Morning or Evening Activity Improves Neuropsychological Performance and Subjective Sleep Quality in Older Adults

Susan Benloucif, PhD[1]; Larry Orbeta[1]; Rosemary Ortiz[1]; Imke Janssen, PhD[1]; Sanford I. Finkel, MD[2]; Joseph Bleiberg, PhD[3]; Phyllis C. Zee, MD, PhD[1]

[1]Department of Neurology, Northwestern University Feinberg School of Medicine, Chicago, IL; [2]Geriatric Institute, Council for Jewish Elderly, Chicago, IL; [3]Neuroscience Research Center, National Rehabilitation Hospital, Washington, DC

Study Objectives: Sleep disturbances and decline in neuropsychological performance are common in older adults. Reduced social and physical activity is likely a contributing factor for these age-related changes in sleep and cognition. We previously demonstrated that a program of structured social and physical activity, with 2 daily activity sessions, 1 in the morning and 1 in the evening for a relatively short period of 2 weeks, improved sleep and neuropsychological performance in community-dwelling older adults. The goals of this pilot study were to determine whether a single daily morning or evening activity session for 2 weeks would also improve sleep and neuropsychological function and whether these effects were dependent on the timing of the activity sessions.

Design: We compared the effect of morning or evening structured activity sessions in a repeated-measures crossover design. Subjective mood, neuropsychological performance tasks, and subjective and objective measures of sleep were assessed at baseline and after the intervention.

Setting: All procedures took place in the participant's residence.

Participants: Twelve older men and women (74.6 ± 5.5 years of age).

Interventions: Subjects participated in 14 days of structured activity sessions in the morning (9:00-10:30 am) or evening (7:00-8:30 pm). Sessions consisted of stretching, low-impact aerobics, and game playing.

Measurements and Results: Exposure to either morning or evening activity significantly improved performance on a neuropsychological test battery. Morning activity sessions increased throughput on 4 of 8 performance tasks, while evening activity sessions improved throughput on 7 of the 8 performance tasks. Subjective sleep-quality ratings, measured by the Pittsburg Sleep Quality Index, improved following activity sessions in either the morning or the evening. Objective measures of sleep did not improve when measured by actigraphy or polysomnography.

Conclusions: These results suggest that short-term exposure to either morning or evening social and physical activity improves objective measures of neuropsychological performance and subjective sleep quality in the elderly. Increasing exposure to social and physical activity may be a useful intervention to improve sleep quality and daytime function in older adults.

Key Words: Sleep, aging, performance, exercise

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INTRODUCTION

THERE IS AN AGE-RELATED INCREASE IN SLEEP COMPLAINTS, WITH MORE THAN HALF OF ADULTS OVER THE AGE OF 65 REPORTING AT LEAST 1 SLEEP COMPLAINT AND MORE THAN ONE THIRD OF OLDER ADULTS REPORTING SLEEP-MAINTENANCE INSOMNIA OR EARLY-MORNING AWAKENING.[1-3] Beginning as early as middle age and increasing with each decade of life, objectively recorded sleep in this population is characterized by reductions in "deep" or slow-wave sleep (SWS) and increases in "lighter" stages (1 and 2) of sleep.[4-6] Older adults also wake up frequently during the night, resulting in sleep fragmentation and decreased sleep efficiency.[1] A substantial proportion of sleep complaints in older adults are associated with mental or physical health problems.[2,7,8] However, even in the absence of physical health problems, more than one fourth of adults over 65 years of age report at least 1 chronic sleep complaint.[2] A decline in cognitive function is also common with advanced age, and a number of studies have shown that disturbed sleep in younger adults has a negative impact on cognitive function and quality of life.[5,9-11] A strong association is also seen between daytime sleepiness and cognitive decline in older adults.[7]

Many of the health changes associated with aging, including the decline in sleep and cognitive abilities, can be attributed to sedentary lifestyles and social disengagement among older individuals.[12-14] Evidence suggests that maintenance of social engagement and avoidance of social isolation are important factors in maintaining cognitive vitality in old age.[14] Adults aged 65 and above with no social ties are at increased risk for incident cognitive decline after adjusting for a variety of factors, including age, initial cognitive performance, education, income, and level of physical activity.[13] Sociopsychological cues, such as daily contacts with other individuals and structured schedules of activity, are also thought to play a role as zeitgebers (synchronizing stimuli) for the circadian variation of the sleep/wake cycle.[15,16] Sleep schedules and social contacts have phase-resetting properties that can be separated from the effects of the light/dark cycle.[17]

Studies that have examined the effect of exercise on sleep indicate that exercise can improve both subjective and objective ratings of sleep quality in older adults.[18] Men aged 60 years and above who are aerobically fit have been shown to have shorter

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Disclosure Statement

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Address correspondence to: Susan Benloucif, Northwestern University Feinberg School of Medicine, Dept. of Neurology, Abbott Hall, 11th Floor, 710 N. Lake Shore Drive, Chicago, IL 60611; Tel: 312-503-1528; Fax: 312-908-5073; E-mail: s-benloucif@northwestern.edu

sleep-onset latencies, less wake time after sleep onset, higher sleep efficiencies, and fewer discrete sleep episodes during the night than sedentary subjects.[19] Aerobic fitness has also been shown to be associated with increased SWS and decreased sleep latency in both young and older adults.[20] Several studies have shown improvement in subjective and objective sleep quality following an exercise intervention. Moderate-intensity exercise over 16 weeks was found to improve subjective sleep quality in 50- to 76-year-old subjects,[21] and aerobic fitness training over a period of 3 months reduced fragmentation of the rest/activity rhythm in elderly men, suggesting improved consolidation of nocturnal sleep.[22] Improvements in subjective sleep quality have also been associated with increased fitness following a year of moderate intensity exercise or stretching in postmenopausal women.[23] Shorter programs of increased social and physical activity can also improve objective sleep quality in older adults.[24]

