

Associations between daily movement-based behaviors, sleep, and affect in older adults: An ecological momentary assessment study

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ABSTRACT

Daily movement-based behaviors and sleep are associated with daily mental health outcomes. However, the associations in older adults remain unclear. This study aimed to determine the same-day association between sleep (duration and quality), physical activity (stepping) and sedentary behaviors (sitting and lying), and affect (positive and negative affect) among older adults using ecological momentary assessment (EMA).

The data collection period was 14 consecutive days. Sleep logs collected sleep duration, while smartphone surveys collected sleep quality and momentary affects. The ActivPAL4 accelerometers computed daily sedentary and physical activity (PA) times. Affects were regressed on the sleep and movement-based behaviors using two separate mixed-effects models, controlling for demographics.

Ninety older adults were included in the analysis: female ($n = 56, 62\%$), white ($n = 71, 79\%$) age ($M = 68.16$ yrs, $SD = 6.47$), sedentary time ($M = 10.13$ hrs/day, $SD = 2.00$), PA time ($M = 1.60$ hrs/day, $SD = 0.65$), sleep duration ($M = 8.25$ hrs/day, $SD = 1.39$), and sleep quality ($M = 6.92$ /day, $SD = 1.39$). More sedentary, PA time, and better sleep quality than usual on a given day were associated with both lower negative affect (bs range = $-0.18 - -0.02$, ps range = $.001 - .025$) and higher positive affect (bs range = $0.05 - 0.14$, $p < .001$). The longer sleep duration than usual on a given day was associated with lower negative affect ($b = -0.06$, $p < .001$). Participants with overall higher sleep

quality than others experienced lower negative affect ($b = -0.33, p = .025$) and higher positive affect ($b = 0.40, p < .001$) across the study period.

Our findings indicated that spending more time in any movements beyond the daily routine and better sleep quality may benefit older adults' psychological well-being by enhancing positive affect and reducing negative affect.

Keywords

ecological momentary assessment, older adults, mental health, physical activity, sleep, affective states, movement-based behaviors

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Introduction

The older adult population has increased from 14% in 2008 to 17.7% in 2021 in developed countries (Organisation for Economic Co-operation and Development, 2022). In the United States, older adults' healthcare expenditure constitutes 35% of the total health expenditure, indicating that only 17% of the population accounts for 35% of healthcare spending in 2019 (Ortaliza & McGough, 2021). As the older adult population's spending consists of the majority of healthcare expenditure and projections suggest continued increases in the future, reducing the healthcare expenditure of older adults is crucial for reducing overall healthcare costs.

Mental health problems in older adults could become a public health crisis. The percentage of older adults aged 65 and over who experienced frequent mental distress in the U.S. in the past 30 days remained consistent from 7.4% in 2015 to 8% in 2020, according to the Behavioral Risk Factor Surveillance System (BRFSS) data (Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Division of Population Health, 2015). This increased rate may seem insignificant, but a rise in the proportion of older adults shows that this

small increase cannot be deemed negligible. The estimated number of older adults aged 65 and over who experienced frequent mental distress was 3.7 million in 2015 and 4.3 million in 2020 (The Kaiser Family Foundation, 2022). Affective states are also important predictors of psychological health (Duncan & Barrett, 2007). Recent literature also supports that affective symptoms, which include depression and anxiety, increase the risks of dementia (John et al., 2019).

Maintaining healthy lifestyle behaviors, including engaging in physical activity (PA) regularly and sleeping sufficiently with good quality, has been shown to be beneficial for health in older adults and could help reduce healthcare costs (Coughlan et al., 2021; Garrett et al., 2004). There is well-established evidence that engaging in physical activity benefits psychological health across the lifespan (Edwards, 2006; Edwards et al., 2005; Weyerer & Kupfer, 1994), whereas engaging in prolonged sedentary time could negatively influence mental health (Copeland et al., 2017). Good sleep quality and sufficient sleep duration also benefit overall health, including affect and cognition (Chaput et al., 2020). Older adults often report changes in sleep quality and duration, and inadequate sleep can increase the risk of mortality and morbidity and nega-

tively influence the quality of life and physical function (Crowley, 2011).

