Adherence to 24-Hour Movement Guidelines Among Chinese Older Adults: Prevalence, Correlates, and Associations with Physical and Mental Health Outcomes

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Abstract

Background: 24-hour movement behaviors: physical activity (PA), sedentary behavior (SB), and sleep, are crucial components affecting older adults' health. Canadian 24-hour movement guidelines for older adults were launched in 2020, emphasizing the combination role of these three movement behaviors in promoting older adults' health. However, research on the prevalence and correlates of guideline adherence and its associations with health outcomes is limited, especially among Chinese older adults.

Objective: This study aimed to investigate the prevalence and correlates of meeting 24-hour movement among Chinese older adults. Furthermore, this study aimed to examine the associations of guideline adherence with older adults' physical and mental health outcomes.

Methods: Using a stratified cluster random sampling approach, a total of 4,562 older adults (67.68±5.03 years; 55.8% female) were recruited from the latest provincial health surveillance of Hubei China from 25-Jul to 19-Nov 2020. Measures included demographics, movement behaviors (PA, SB and sleep), body mass index (BMI), waist circumference, waist-hip ratio (WHR), percentage body fat (PBF), systolic and diastolic pressure, physical fitness, depression, and loneliness. Generalized linear mixed models were employed to examine the associations between variables using SPSS 28.0.

Results: Only 1.8% of participants met all three movement guidelines, while 32.1%, 3.4% and 66.4% met the individual behavioral guideline for PA, SB and sleep, respectively. Participants, who were older, female and lived in the municipalities with lower economic levels, were less likely to meet all three movement guidelines. Meeting more movement guidelines was associated with greater physical and mental health outcomes among older adults, except systolic and diastolic pressures.

Conclusions: This is the first study to investigate the adherence of 24-hour movement guidelines among Chinese older adults regarding the prevalence, correlates, and associations with physical and mental health outcomes. The findings emphasize the urgent need of promoting healthy movement behaviors among Chinese older adults. Future interventions to improve the older adults' physical and mental health should involve enhancing their overall movement behaviors and considering the demographic differences.

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Conclusions: This is the first study to investigate the adherence of 24-hour movement guidelines among Chinese older adults regarding the prevalence, correlates, and associations with physical and mental health outcomes. The findings emphasize the urgent need of promoting healthy movement behaviors among Chinese older adults. Future interventions to improve older adults' physical and mental health should involve enhancing their overall movement behaviors and consider demographic differences.

Keywords: physical activity; sedentary behavior; sleep; cardiometabolic indicators; physical fitness; mental health; post-COVID-19 era; older adults

Introduction

The number of older adults (≥ 60 years) worldwide was estimated to be one billion in 2019. This figure is expected to double by 2050, accounting for around 22% of the global population [1]. This demographic shift has been occurring at an unprecedented pace and may accelerate in the coming decades, and will bring considerable challenges to worldwide societies, especially in developing countries [1,2]. As a vulnerable group, older adults have shown a decreased level of physical fitness

as well as a high morbidity and mortality of infectious respiratory diseases, cardiometabolic diseases, and mental disorders (e.g., late-life depression), which has worsened because of the outbreak and continuation of the COVID-19 pandemic [3-5]. Older adults' daily routines have been substantially altered [6]. They have been challenged by requirements to increase their time living at home, limits to physical and social connection with other family members and friends, temporary decreases or cessation of employment and recreational activities, and loneliness and fear of illness and death for themselves and others [3,6-8]. Therefore, promoting physical and mental health among older adults during the pandemic and beyond to achieve healthy ageing is a public health and socioeconomic imperative globally [7].

24-hour movement behaviors, including physical activity (PA), sedentary behavior (SB) and sleep, have been shown to have prominent impacts on a wide range of physical and mental health outcomes among older adults [9-11]. For example, regular engagement in PA has been reliably associated with better health-related outcomes, such as body mass index (BMI) [12-13], percentage body fat (PBF) [12-13], waist circumference [14-15], waist-hip ratio (WHR) [15-16], systolic and diastolic blood pressures (SP and DP) [17], physical fitness [18-19], depression and loneliness [20-22]. Similarly, adequate sleep duration has been shown to be associated with greater cardiorespiratory fitness [23-24] and decreased risks of metabolic-related diseases [25] and mental disorders [26] among older adults. In contrast, prolonged sedentary time has been shown to be a modifiable risk factor that negatively affects older adults' physical and mental health [19, 27-29].