Problem solving and the ability to integrate new information decline both with age and with decreasing physical fitness.[25] Participation in a regular aerobic exercise program has been shown to slow or even reverse age-related declines in cognitive abilities in middle age.[26] Middle-aged to older adults who exercise regularly exhibit better neuropsychological performance than sedentary controls, even when controlling for self-rated health, medical conditions, and medication use.[27-29] In a longitudinal study, after controlling for baseline health status, women over the age of 65 with greater physical activity levels at baseline were less likely to experience cognitive decline during the 6 to 8 years of follow up than were women with low levels of physical activity.[30] Controlled studies have also demonstrated the effectiveness of exercise to improve cognitive performance in previously sedentary older adults. Sedentary adults aged 55 and older who participated in a 4-month aerobic exercise program (walking/jogging) or 6 months of regular walking showed greater improvement in cognitive function than controls who were either inactive or performed stretching and toning.[31, 32]

Our group has shown that a combined program of social and moderate level of physical activity, with 2 daily activity sessions, 1 in the morning and 1 in the evening for 2 weeks, increased SWS and improved memory functioning on selected paper and pencil tests and a computerized test battery in older adults between 65 and 92 years of age in comparison with a control group.[24] Although effective, a program that requires both morning and evening sessions on a daily basis has limited practical applications. Therefore, in the present pilot study, we sought to determine whether a single daily session of social and moderate physical activity would be sufficient to improve sleep and daytime neuropsychological performance in older adults and to assess whether the time of participation (morning or evening) would affect the efficacy of the intervention.

METHODS

Subjects

Older adults were recruited from independent-living retirement facilities and residential apartments via community presentations, fliers, and word of mouth. Fourteen subjects were enrolled in this pilot study, 7 of the subjects were recruited from the same independent-living retirement community, and 7 of the subjects were recruited from 3 different apartment complexes. Data are reported from 12 of the subjects who completed both phases of the crossover protocol. The group consisted of 4 men and 8 women between 67 and 86 years of age (mean 74.4 ± 5.5 years). Subjects had no or mild dementia, scoring above 26 on the Mini-Mental Status Examination.[33] Subjects were healthy older adults or adults with chronic but stable medical conditions and independent in their activities of daily living. Subjects with acute or unstable medical conditions were excluded. Chronic medical conditions present in the group of subjects included hypertension, arthritis, and diabetes. Of the 2 subjects who did not complete the crossover, 1 woman withdrew from the study due to time constraints and 1 man did not complete the crossover due to a change in medical condition during the course of the 3-month study. Subjects were free of psychotropic or hypnotic medication use. The study was approved by the Northwestern University Institutional Review Board, and informed consent was obtained from all participants. Subjects were compensated for their participation.

Procedures

The protocol had 2 components, counterbalanced in order, of intervention in either the morning (9:00 to 10:30 AM) or evening (7:00 to 8:30 PM). Each study consisted of a 10-day baseline period including 10 days of sleep and activity logs and actigraphy and 2 days of testing at the end of the baseline period, a 14-day intervention period (morning or evening activity), and 2 days of posttreatment testing immediately following the intervention period. There was a 1-month washout period between each study. Throughout each study, sleep and activity were assessed via wrist-worn activity monitors (Cambridge Neurotechnology, Ltd., Cambridge, UK) and daily sleep and activity logs. During the baseline and posttreatment testing, daytime performance, mood, and vigor were assessed every 2 hours throughout the day for 12 hours. Subjective sleep quality was assessed with the Pittsburgh Sleep Quality Index (PSQI) at baseline and posttreatment. Sleep recording with polysomnography (PSG) was conducted on the 2 baseline and posttreatment nights. All procedures were conducted in the homes of the participants.

Intervention

Groups of 2 to 3 subjects from the same building joined in the social/physical activity sessions. Subjects from the retirement community met in the community room, while subjects from the apartment complexes met in 1 of the subject's apartments. Each 1.5-hour session was led by a member of the research staff and consisted of approximately 30 minutes of mild physical activity, 30 minutes of social interaction, with a final 30 minutes of mild to moderate physical activity. The sessions began with warm-up stretching and mild to moderate physical activity (walking, stationary upper and lower body exercises), followed by seated social interaction (talking while playing board or card games). The final period consisted of mild to moderate physical activity (nonstationary exercises such as rapid walking, calisthenics, or dancing) for 20 minutes, ending with a 10-minute cool down. The specific activities were adjusted based on the physical condition of the participants and increased in rigor over the 14-day period. A variety of games and exercises were utilized to maintain the motivation and interest of the participants. Subjects were not asked to refrain from exercise at other than scheduled times.