Ecological momentary assessment (EMA) is an intensive longitudinal method that captures real-time data, which includes health behavior (e.g., physical activity and sleep) and mental health states (Burke et al., 2017; Shiffman et al., 2008). For example, studies have discovered that physical activity was positively associated with positive affect (Wen et al., 2018), energetic feelings (Liao et al., 2017b), and negatively associated with negative affect (Liao et al., 2017a). Sedentary behavior has been shown to have a negative relationship with positive affect (Wen et al., 2018). Also, studies found that good-quality sleep benefits mood and affective states (Hamilton et al., 2007; Triantafyllou et al., 2019), and longer sleep duration predicts lower anxiety (Cox et al., 2018).

However, only a few EMA studies have focused on older adults. According to the systematic reviews synthesizing EMA, sleep, affect, and physical activity, only one study found a diurnal association between affect and sleep (Konjarski et al., 2018). Three studies reported the association between affect and physical activity (Zapata-Lamana et al., 2020). Although a recent EMA study focusing on older adults did not support the association between affective states and physical activity, it found a bidirectional association between momentary energetic feelings and step count (Hevel et al., 2021).

In addition to the issue that older adults have been understudied, their characteristics differ from other population groups. The day-to-day time allocation for older adults is usually different from that of other age groups as many are retired and thus have more autonomy in their day time activities as well as with their movements throughout the day. Stepping can be a useful way to gather data on older adults' physical activity, as it involves all walking intensities (Grant et al., 2008). Therefore, the current EMA study focused on determining the daily association between affective states (negative and positive) and the daily time spent on PA (stepping) or sedentary (i.e., sitting and lying) and sleep (i.e., sleep quality and duration) in older

adults. EMA allows for the conducting of between- and within-individuals analysis. Therefore, using between-individuals analysis, we examined four hypotheses: older adults with (1) less sedentary time, (2) more PA time, (3) more sleep time, and (4) higher sleep quality compared to others would experience better affective states (i.e., lower negative affect and higher positive affect). Similarly, using within-individuals analysis, we investigated whether older adults with (1') less sedentary time, (2') more PA time and (3') more sleep time, and (4') higher sleep quality than their usual would experience better affective states on a given day.

Method

Participant recruitment

Participants who met the following inclusion criteria were enrolled in the current study: (1) age 60 years or older, (2) able to speak and read English fluently, (3) able to use smartphones, (4) able to walk without others' assistance, and (5) no brain diseases or abnormalities. There were no specific exclusion criteria and no restrictions on the geographical location, given that the target population of older adults currently lives in the United States. Using the convenience sampling method, our recruitment included flyers, email listservs, and a word-of-mouth strategy. The recruitment process spanned from January 2021 to November 2022.

Study procedure

This study was a fully remote observational study across 14 consecutive days. If participants met the inclusion criteria, they provided verbal consent and were mailed a study packet that included a smartphone (Xiaomi MiA3 and Xiaomi Note8 smartphones with Android version 9) and accelerometers (ActivPAL micro 4 (ActivPAL4) PAL Technologies, Glasgow, Scotland). Participants also completed an online questionnaire (via Qualtrics) to report their demographics and typical health status prior to the virtual training session. The one-time virtual training session was con-

ducted by a trained study team member and included instructions on using the phone and accelerometer and answering the EMA surveys.

Participants received six signal-contingent EMA surveys, consisting of four quasi-randomly prompted and two self-initiated, each day. The four prompted surveys were delivered within 3–5-hour interval time blocks. The prompted surveys' delivery timing was tailored individually based on their self-reported usual wake-up time to avoid sleep disturbance. Two self-initiated surveys included a morning survey and an evening survey. Participants were asked to answer the morning survey within one hour from when they woke up and the evening survey before going to bed or before midnight. Participants were instructed not to answer the prompt surveys when they felt unsafe to answer, such as driving. However, participants were allowed to answer the make-up survey. The prompted and make-up initiated surveys were coded differently, and we used both answered surveys in the analysis.

During the survey period, participants wore an ActivPAL4. The participants mailed back the research materials when the study period was over. If the participants reached an 80 percent compliance rate, they received a USD 120.00 prepaid gift card.

Measurements

Demographics

Qualtrics surveys collected data on age, gender, and race. Gender and race were treated as binary variables. Originally, race was categorized into five categories but was aggregated into two, white and non-white, due to the unbalanced sample.