Historically, most studies have focused only on the effect of one of these specific movement behaviors on health-related outcomes, whereas the interrelationship and joint effect of these movement behaviors were comparatively ignored [30-31]. In recent decades, an increasing collection of evidence has supported the combined effects on health among different populations, including preschool children [32], school children [33-36], adolescents [33,36], adults and older adults [30-31]. Drawing on the theoretical underpinnings of time-use epidemiology and bolstered by recent empirical findings, the Canadian 24-hour Movement Guidelines for adults aged 18-64 years and those aged 65 years or older were established in 2020 [31]. These guidelines advocate for adults aged 18 years and above to engage in a minimum of 150 minutes of moderate to vigorous physical activity (MVPA) cumulatively per week. Additionally, they recommend limiting sedentary behavior (SB) to no more than 8 hours daily, with recreational screen time not exceeding 3 hours, and maintaining a sleep duration of 7-9 hours for adults aged 18-64 years and 7-8 hours for those aged 65 years and older. Furthermore, the guidelines emphasize the importance of regular bed and wake-up times.

The launch of adults' 24-hour movement guidelines has inspired relevant research interest in the combination of 24-hour movement behaviors among adult populations [37-42]. For instance, a national-level surveillance (2007-2013) found that Canadian adults (18-79 years) who adhered to all three movement guidelines had more favorable BMI, waist circumference, aerobic fitness, and cardiometabolic biomarkers (e.g., C-reactive protein, insulin levels) [38]. A recent cross-sectional study indicated an inverse association of meeting 24-hour movement guidelines with mental health outcomes (e.g., depression) among Chinese caregivers of preschoolers (aged 35.5 ± 4.9 years) during the COVID-19 pandemic [41]. However, there is a lack of evidence among Chinese older adults.

In addition, previous studies have found that meeting 24-hour movement guidelines was correlated with a range of demographic factors, such as sex, education level, marital status, health condition and economic status among adult populations [37,38,42]. However, all the above studies focused on the young and middle-aged adults, while to the best of our knowledge, there is a scarcity of recent evidence on the correlates of meeting 24-hour movement guidelines among older adults (≥ 60 years).

Therefore, this study aimed to (1) investigate the prevalence of meeting 24-hour movement guidelines among Chinese older adults; (2) investigate the correlates of meeting 24-hour movement

guidelines among Chinese older adults; and (3) examine the association of adherence to 24-hour movement guidelines with physical (i.e. BMI, waist circumference, WHR, PBF, SBP, DBP, and physical fitness) and mental (i.e. depression, loneliness) health outcomes among Chinese older adults.

Methods

Participants and Procedure

Participants were recruited from the latest provincial health surveillance of Hubei China (HSHC) [43]. The HSHC is an ongoing consecutive cross-sectional surveillance that collects various health indicators on a representative sample of Chinese residents living in the Hubei province of China every five years [43]. A self-weighted stratified cluster random sampling approach was applied in the HSHC, where participants were randomly selected from 17 municipalities of Hubei province, stratified by communities, towns (villages), and districts (counties) for each municipality. In this study, eligible participants were required to meet the inclusion criteria, including (1) older adults aged 60-79 years; (2) adequate language skills (i.e., reading and writing capabilities in Chinese); and (3) no restriction of physical mobilities (e.g., passed the PAR-Q). Participants excluded from this study were those outside the specified age range, unable to read and comprehend Chinese, failing the PAR-Q, and those diagnosed with cognitive or sleep disorders. A total of 32,080 participants were contacted, and 27,826 agreed to participate in the surveillance (86.7% response rate). After eligibility checks, 4,953 eligible participants were invited to complete data collection.