Daytime Performance, Mood, and Vigor

Cognitive and psychomotor performance were assessed throughout the 2 days of baseline and posttreatment testing with paper and pencil tests and the Automated Neuropsychological Assessment Metrics test battery.[24,34-36] Baseline and posttreatment testing conditions were controlled to the extent possible within the limitations of a field study. Subjects were allowed to eat at their usual times, to participate in usual activities, and to leave their apartments between test sessions. Testing by the study coordinator occurred in each subject's own apartment during the day, just prior to the nights of PSG recording. Testing sessions, each lasting approximately 20 minutes, were conducted every 120 minutes for 12 hours beginning 2 hours after habitual wake. The automated computer performance battery was conducted using the same laptop computer and consisted of 4 tests: Sternberg Memory (4 letters), Running Memory, Math Processing, and Spatial Processing. Accuracy and reaction times were recorded for each test item, and task throughput was calculated as the number of correct responses divided by the average reaction time, multiplied by 100.

To minimize practice effects and allow the subjects to become familiar with the computer controls (left and right clicks on the computer mouse), subjects were loaned a laptop computer and instructed to practice the performance tasks several times each day on the week prior to the baseline testing period. Practice was monitored to ensure that the subjects had reached a plateau in the percentage of correct responses, which usually took about 10 practice trials. Subjects continued to practice after this time until they felt comfortable with the operation of the computer and with the tests. On the evening prior to testing, subjects practiced the test battery in the presence of research staff to ensure understanding of the testing procedures. In addition to the computerized tests, timed paper and pencil tests (symbol copying, digit-symbol substitution, visual search (E search), and a 2-letter logical reasoning task (M before C) were administered to assess fine-motor speed and coordination, verbal reasoning, attention, visual scanning, and visual-motor efficiency and integration. Throughput of the paper and pencil tests was calculated as the number of correct responses divided by the time allotted for each test, multiplied by 100.

Subjective measures of global vigor and global affect were derived from visual analog scale ratings. Subjects indicated, by placing a mark on a 10-cm line, how they felt at the moment. The left side of the line stated "very little" and was scored as 0, the right side of the line stated "very much" and was scored as 10. Questions assessed alertness, sleepiness, weariness, and amount of effort (vigor), and happiness, sadness, calmness, and tenseness (affect).[37]

Sleep

Subjects maintained daily sleep diaries in which bedtime, wake-up time, estimated total sleep time, sleep-onset latency, wake after sleep onset, naps, and any unusual events during the day or night were recorded. Sleep and activity were also recorded throughout the baseline and intervention period by an activity monitor (Actiwatch system Cambridge Neurotechnology, Ltd, Cambridge, England). Subjects wore an Actiwatch on the nondominant wrist continuously during the study (except when bathing or swimming). Daily activity recordings obtained via the wrist monitors were utilized to verify sleep periods. Five days from the baseline period and 5 days from the second week of the treatment period were used to calculate the total sleep time, sleep efficiency, sleep-onset latency, wake after sleep onset, and mean activity level (Sleepwatch Analysis Software, Cambridge Neurotechnology, Cambridge, England). Complete activity records (baseline and posttreatment for both the morning and evening protocols) were available for 10 of the 12 subjects.

Following the final testing session on the 2 baseline and posttreatment testing days (approximately 8:00 PM) electrodes were attached for PSG recording of sleep using the 10-20 system for monitoring central and occipital electroencephalogram, electrooculogram and submental electromyogram.[38,39] A portable sleep-recording system (Digitrace Care Services, Boston, Mass) was used to record sleep unattended in the subject's own bedroom. Due to the already extensive testing and research-participant burden, a third adaptation night was not performed. The "first-night effect" of an unfamiliar sleep environment was minimized by having the subjects sleep in their own beds. Polygraphic sleep recordings were visually scored at 30-second epochs by an experienced sleep technician, according to standard criteria.[40] The following sleep measures were calculated from the polysomnographic record: total sleep time, sleep efficiency, wake after sleep onset, sleep-onset latency, sleep maintenance, stage 1, stage 2, stage 3+4 (SWS), and rapid eye movement sleep. The PSG data from 2 subjects were excluded from the analysis because of technical difficulties in 1 subject and medication use in the second. Thus, PSG data were available for 10 subjects.

Subjects completed the PSQI at the end of the baseline period and following the 2-week treatment period.[41] The 21-item PSQI yields a global score, which represents the sum of 7 individual component scores. The component scores are (1) subjective sleep quality, (2) sleep latency, (3) sleep duration, (4) habitual sleep efficiency, (5) sleep disturbances, (6) use of medications for sleep, and (7) daytime dysfunction.[41] Subjects were asked to rate their sleep over a 2-week period at baseline and at the completion of the intervention.

Statistical Analyses

This study was designed as an AB/BA crossover trial.[42] Each subject was treated in the morning protocol and in the evening protocol, each for 2 weeks. However, subjects were randomly assigned to 1 of the 2 groups, defined by whether the morning or evening treatment was taken first. The primary analysis consisted of comparing pretreatment values to posttreatment values from baseline to posttreatment for performance tests and visual analog scale variable. To analyze actigraphy, sleep variables, performance tests, and mood/vigor ratings, we used repeated-measures analysis of variance (rm-ANOVA) with 2 repeated factors (AM vs PM activity, and Baseline vs Posttreatment). Preplanned comparisons were treatment (average of Day 1 and Day 2 vs average of Day 3 and Day 4) for each protocol. To put measures from different tests on the same scale, we calculated the percentage change from baseline for each time point for each person. On these percentages, we used rm-ANOVA with 2 within-subjects factors (protocol and time point). As sleep stages are not equally distributed over the entire night, sleep parameters were also compared over halves and thirds of the night. In some instances, such as with SWS parameters and certain neuropsychological tests, unplanned comparisons were implemented due to new information that became available during the conduct and analysis of the studies. Because a crossover design was used, the average from baseline and posttreatment values of each test from the study were also analyzed using the methods of Senn,[42] both as an alternative analysis and to test the assumption of no carryover effect from the first treatment to the second. No carryover or period effects were found, so that we can assume that the washout period was sufficiently long enough. We therefore used the pooled data for each treatment from both periods to estimate the treatment effect.