Movement-based behaviors

PA (stepping) and sedentary time were measured by ActivPAL4. We calculated sedentary time by subtracting the sitting time recorded by ActivPAL4 from the sleep time. The ActivPAL4 was taped onto the participants' right thigh using waterproofed medical grade

tape, and participants were instructed to keep the monitor on for 24 hours/day. The ActivPAL4 has been validated as one of the gold standards for measuring sedentary behavior and determining posture (Aminian & Hinckson, 2012; Kozey-Keadle et al., 2011), including among older adults (Edwardson et al., 2017; Harrington et al., 2011). The original event-based activPAL algorithm implemented in PALanalysis v7 (i.e., VANE algorithm) identified the collected movement (i.e., stepping and standing) and sedentary behavior time.

Sleep

Sleep constructs used in this study were nighttime sleep duration and self-rated sleep quality. We used self-reported logs, self-reported morning surveys, and ActivPAL4 to determine the sleep duration. The daily log was the primary source, the morning survey was secondary, and ActivPAL4 was the tertiary source in the event of missing data. We calculated the sleep duration based on self-reported bed and wake-up times from the log. If the log was not reported, the morning survey, which also asked about bedtime and wake-up times, was used. When both self-reported measures were not available, we used primary lying time (i.e., lying without sitting) as a proxy of sleep duration measured by ActivPAL4 as a tertiary source because of a lack of evidence in measuring sleep duration using ActivPAL4 (Courtney et al., 2021). The morning surveys asked about the subjective sleep quality of the previous day, using a 0 ~ 100 slider scale (0 = *the worst quality*, 100 = *the best quality*). Subjective sleep quality was extracted from the Pittsburgh Sleep Quality Index (Buysse et al., 1998).

Positive and negative affect

Four momentary surveys captured the positive and negative affect of participants in this study, using terms from the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988). Each survey asked six questions to measure negative and positive affect, using a 0 ~ 100 slider scale (0 = *not at all*, 100 = *fully*). The following questions were used to capture the neg-

ative and positive affect: (1) How much are you feeling anxious/tense right now? (2) How much are you feeling fatigued/tired right now? (3) How much are you feeling depressed/sad right now? (4) How much are you feeling energetic/excited right now? (5) How much are you feeling happy/joyful right now? (6) How much are you feeling calm/relaxed right now? Each question was designed to capture three levels of negative (i.e., (1), (2), (3)) and positive (i.e., (4), (5), (6)) arousals. Each momentary response was aggregated to a daily level for analysis.

Statistical analysis

Data processing

Only valid days of at least 10 hours of wear time were included in the analysis (Migueles et al., 2017). The daily affective states were regressed by daily time spent on movement-based behaviors and sleep using a multilevel linear model. The participants' demographic (sex, race, and age), their daily mean level of time spent on sleep, sedentary, and PA, and their daily mean sleep quality were level-2 predictors (i.e., between-individual (BI) variables). Participants' daily fluctuation of time spent on sleep, sedentary, and PA and sleep quality were considered level-1 predictors (i.e., within-individual (WI) variables). Level-1 predictors were calculated using the person-mean centering approach, which subtracts the mean level of time spent on the activity type from each daily hour spent on the activity. Standing time was not included in the analysis to avoid collinearity with stepping time. The primary outcome of interest was the day-level of negative and positive affect.

The following equations represent the multilevel model explained above:

(Positive/Negative) Affect_{ij} = β_{0j} + β_1 Sedentary hour (WI)_{ij} + β_2 PA hour (WI)_{ij} + β_3 Sleep duration (WI)_{ij} + β_4 Sleep quality (WI)_{ij} + β_5 Day_{ij} + β_6 Age_j + β_7 Sex_j + β_8 Race_j + β_9 Sedentary hour (BI)_j + β_{10} PA hour (BI)_j + β_{11} Sleep duration (BI)_j + β_{12} Sleep quality (BI)_j + b_{0j} + ϵ_{ij}

Coefficient β_{0j} represented the intercept indicating the mean level of participants' negative or positive affect level, while b_{0j} is a random intercept allowing the model to treat each individual differently. While β_1 to β_{12} were fixed effects, β_1 to β_4 represented the association between positive and negative affect and individuals' daily time spent on each type of activity. β_6 to β_8 were the association between affective states and the subject's demographics, and β_9 to β_{12} were associations between affective states and individual-specific time spent on each activity. The coefficient ϵ_{ij} was an error including random and systematic daily affective states and individual-specific affective states. Proc mixed procedure was used with SAS 9.4.

