and likely attenuated the associations of interest. To illustrate, the LIFE study had a mean time for the 400MWT of 510 seconds (8.5 minutes), yielding a mean gait speed of 0.78 m/s, whereas the InChianti Study, which involved a representative sample of community-dwelling older persons, had a mean time for the 400MWT of 331 seconds (5.5 minutes), yielding a mean gait speed of 1.12 m/s.[50] Similarly, 44.7% of LIFE participants had an SPPB score ≤7, whereas a prior study found that only 10.0% of a representative sample of community-dwelling elders (EPESE) had an SPPB <7.[22] Second, although missing values were infrequent for mobility and sleep-wake measures, 28.9% of LIFE participants did not

complete a minimum of 5-days of accelerometry. Nonetheless, these participants had a similar level of functional limitations as those who completed at least 5-days of accelerometry (mean SPPB scores of 7.2 ± 1.5 and 7.4 ± 1.6, respectively). Third, because symptom-awareness decreases with age,[51] the ISI, ESS, and PSQI may be limited as indicators of severe sleep-wake disturbances in older persons. Moreover, self-reported snoring and apneas have diminished predictive capacity for sleep apnea in older persons, thereby potentially limiting the accuracy of the BQ.[52] To address these limitations, future studies will need to enroll older persons who have a broader range of mobility capacity and physical activity, as well implement an objective evaluation of sleep-wake disturbances (e.g. wrist actigraphy and polysomnography).

In conclusion, in a large sample of sedentary community-dwelling elders with functional limitations (LIFE Study), sleep-wake disturbances were prevalent, but only mildly severe, and were g not associated with mobility impairment or physical inactivity. The next step in this line of research is to evaluate changes in these variables over time when the longitudinal LIFE Study ends. Doing so may provide important insights regarding ongoing associations of mobility impairment and physical inactivity with sleep-wake disturbances, as well as regarding the effects of increased physical activity on sleep-wake disturbances.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Research investigators for the LIFE Study group are listed in the On-Line Appendix B.

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Table 1

Demographic and clinical characteristics

Characteristic	N [a]	Mean ± SD or No. (%)
Age (years)	1635	78.9 ± 5.2
Females		1098 (67.2)
Non-white	1629	390 (23.9)
BMI (kg/m^2)	1,635	30.2 ± 6.1
BMI ≥30		752 (46.0)
Smoking status		
Never	1,606	834 (51.9)
Former		722 (45.0)
Current		50 (3.1)
3MSE	1635	91.6 ± 5.4
<89		439 (26.9)
CES-D [b]	1553	9.2 ± 8.4
≥16	1592	312 (19.6)
Number of medical conditions [c]	1631	1.5 ± 1.0
Hypertension	1621	1151 (71.0)
Diabetes mellitus	1628	414 (25.4)
Symptomatic arthritis	1625	318 (19.6)
Chronic lung disease [d]	1627	253 (15.6)
Coronary artery disease	1627	129 (7.9)
Stroke	1628	109 (6.7)
Heart failure	1622	71 (4.4)
Number of prescription medications used	1633	5.4 ± 3.3
Polypharmacy		1150 (70.4)
CNS-based		655 (40.1)
Caffeine/energy drink use	1635	1302 (79.6)
Reduced health status	1631	271 (16.6)

Abbreviations: BMI, body mass index; CES-D, Center for Epidemiologic Studies Depression Scale; CNS, central nervous system; COPD, chronic obstructive pulmonary disease; 3MSE, Modified Mini-Mental Status Exam; SD, standard deviation.

[a] N varies as a consequence of missing values.

[b] If the CES-D score was ≥ 16 but in the presence of missing questionnaire items, participants were classified as having high levels of depressive symptoms (i.e., included as a categorical variable), whereas their continuous scores were considered missing (i.e., not included in the calculation of mean values).

[c] These were self-reported, physician diagnosed, and selected on the basis of their known associations with sleep-wake disturbances.[1,2,4,7,8]

[d] Asthma, chronic bronchitis, emphysema, or COPD.

Table 2

Mobility, physical inactivity, and sleep-wake disturbances

Characteristic	N [a]	Mean ± SD or No. (%)
Mobility		
400m walk time (minutes)	1635	8.5 ± 1.9
Slow gait speed (400m gait speed <0.8 m/s)		712 (43.5)
Short Physical Performance Battery (SPPB)		7.4 ± 1.6
Moderate-to-severe mobility impairment (SPPB ≤ 7)		731 (44.7)
Physical inactivity		
Sedentary time (%) [b]	1173	77.0 ± 8.0
Sleep-wake questionnaires [c,d]		
Insomnia Severity Index (ISI) [e]	1578	5.8 ± 5.1
Insomnia (ISI ≥8)	1610	532 (33.0)
Subgroup of ISI ≥8	500	12.1 ± 3.6
Epworth Sleepiness Scale (ESS) [f]	1589	6.1 ± 3.9
Daytime drowsiness (ESS ≥10)	1591	288 (18.1)
Subgroup of ESS ≥10	286	12.5 ± 2.5
Pittsburgh Sleep Quality Index (PSQI) [g]	1620	5.9 ± 3.8
Poor sleep quality (PSQI >5)	1629	778 (47.8)
Subgroup of PSQI >5	769	9.2 ± 2.8
Berlin Questionnaire: high risk of sleep apnea [h]	1613	530 (32.9)

Abbreviations: SD, standard deviation; 400m, 400 meter.