RESULTS

The morning or evening sessions increased levels of physical activity, as determined by wrist-worn activity monitors (Figure 1). At baseline, there was a tendency for higher levels of activity in the morning (9:00-10:30 AM) than in the evening (7:00-8:30 PM, *P* = .077). The social/physical activity intervention increased activity levels in comparison with activity levels measured at the same time of day during the baseline period (*P* = .002). Morning activity sessions resulted in activity counts that were 1.9 times those observed during baseline. Evening activity sessions resulted in activity counts that were 2.1 times those observed during baseline. Peak activity counts during treatment were approximately 3 times those observed during the baseline period. There was no significant difference between the effect of the morning or evening intervention on activity levels, and no interaction between the 2 factors (AM vs PM, baseline vs posttreatment).

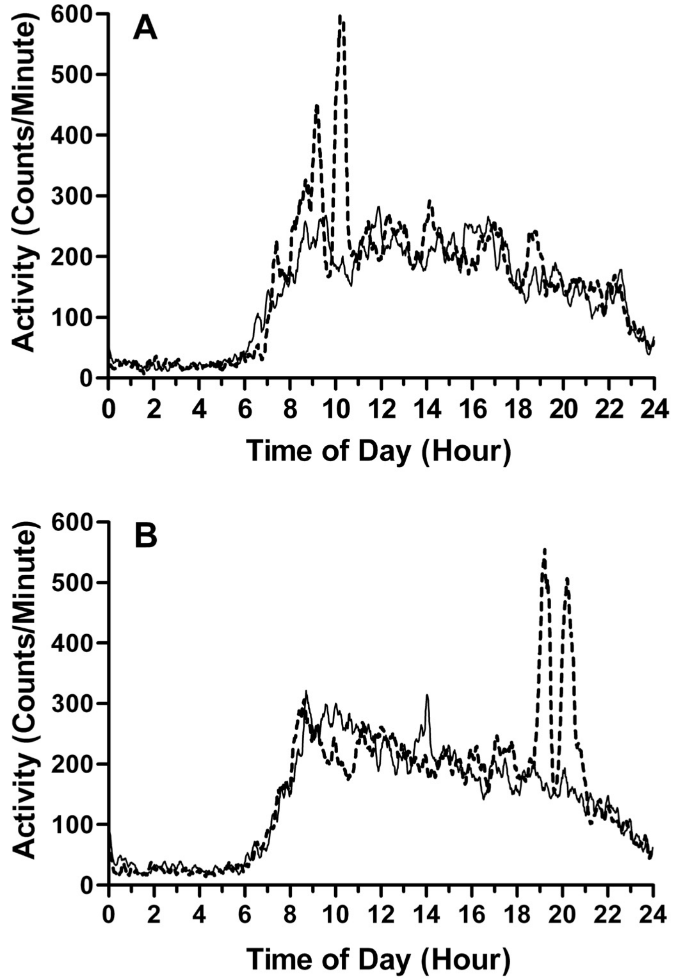

Figure 1—Average 24-hour activity profiles at baseline (solid) and during treatment (dashed). Subjects participated in both the (A) morning and (B) evening activity protocols in a repeated-measures crossover design. The 90-minute activity intervention consisted of 30 minutes of social interaction bordered by two 30-minute periods of physical activity. Activity levels were measured by wrist-worn activity monitors and averaged over 5 days at baseline and during the last week of treatment.

Daytime Performance and Mood

Social/physical activity intervention for 14 days in either the morning or the evening improved neuropsychological performance (Figure 2). Overall percentage change in throughput ranged form 4.80% ± 1.73% (Digit symbol substitution) to 6.76% ± 2.71 % (M before C) for the morning activity protocol. Overall percentage change in throughput ranged from 3.86% ± 1.48% (Sternberg 4) to 6.89% ± 1.85% (Digit Symbol Substitution) in the evening activity protocol (Figure 2). The effect size for those tests that were significantly improved by the intervention ranged from 0.598 (M before C) to 1.235 (E search, Table 1). There was no significant difference in percentage change in performance between the morning and evening activity protocols. However, the number of tests that showed improvement was greater for the evening activity protocol. Assessment of treatment-induced changes in throughput (baseline to posttreatment) revealed significant improvement on 4 of 8 tests following 14 days of morning activity (Mathematical Processing, Digit Symbol, E search, M before C) and 7 out of 8 tests following evening activity (Sternberg 4, Symbol copy, Mathematical processing, Running memory, Digit symbol, E search, M before C) (*P* < .05, Table 1). Activity session-induced improvements in performance across the 7 daily time periods are illustrated in Figure 2. Improvements in performance following the evening activity protocol were generally observed throughout the entire day, whereas improvements in performance following morning activity were less consistently observed throughout the day.

To determine whether order or practice effects contributed to the improvement in neuropsychological performance, we plotted throughput by the order of testing (Figure 3: First baseline, First posttreatment, Second baseline, Second posttreatment) irrespective of the timing of the intervention. With the exception of the spatial-processing task, performance on the highly practiced computerized performance tests returned to near baseline levels in the washout period between the first and second treatment conditions, indicating a negligible effect of practice (Figure 3, left panel). Statistical comparison revealed that treatment-induced improvements in throughput (baseline to posttreatment) on mathematical processing and running memory were significantly greater (*P* = .02 and *P* = .01, respectively) than changes in throughput due to practice alone (change from the first posttreatment to second baseline). This difference also approached significance for the Sternberg 4 test (*P* = .12).