Results

Demographics and EMA prompt delivery

One hundred seven older adults initially participated in the current study, but 14 of them dropped out at various times during the study due to personal reasons. Accelerometer data were not obtained from three participants due to malfunctions. Therefore, a total of 90 participants were included in the analysis. Participants answered 3,901 surveys out of 5,040 surveys and wore the ActivPAL for 26,978 hours out of 30,240 hours, with average wearing hours of 21 hours ($M = 12.80$ days $SD = 2.40$). Overall, there was a 77% compliance rate for answering the surveys and 89% for wearing ActivPAL. Among all answered surveys ($M = 45.38$, $SD = 15.43$), 19% were self-initiated ($M = 10.03$, $SD = 9.07$), and 81% were randomly prompted ($M = 35.34$, $SD = 13.04$).

Table 1 summarizes participants' demographics, average time spent on sedentary, PA, and sleeping, and scores of sleep quality and affective states. The majority of the participants were female (62%) and white (79%). On a given day, participants maintained a good sleep duration of over 8 hours (Liu et al., 2016) but engaged a long time in sedentary behavior of more than 10 hours (Rosenberger et al., 2016). Most participants reported their sleep quality was higher than a

midpoint of 5 and completed each survey in 10 minutes. The Cronbach's alpha for a single item (i.e., sleep quality) showed a high reliability ($\alpha = 0.88$). The participants generally experienced low negative affect and

high positive affect. Participants responded on average within 2 minutes of prompted surveys; however, when they had to manually answer surveys, the average response time increased to 96 minutes.

Table 1
Demographics and descriptive statistics

	<i>M</i> or (%)	<i>SD</i>	<i>Min</i>	<i>Max</i>
Male (<i>n</i> = 34)	(38%)	-	-	-
Female (<i>n</i> = 56)	(62%)	-	-	-
White (<i>n</i> = 71)	(79%)	-	-	-
Non-white (<i>n</i> = 19)	(21%)	-	-	-
Age (yrs)	68.37	7.06	60	91
Latency (prompted; mins)	2.34	5.48	0	39.87
Latency (manually; mins)	96.81	79.75	0.13	451.68
Time to completion (mins)	6.79	4.99	2.49	41.57
Sedentary time (hrs)	10.13	2.00	5.57	14.65
Standing time (hrs)	3.74	1.59	1.12	9.05
PA time (hrs)	1.60	0.65	0.31	3.13
Sleep duration (hrs)	8.25	0.97	2.75	13.00
Sleep quality (scores)	6.92	1.44	3.29	9.79
Positive affect (scores)	6.65	1.36	3.37	9.90
Negative affect (scores)	1.47	1.39	0	5.58

Associations between physical activity, sedentary behavior, sleep, and affective states

Table 2 includes a correlation table of variables of interest. Intra-Class Correlations (ICC) are provided in the diagonal in the parentheses, indicating that 70% of the variance of the negative affect was explained

by between-individual variability or errors, and the remaining 30% of the variance was explained by within-individual variability. As explained above, standing time was not included when analyzing to avoid collinearity because it has the highest correlation with other variables, especially with the sedentary time ($r = -.79$).

Table 2
Pearson correlation of independent variables

	1	2	3	4	5	6	7
1. Negative affect	(.70)	-.32***	-.03	.05**	.01	-.01	-.02
2. Positive affect	-.49***	(.54)	.01	-.04**	-.01	-.01	.02
3. Sedentary time (hrs)	< .01	-.01	(.62)	-.63***	-.46***	-.51***	-.06***
4. Standing time (hrs)	.01	.03	-.79***	(.72)	.47***	-.17***	-.01
5. PA time (hrs)	-.07***	.03	-.54***	.45***	(.64)	-.17***	-.01
6. Sleep duration (hrs)	< -.01	-.02	-.40***	-.15***	-.17***	(.45)	0.11***
7. Sleep quality (hrs)	-0.18***	.17***	-.03*	.07***	.03*	-.04*	(.40)

Intra-Class Correlations (ICC) are written in parentheses, and the below diagonal indicates between-individuals correlation while the upper diagonal includes within-individuals correlation. *** $p < .001$; ** $p < .01$, * $p < .05$