[a] N varies as a consequence of participants being excluded because of poor testing performance, missing values, or subgroup analysis.

[b] Percent of accelerometer wear time with activity <100 counts/minute, averaged across days. Limited to participants with at least 5 days of wear time and at least 10 hours on each day.

[c] The results of the ISI, ESS, and PSQI questionnaires were reported in three ways: 1) overall mean score, 2) number of participants who had a sleep-wake disturbance, and 3) mean score for the subgroup who had a sleep-wake disturbance. The BQ was reported only as a dichotomous variable.

[d] Sample sizes for the ISI, ESS, and PSQI also varied according to the reported analysis. In particular, if the ISI, ESS, or PSQI score met criteria for a sleep-wake disturbance but the questionnaire was otherwise incomplete, a sleep-wake disturbance was still established (reported as a categorical variable), whereas the continuous score was considered missing (not included in the calculation of mean values). For example, the sample size was 1610 for estimating the frequency of insomnia (ISI ≥8) but only 1578 when calculating the overall mean ISI. Similarly, the calculation of the mean ISI among the 532 participants who had insomnia (ISI ≥8) was based on a sample size of only 500 participants.

[e] ISI ranges from 0–28, with higher scores signifying more severe insomnia.

[f] ESS ranges from 0–24, with higher scores signifying more severe daytime drowsiness.

[g] PSQI ranges from 0–21, with higher scores signifying a worse sleep quality.

[h] Required ≥2 positive categories on the Berlin Questionnaire.

Table 3

Amount of variation in sleep-wake disturbances that is explained by mobility and physical inactivity (continuous variables)

Characteristic	Sleep-Wake Disturbances					
	Insomnia Severity Index [a]		Epworth Sleepiness Scale [b]		Pittsburgh Sleep Quality Index [c]	
	R-Squared Expressed As Percent [d] (*p* value) e					
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Mobility						
400m walk time (minutes)	0.013 (0.65)	0.247 (0.04)	0.038 (0.44)	0.078 (0.27)	0.111 (0.19)	0.069 (0.26)
SPPB score	0.015 (0.63)	0.000 (0.97)	0.001 (0.89)	0.000 (0.94)	0.009 (0.70)	0.009 (0.69)
Physical inactivity						
Sedentary time (%) [f]	0.056 (0.43)	0.105 (0.26)	0.426 (0.03)	0.024 (0.60)	0.139 (0.21)	0.115 (0.22)

Abbreviations: BMI, body mass index; CNS, central nervous system; SPPB, short physical performance battery; 3MSE, Modified Mini-Mental Status Exam; 400m, 400 meter.

[a] Ranges from 0–28, with higher scores signifying more severe insomnia.

[b] Ranges from 0–24, with higher scores signifying more severe daytime drowsiness.

[c] Ranges from 0–21, with higher scores signifying a worse sleep quality.

[d] The percent contribution to R-squared values by the corresponding explanatory variable — e.g., in adjusted models, the 400m walk time explained only 0.247% of the variability in the Insomnia Severity Index.

[e] Adjusted for age, gender, non-white, BMI, 3MSE, high level of depressive symptoms (CES-D ≥16), number of medical conditions, polypharmacy, CNS-based medication, use of caffeine/energy drinks, and reduced health status (see Methods).

[f] Percent of accelerometer wear time with activity <100 counts/minute, averaged across days. Limited to participants with at least 5 days of wear time and at least 10 hours on each day.

Table 4

The odds ratios of having a sleep-wake disturbance, among participants who had slow gait speed, moderate-to-severe mobility impairment, and high sedentary time (categorical variables)

Characteristic	Sleep-Wake Disturbance							
	Insomnia [a]		Daytime Drowsiness [b]		Poor Sleep Quality [c]		High Risk of Sleep Apnea [d]	
	Odds Ratio (95% Confidence Interval) [e]							
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Slow gait speed [f]	0.99 (0.80, 1.23)	0.84 (0.66, 1.06)	1.13 (0.87, 1.47)	1.12 (0.84, 1.48)	1.10 (0.90, 1.35)	0.95 (0.76, 1.19)	1.23 (0.99, 1.52)	1.05 (0.82, 1.35)
Moderate-to-severe mobility impairment [g]	0.91 (0.73, 1.12)	0.90 (0.71, 1.13)	1.03 (0.79, 1.34)	0.99 (0.76, 1.31)	0.99 (0.81, 1.21)	1.00 (0.80, 1.24)	0.95 (0.77, 1.18)	0.99 (0.78, 1.26)
High sedentary time [h]	1.05 (0.79, 1.40)	1.01 (0.74, 1.39)	1.41 (1.01, 1.98)	1.18 (0.83, 1.69)	0.83 (0.63, 1.08)	0.82 (0.61, 1.10)	0.95 (0.71, 1.27)	0.92 (0.66, 1.27)

Abbreviations: BMI, body mass index; CES-D, Center for Epidemiologic Studies Depression Scale; CNS, central nervous system; 3MSE, Modified Mini-Mental Status Exam.