In comparison, throughput on the paper and pencil tests, which were not practiced prior to baseline testing, remained at the same level or slightly higher on the second baseline period as on the first posttreatment period, indicating a contribution of practice effects to the improvement in throughput after treatment (Figure 3, right panel). The improvement during the treatment period

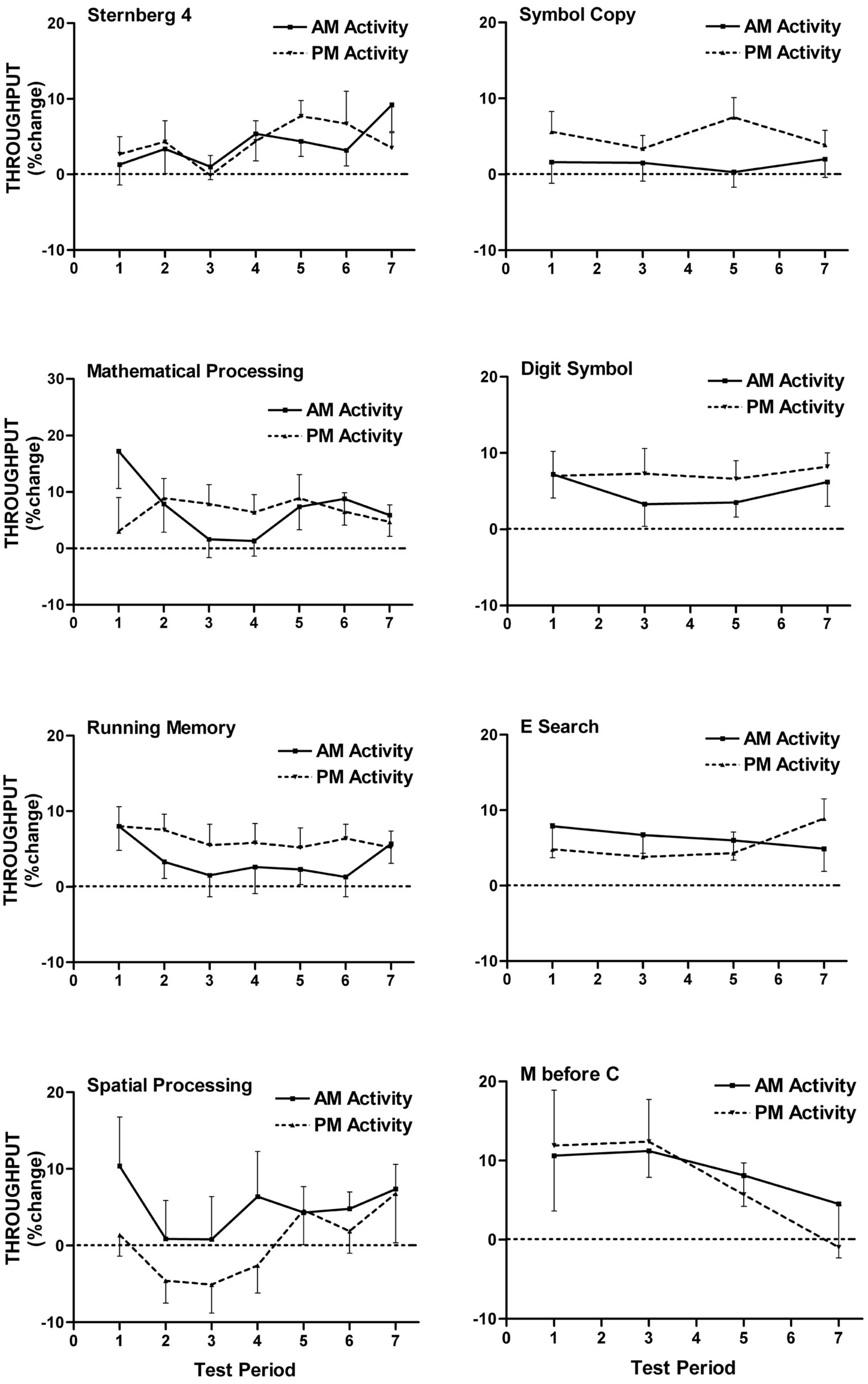

Figure 2—Percentage improvement in throughput of neuropsychological performance tests. Subjects completed both morning (solid) and evening (dashed) activity protocols in a repeated-measures crossover design. Computerized neuropsychological performance tests (left panel) were conducted every 2 hours throughout the day, beginning 2 hours after wake. Throughput was calculated as accuracy/reaction time × 100. Paper and pencil tests (right panel) were completed every-other test period. Throughput was calculated at the number of correct responses/allotted time × 100.