Table 3
Multilevel models coefficients

	Model 1		Model 2	
	Negative affect		Positive affect	
	Coefficients	SE	Coefficients	SE
Fixed effects				
Intercept (β_0)	7.58	2.81	0.65	2.58
Age (β_6)	0.01	0.02	0.02	0.02
Sex (β_7)	-0.15	0.33	0.04	0.31
Race (β_8)	0.15	0.42	-0.44	0.39
Day (β_5)	< 0.01	0.003	-0.02**	< 0.01**
Within-individuals sedentary time (β_1)	-0.08**	0.01**	0.06**	0.01**
Between-individuals sedentary time (β_9)	-0.12	0.11	0.10	0.10
Within-individuals PA time (β_2)	-0.18**	0.03**	0.14**	0.04**
Between-individuals PA time (β_{10})	-0.52	0.33	0.39	0.30
Within-individuals sleep duration (β_3)	-0.06**	0.01**	0.03	0.02
Between-individuals sleep duration (β_{11})	-0.23	0.19	0.23	0.18
Within-individuals sleep quality (β_4)	-0.02*	0.01*	0.05**	0.01**
Between-individuals sleep quality (β_{12})	-0.33*	0.11*	0.40**	0.10**
Random effects				
Variance intercept (σ_j)	1.87		1.55	
Residual variance (ϵ_{ij})	0.42		0.60	

*** $p < .001$; ** $p < .01$, * $p < .05$

Table 3 shows the estimated coefficients of the two multilevel regression models testing each affective outcome. According to the between-individuals analysis, only sleep quality has a statistically significant effect on negative and positive affect. Participants who reported higher mean sleep quality than others experienced less negative affect ($b = -0.33$, $p = .003$) and more positive affect ($b = 0.40$, $p < .001$).

According to the within-individuals analysis, sleep quality, sedentary time, PA time, and sleep duration had a statistically significant effect on the negative affect, and sleep quality, sedentary time, and stepping time had a significant effect on the positive affect. On a given day, participants experienced less negative affect when they were more sedentary ($b = -0.08$, $p < .001$), more physically active ($b = -0.18$, $p < .001$), and sleeping more ($b = -0.06$, $p < .001$), and reported having better sleep quality ($b = -0.02$, $p = .0013$) than on their usual day. Similarly, on a given day, participants experienced more positive affect when they were more sedentary ($b = 0.06$, $p < .001$) and more physically active ($b = 0.14$, $p < .001$), and reported better sleep quality ($b = 0.05$, $p < .001$) than on their usual day. While all demographic covariates were not statistically significant, positive affect decreased as the day passed ($b = -0.02$, $p < .001$).

Discussion

The current study applied EMA to examine the association between movement-based behaviors (i.e., sedentary behavior and PA), sleep (i.e., duration and quality), and affective states (positive and negative affect) in older adults over 60. Our hypotheses were partially supported as the findings suggest that participants with better sleep quality experienced less negative and higher positive affect than those with poor sleep quality (hypothesis 4). "Participants also experienced lower negative affect and higher positive affect when they were more sedentary and physically active or when they had more and better sleep compared to their typical day (hypotheses 2', 3', and 4'). This study expands the previous literature on the associations

between physical activity level and psychological health by exploring the everyday associations in an understudied population, older adults. Additionally, this study is valuable as the primary predictors of interest were time spent on each movement-based behavior. The benefit of moderate to vigorous physical activity (MVPA) to psychological health is well defined across all populations, and older adults' limited physical capacity is a barrier to merely focusing on pursuing MVPA (Zapata-Lamana et al., 2020). Therefore, the findings of the present study show that increased stepping benefits affective states on the given day regardless of intensity and could be more practical to older adults.

These findings are aligned with previous studies. For example, two ambulatory assessment studies discovered a positive association between physical activity and positive affect in young adults (Bossmann et al., 2013; Kanning & Schoebi, 2016). One ambulatory assessment study using a Multi-Dimensional mood Questionnaire (MDMQ) discovered daily living physical activity could improve affective states in older adults (Kanning et al., 2015). While MDMQ is a valid and reliable measurement for distinguishing dimensions (valence, calmness, and energetic arousal) of affective states, it is a semantic differential scale, assuming the negative and positive sides of each dimension are dependent. The current study could contribute to determining the association between movement-based behavior and affective states in older adults by applying the two-factor model: positive and negative affect as two independent dimensions (Limberger et al., 2023). Future studies may be able to use a more complex dimension model, for example, a six factors model (tension, tiredness, alertness, calmness, good mood, and bad mood) to assess three dimensions (Limberger et al., 2023).