[a] Insomnia Severity Index: ≥ 8 (insomnia) vs. <8 (reference group).

[b] Epworth Sleepiness Scale: ≥ 10 (daytime drowsiness) vs. <10 (reference group).

[c] Pittsburgh Sleep Quality Index: >5 (poor sleep quality) vs. ≤ 5 (reference group).

[d] Berlin Questionnaire: ≥ 2 positive categories (high risk of sleep apnea) vs. <2 positive categories (reference group).

[e] Adjusted for age, gender, non-white, BMI, 3MSE, high level of depressive symptoms (CES-D ≥ 16), number of medical conditions, polypharmacy, CNS-based medication, use of caffeine/energy drinks, and reduced health status (see Methods). Results for sedentary time changed minimally when accelerometer wear time was entered into the adjusted model.

[f] 400 meter gait speed <0.8 m/s.

[g] Short Physical Performance Battery score ≤ 7.

[h] Highest quartile of percent accelerometer wear time with activity <100 counts/min. Limited to participants with at least 5 days of wear time and at least 10 hours on each day.

Table 5

Odds ratios for the associations of slow gait speed, moderate-to-severe mobility impairment, and high sedentary time with poor sleep quality (PSQI >5), according to effect modifier

Effect Modifier	Slow Gait Speed [a]		Moderate-to-Severe Mobility Impairment [b]		High Sedentary Time [c]	
	Poor Sleep Quality (PSQI >5)					
	OR (95% CI) [d]	P value for Interaction	OR (95% CI) [d]	P value for Interaction	OR (95% CI) [d]	P value for Interaction
Gender						
Female	0.84 (0.64, 1.09)	0.11	0.97 (0.75, 1.26)	0.71	0.83 (0.56, 1.23)	0.77
Male	1.22 (0.83, 1.80)		1.06 (0.73, 1.53)		0.90 (0.58, 1.42)	
BMI						
≥30	1.07 (0.78, 1.46)	0.23	0.92 (0.68, 1.26)	0.52	1.24 (0.81, 1.91)	0.02
<30	0.82 (0.61, 1.12)		1.06 (0.79, 1.42)		0.62 (0.41, 0.93)	
CES-D						
≥16	0.92 (0.72, 1.17)	0.62	1.05 (0.83, 1.33)	0.30	0.86 (0.63, 1.19)	0.95
<16	1.06 (0.63, 1.78)		0.78 (0.47, 1.30)		0.84 (0.41, 1.72)	
Multimorbidity						
Medical conditions ≥2	1.29 (0.94, 1.78)	<0.01	1.09 (0.80, 1.50)	0.43	0.94 (0.61, 1.44)	0.59
Medical conditions <2	0.71 (0.53, 0.96)		0.93 (0.69, 1.23)		0.80 (0.54, 1.20)	
Polypharmacy						
≥ 4 medications	1.02 (0.79, 1.32)	0.23	0.99 (0.77, 1.28)	0.96	0.85 (0.61, 1.19)	0.88
< 4 medications	0.76 (0.50, 1.15)		1.01 (0.68, 1.49)		0.89 (0.50, 1.59)	
CNS-based medication						
Any	0.99 (0.70, 1.39)	0.70	0.95 (0.68, 1.33)	0.70	0.96 (0.61, 1.51)	0.53
None	0.91 (0.69, 1.21)		1.03 (0.78, 1.36)		0.80 (0.54, 1.17)	
Health status [e]						
Reduced	1.30 (0.76, 2.23)	0.20	0.97 (0.57, 1.65)	0.91	0.89 (0.44, 1.80)	0.92
Not reduced	0.89 (0.70, 1.13)		1.00 (0.79, 1.27)		0.85 (0.62, 1.18)	

Abbreviations: BMI, body mass index; CES-D, Center for Epidemiologic Studies Depression Scale; CI, confidence interval; CNS, central nervous system; OR, odds ratio; PSQI, Pittsburgh Sleep Quality Index; 3MSE, Modified Mini-Mental Status Exam.

[a] 400 meter gait speed <0.8 m/s.

[b] Short Physical Performance Battery score ≤7.

[c] Highest quartile of percent accelerometer wear time with activity <100 counts/min. Limited to participants with at least 5 days of wear time and at least 10 hours on each day.

[d] Adjusted for age, gender, non-white, BMI, 3MSE, high level of depressive symptoms (CES-D ≥16), number of medical conditions, polypharmacy, CNS-based medication, use of caffeine/energy drinks, and reduced health status, without the variable that was the effect modifier of interest. See Methods.

[e] Reduced health status was defined as a rating of “poor.”