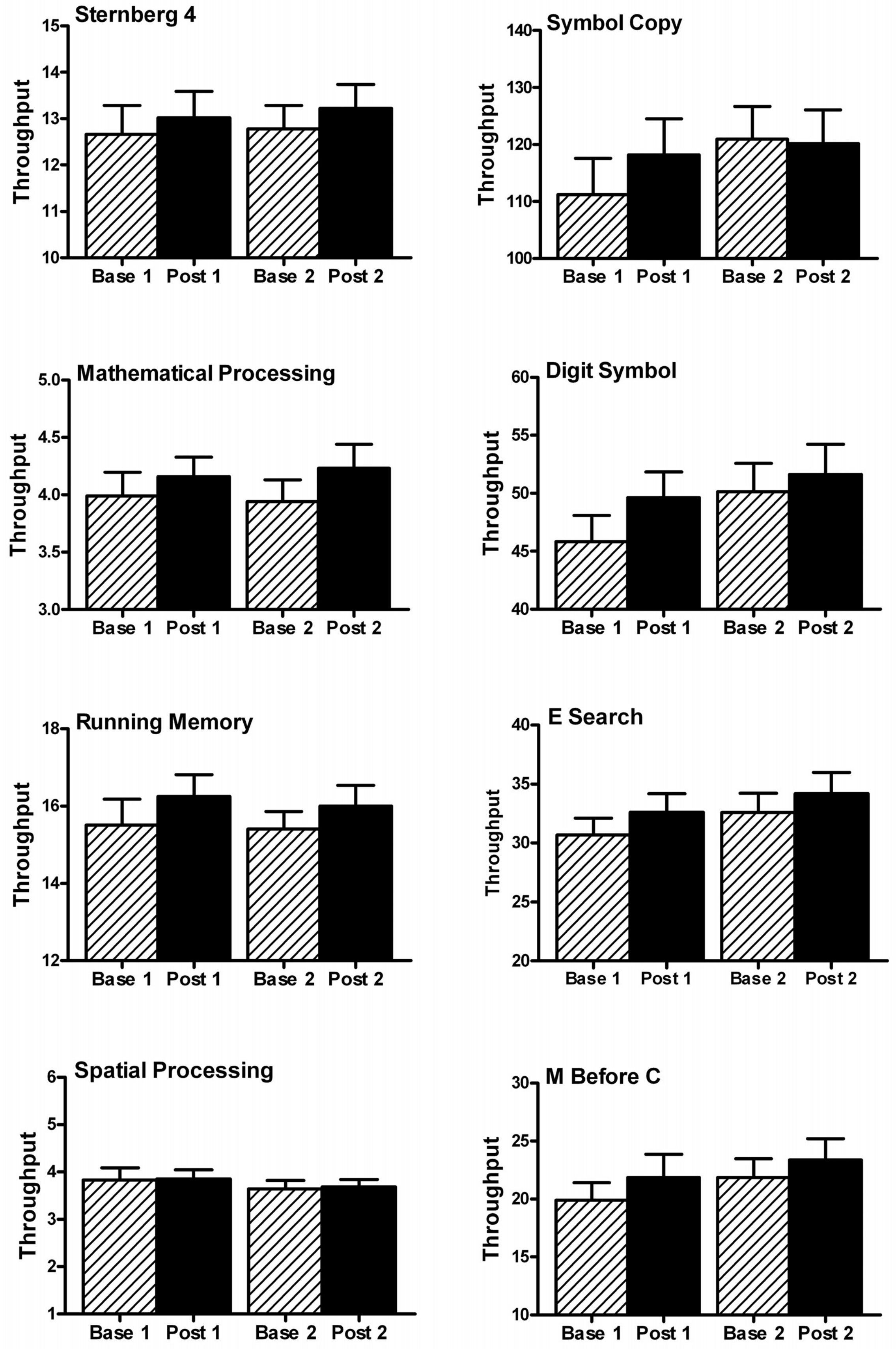

Figure 3—Treatment and practice effects on improvements in neuropsychological performance. Throughput on the neuropsychological performance tests was plotted based on the order of the test session (Base 1: First baseline, Post 1: First posttreatment, Base 2: Second baseline, Post 2: Second posttreatment), irrespective of the timing of the intervention (AM or PM). With the exception of spatial processing, throughput on the computerized performance tests (left panel) returned toward baseline values in the 1-month washout period between the first treatment and second treatment periods. Throughput on the paper and pencil tests (right panel) either remained the same or increased very slightly between treatment periods. These results indicate that improvements in throughput from baseline to posttreatment were not merely due to practice effects.

(baseline vs posttreatment) tended to be greater in comparison with the washout period (first posttreatment vs second baseline) for the Digit Symbol test (P = .09) but was not significantly greater for the other paper and pencil tests. However, while throughput remained stable (neither increasing nor returning to baseline levels) from the first posttreatment test session to the second baseline session, throughput increased significantly between the second baseline and posttreatment sessions for Digit Symbol (P = .02) E Search (P = .02) and M before C (P = .03) tests. Thus, both practice and intervention effects contributed to the improvement in performance for these paper and pencil tests over the course of the protocol.

There was no effect of evening activity on any of the mood or vigor variables as measured by the visual analog scale. However, with the morning social and physical activity sessions, there was a significant increase in subjective ratings of calm (P = .015), predominantly due to improvements in the afternoon (2:00 and 4:00 PM), and a trend for higher rating of feeling happy throughout the day (P = .069).

Subjective Sleep Quality

Baseline subjective sleep quality as assessed by the PSQI did not differ prior to the 2 intervention phases. PSQI results were available from 9 out of 12 subjects. Global scores averaged 6.33 ± 3.84 for the 2 weeks prior to the morning activity condition and 6.44 ± 2.07 prior to the evening activity condition. Using a criterion of a global PSQI score of 5 or less, 4 of the 9 subjects were classified as “good” sleepers at baseline.[41,43] The subgroup of good sleepers consisted of 1 man and 3 women, while the subgroup of “poor” sleepers consisted of 1 man and 4 women.