The current study suggests that sleep quality and duration are crucial factors in affective states. Similarly, previous studies suggest that sleep quality is also associated with higher positive and lower negative affect in college students (Simor et al., 2015). In addition, sleep restriction therapy improves both pos-

itive and negative moods in patients with insomnia (Miller et al., 2013). Poor sleep quality increases negative affect (Short et al., 2017). Evidence from the current study indicates that good sleep quality is beneficial for psychological well-being, according to both between and within-individual analysis. Therefore, a future study with a more detailed measurement of sleep quality, such as the number of waking up times during sleep, is needed (Moderie et al., 2020). Utilizing the recent wearable devices in the study could be one possible way. Despite its proprietary algorithm, a commercial wearable device, such as Fitbit, has been mentioned to be fairly compatible with sleep measures from polysomnography (Baron et al., 2018; Chinoy et al., 2020; Evenson et al., 2015). As the current study highlights the significance of sleep quality, the use of consumer wearable devices can serve as a valuable resource for collecting sleep outcomes in older adults' natural environment, complementing traditional methods.

Contrary to previous studies that discovered short and long bouts of sedentary behavior had a positive relationship with negative affect among adolescents and working-age populations (Kinnaefick & Thøgersen-Ntoumani, 2014; Zink et al., 2022), and an inverse association with positive affect in children (Wen et al., 2018), the current study showed different results in older adults. In fact, negative affect and sedentary behavior do not necessarily have a positive association; the social context (i.e., alone vs. not alone) and the environmental context (i.e., work vs. leisure) of sedentary behaviors are also imperative factors that need to be taken into account (Kanning et al., 2021). Further EMA studies are encouraged to determine the type of sedentary behavior and related social context. A hybrid EMA delivery scheme mixed with random signal and event-contingent strategy will help differentiate affective states during the usual activity versus specific sedentary activity. These findings may expand evidence to explain why older adults' link between physical activity and psychological health may be different from other populations and identify the types of

sedentary behavior that are beneficial to promote psychological health.

Additionally, the current study focused on the same-day association of affective states and physical activity and sleep. Future studies can investigate the momentary association, the lag effect, or the dose-response of movement behaviors and sleep on affective states to broaden the evidence of the psychological impact of everyday health behaviors in older adults.

Strengths and limitations

This study had several strengths. First, this study used EMA to collect the real-time affective states that fluctuate on a daily basis, allowing within-individual analysis to examine the same-day association between movement behaviors and psychological health. The study was conducted fully remotely, which enhances the ecological validity. Second, ActivPAL4 accelerometers were used to measure physical activity time, which eliminates the recall and social desirability bias from traditional physical activity surveys. Finally, smartphones collected affective states in real time for 14 days. While the survey compliance rate was higher than that of previous studies at 77%, it fell just short of the recommended compliance rate of 80% (Jones et al., 2019).

The limitations of the current study must be disclosed. A convenience sampling method was used, which means it was vulnerable to selection bias. Further, the sample was primarily white and female. The results may not be generalizable to other older adult populations. Although the 14-day EMA study period is relatively long, it is still a snapshot of years. Considering the current study's two years rolling-based recruitment strategy, participants' movement behavior and sleep patterns may differ across seasons and weather conditions (Ferguson et al., 2023). In addition, ActivPAL4 cannot distinguish between aerobic and non-aerobic physical activity. The information about daily muscle strengthening activity is also crucial to prevent older adults' muscle atrophy, maintain balance to avoid falling, and mitigate depression (Khodadad Kashi et al., 2023). However, it is important to note that studies

about the benefit of muscle-strengthening training on psychological well-being are still understudied, especially regarding the between- and within-individual analysis. Developing technology to measure the daily intensity of muscle training as accurately as aerobic activity is required to extend knowledge about the psychological benefits of physical activity in the contexts of daily life.

Conclusion

The daily associations between sleep, physical activity, sedentary behavior, and affective states were observed in older adults using an intensive longitudinal method. The significant associations are mostly observed at the within-individual level. These results underscore the importance of capturing the day-to-day changes to advance understanding of the association between health behaviors and outcomes in daily contexts. Future studies are encouraged to consider different types of sedentary behaviors when studying their connections with affective states in older adults. Intervention strategies that promote more movement behavior from older adults' daily activity routines may be beneficial to maintaining psychological well-being.

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Competing interests

The authors have declared that no competing interests exist.

Data availability statement

All data reported in this study are available upon request.