There was a significant improvement in subjective sleep quality following 2 weeks of either morning or evening social and physical activity ($F_{1,8}$ = 12.71, P = .007), with no difference between the treatment conditions. The global PSQI scores following morning or evening activity sessions were 5.0 ± 2.5 and 5.25 ± 2.89, respectively. The global PSQI score of subjects who were good sleepers (score 5 or less) at baseline did not change (average change of 0.3 ± 1.2) over the 2 treatments, while those classified as poor sleepers at baseline improved their global score by an average of 2.1 ± 2.0. The component scores of subjective Sleep Latency (P = .06), Sleep Duration (P = .10), and Sleep Efficiency (P = .10) were the greatest contributors to the significant improvement in the Global score for the entire group.

To determine whether there was a relation between improvements in sleep and improvements in neuropsychological performance, we conducted correlation analysis between the baseline to posttreatment change in the global PSQI score and the baseline to posttreatment change in throughput. There was no statistically significant correlation between improvement in subjective sleep quality and improvement in throughput on any of the neuropsychological performance tasks in this sample.

Sleep Measures

Sleep parameters as assessed by actigraphy and polysomnography are shown in Tables 2 and 3, respectively. Baseline SE was 81% as measured by actigraphy and 76% as measured by PSG. Total sleep time at baseline averaged 6 hours 20 minutes measured by actigraphy and 5 hours 50 minutes measured on the 2

Table 1—Effects of Morning and Evening Activity on Neuropsychological Performance Measures

Performance Task	**Morning Activity**		**Evening Activity**	
	Effect	*P* value	Effect	*P* value
Sternberg 4	0.700	.052	0.753	.035*
Mathematical Processing	0.858	.018*	0.719	.028*
Running Memory	0.600	.053	0.934	.006*
Spatial Processing	0.341	.659	0.028	.481
Symbol Copy	0.178	.294	0.817	.014*
Digit Symbol	0.801	.023*	1.075	.001*
E Search	1.235	.004*	0.982	.004*
M before C	0.720	.042*	0.598	.016*

Effect size and P values for comparison of baseline vs posttreatment changes in throughput (*P < .05)

Table 2—Results of Actigraphy Obtained During 5 Baseline Nights and 5 Treatment Nights

Parameter	**Morning Activity**		**Evening Activity**	
	Baseline	Posttreatment	Baseline	Posttreatment
TST, h	6.43 ± 0.37	6.30 ± 0.20	6.25 ± 0.23	6.33 ± 0.37
SOL, h	0.18 ± 0.05	0.22 ± 0.03	0.22 ± 0.03	0.18 ± 0.03
SE, %	81.07 ± 2.90	82.00 ± 2.50	80.10 ± 3.20	79.10 ± 4.30
WASO, h	0.93 ± 0.17	0.85 ± 0.18	0.97 ± 0.20	1.02 ± 0.20
Sleep start	23.60 ± 0.18	23.03 ± 0.48	23.63 ± 0.22	23.67 ± 0.15
Sleep end	7.20 ± 0.23	6.90 ± 0.17	7.10 ± 0.25	7.22 ± 0.23
Get up time	7.35 ± 0.22	7.03 ± 0.17*	7.28 ± 0.25	7.50 ± 0.20

Data are presented as mean ± SEM. TST refers to total sleep time; SOL, sleep-onset latency; SE, sleep efficiency; WASO refers to wake after sleep onset.
*P <.05

nights of polysomnographic recording. Actigraphy measures showed an earlier getting up time by 19 minutes during the last week of the morning activity protocol (P = .013). In addition, with the morning activity session, there was a trend for earlier sleep onset (34 minutes, P = .058), as well as earlier sleep offset (18 minutes, P = .081). The only parameter to change in the evening activity condition was a tendency for subjects to get out of bed at a later time during the last week of the treatment period (13 minutes, P = .079).

PSG parameters showed no change in sleep latency, sleep efficiency, sleep maintenance, or in the amount or percentage of sleep stages for either morning or evening activity conditions from baseline to the 2 nights immediately following treatment (Table 3). Correlation analysis did not show a relation between the effectiveness of the activity intervention to increase activity levels and treatment-induced changes in sleep parameters.

DISCUSSION

Participation in a short-duration social and physical activity program either in the morning or early evening improved neuropsychological performance and subjective sleep quality in older adults. However, neither activity session significantly improved sleep parameters as measured by actigraphy or PSG. Subjective ratings of vigor and mood were largely unaffected by exposure to either the morning or evening activity sessions.

A single daily session of social and physical activity resulted in a 4% to 6% improvement in neuropsychological performance from baseline within individuals. Given the short duration and moderate level of the intervention, the effect size compares favorably with the 11% improvement in performance observed in digit symbol performance following 4 months of aerobic exercise in previously sedentary older adults.[31] This improvement in neuropsychological performance was not merely due to a practice effect, as performance returned to baseline following a washout period of 1 month on the computerized tests and improved more than the magnitude attributable to practice effects on the paper and pencil tests. We previously reported activity-induced improvements in neuropsychological function in comparison with a control group.[24] Thus, we believe that the observed improvement in neuropsychological performance is due to the activity intervention, rather than participation in the experimental protocol by itself.

Although this study cannot distinguish the relative contribution of the social and physical activity components to the observed effects, the improvement in neuropsychological function is consistent with a number of studies documenting the beneficial effects of exercise on cognition.[27,31,32,44,45] A meta-analysis of 134 studies in both young and older adults indicates that exercise has a small positive effect on cognition.[45] In older adults, walking rapidly for 45 minutes 3 days a week for 6 months was shown to improve mental-processing abilities that otherwise decline with age, such as executive control processes.[32] These improvements in performance observed following regular walking were associated with relatively small increases in aerobic fitness.

We previously reported that 14 days of activity sessions in both the morning and the evening, totaling 3 hours of activity per day, improved daytime neuropsychological performance in older adults.[24] The present results indicate that a more practical program of a single 1.5-hour session of daily social and moderate level of physical activity is sufficient to improve neuropsychological performance in older adults. Determination of whether social or physical activity alone is sufficient for these effects may permit even briefer intervention periods, thereby further facilitating compliance.

Improvements in performance between morning and evening activity sessions were not significantly different. However, evening activity resulted in improvements on a greater proportion of the tests. The average activity level of older adults is lower in the evening than in the morning,[24] suggesting that increasing activity at a normally less-active time of day may be particularly important. To enhance both efficacy and compliance when prescribing the timing of the activity program, it may be important to take into account the possible phase-dependent response to exercise and individual morningness/eveningness tendencies, as well as personal preference and schedules of the individual. However, it should be noted that in spite of all of these potential variables, regular activity at any time of day would be preferable to irregular activity at a specified time of day.

The mechanism by which exercise may improve neuropsychological performance is not known. It has been suggested that much of the decline in intellectual ability with age is due to age-related slowing in basic central information-processing activities.[46,47] For example, age-related differences in digit-symbol performance have been found to reflect a slower rate of processing information rather than deficits in memory or other specific processes.[48] The improved cognitive performance associated with exercise may therefore reflect changes in the speed of basic processing.[31] This hypothesis is supported by the finding that

Table 3—Results of Polysomnography Obtained During 2 Baseline Nights and 2 Nights After Treatment

Parameter	Morning Activity		Evening Activity	
	Baseline	Posttreatment	Baseline	Posttreatment
TST, min	346.7 ± 20.0	339.7 ± 20.8	353.0 ± 12.2	339.7 ± 10.0
SOL, min	20.0 ± 4.5	19.5 ± 4.5	16.9 ± 3.6	18.7 ± 3.2
Efficiency, %	74.2 ± 4.2	70.7 ± 4.2	77.0 ± 3.3	77.2 ± 3.5
WASO, min	81.9 ± 21.7	100.9 ± 21.6	76.9 ± 17.1	68.7 ± 18.8
Stage 1, min	44.1 ± 6.4	48.6 ± 8.1	51.7 ± 9.1	66.0 ± 15.9
Stage 2, min	209.7 ± 19.3	193.2 ± 16.4	205.9 ± 11.2	190.6 ± 7.8
SWS (Stage 3 + 4), min	28.0 ± 6.0	24.2 ± 4.4	22.6 ± 5.4	22.8 ± 6.1
REM sleep, min	65.0 ± 7.6	71.2 ± 8.8	72.9 ± 3.7	72.2 ± 5.7

Data are presented as mean ± SEM. TST refers to total sleep time; SOL, sleep-onset latency; WASO: wake after sleep onset; SWS: slow-wave sleep; REM, rapid eye movement.

increased fitness in older adults is associated with better performance on age-sensitive measures of visual sensitivity, speed of processing of sensory information, central inhibition, and cognitive efficiency.[29] It has also been proposed that exercise may improve basic processing speed via its cardiovascular and metabolic effects on the brain.[14,31,46,48]

The improvement in subjective sleep quality following the morning or evening activity sessions in this study are consistent with reports showing exercise-induced improvements in subjective sleep.[21,23,44] Although subjective sleep quality improved, objective PSG parameters did not improve in our study. Several factors may have contributed to the lack of effect of the intervention on objective sleep measures. First, subjects were not selected based on their level of social or physical activity or sleep quality at baseline, resulting in a possible "ceiling effect" in some of the subjects. Second, the addition of a habituation night to the protocol might have reduced night-to-night variability in sleep quality and resulted in more consistently observed changes in sleep measures. Third, although sleep apnea was screened for by history and questionnaires, it was not excluded using PSG criteria. Therefore, it is possible that underlying sleep-disordered breathing could have affected the results. A lack of correlation between subjective sleep ratings and PSG sleep variables in older adults has previously been reported, also raising the possibility that subjective sleep quality is fundamentally different from measures obtained by PSG.[41,43] In addition, behavioral measures of central nervous system function appear to be more sensitive to health status than changes in electroencephalograms, and fitness levels may have to be raised to higher levels for measurable changes in electroencephalograms to be observed.[29,31] We previously observed improvements in both SWS and in neuropsychological performance following activity in both the morning and evening,[24] suggesting that while the activity program in the current study was adequate to improve subjective sleep quality, it may not have been sufficient to significantly improve objective PSG parameters. Nevertheless, subjective sleep quality may be just as important, if not more important, as an outcome measure from the patient's standpoint for improving quality of life.

In summary, results from this pilot study suggest that increasing social and physical activity for a relatively short duration of 14 days in either the morning or early evening can improve daytime neuropsychological function and subjective sleep quality in older adults. Results further suggest that while evening activity sessions may have a more consistent effect, activity at a time of the day that is practical will be the most beneficial. Future controlled randomized clinical trials of behavioral approaches are needed to confirm the benefits of increasing social and physical activity levels in older sedentary adults with insomnia.

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