This study followed the Declaration of the Helsinki World Medical Association [44] and the strengthening the reporting of observational studies in epidemiology (STROBE) statement [45]. Ethics approval was obtained from the General Administration of Sport of China (CISS-2019-01-31) and Hubei Institute of Sport Science (HISS-2019-03-01). All participants who were interested in participating in the surveillance were asked to sign a written informed consent form before the study commencement. Eligible participants were further invited to complete the study measures at a multi-function stadium, lasting approximately 30 minutes/person. To ensure the assessment quality, for each municipality, the data collection was conducted by a trained health surveillance team, which consisted of 15-20 qualified assessors who passed a competency examination, according to consistent standard operating procedures. Data was collected from 25 Jul 2020 (three months after the lockdown was withdrawn) to 19 Nov 2020.

Measures

Adherence of 24-Hour Movement Guidelines

The Chinese version of International Physical Activity Questionnaire long form (IPAQ-LC) was used to measure the PA, SB and sleep (ICC=0.79-0.87) [46-47]. For PA, participants were asked to report the frequency (days) and duration (minutes) they spend in three intensities of PA (i.e., light PA, moderate PA, and vigorous PA) during the past seven days. Weekly time of PA was calculated by frequency x duration. For sedentary and sleep time, participants were asked to report the time (hours and minutes per day) they spent in these two behaviors on weekdays and weekends separately during the past week. Daily time of SB and sleep was calculated by the weekly time of SB and sleep divided by seven days. According to the Canadian 24-hour movement guidelines [31], participants were categorized as 0=meeting none of movement guidelines, 1=meeting one of movement guidelines, 2=meet two of movement guidelines, and 3=meeting all three movement guidelines.

Physical Health Outcomes

Physical health outcomes included objectively measured body mass index (BMI), waist circumference, waist-hip ratio (WHR), percentage body fat (PBF), systolic pressure (SP), diastolic

pressure (DP), and physical fitness. Participants were informed to not participate in any vigorous PA 12-hour before the assessment. The assessments were conducted at indoor multi-function sport gymnasiums, with ambient temperature kept constant during the measures for all participants.

Body weight and body height were measured using portable stadiometer (GMCS-SGJ3, Beijing, China; to the closest 0.05kg) and calibrated medical digital scales (GMCS-RCS3, Beijing, China), which were further used to calculate BMI (kg/m^2) [48]. Waist and hip circumference were measured using specific tape measures (GMCS-WD3, Beijing, China; to the closest 0.1cm). WHR was calculated as waist circumference (cm) divided by hip circumference (cm). PBF was measured using portable bioelectrical impedance (GMCS-TZL3, Beijing, China). Participants were measured after either an overnight or 2-hour fast and were asked to remove their footwear and socks before stepping on to the measurement instrument. The whole assessment followed a standard procedure (e.g., placing feet on the four pads, arms kept straight down, not touching the inner thighs) guided by the qualified assessors. SBP and DBP were measured after participants sat for 15 min using digital instruments (GMCS-XY3, Beijing, China).

Physical fitness was measured based on the standard protocol of National Physical Fitness Surveillance of China [49-50]. The entire physical fitness assessment included seven tests in this study: (1) vital capacity test, using spirometer (GMCS-FHL, Beijing, China); (2) handgrip strength test, using a mechanical dynamometer (GMCS-WCS3, Beijing, China); (3) chair sit-and-reach test; (4); 30-second chair stand test; (5) 2-min step test; (6) one-leg standing with eye-closed balance test; and (7) choice reaction time test, using traditional test plate (GMCS-FYS, Beijing, China). Each test was conducted twice and the best performance of two trials were recorded for analyses. The total physical fitness score was the sum of the weighted score of each test, ranging from 10 to 100, with a higher score indicating a greater physical fitness [49-50]. Prior to testing, all participants were fully familiarized with measurement procedures.

Mental Health Outcomes

Depression was measured using the 9-item Chinese version of the Patient Health Questionnaire (PHQ-9) [51-52]. Following the instruction question “how often were you bothered by the following problems over the past two weeks…”, participants were asked to give answers to nine situations, e.g., “little interest or pleasure in doing things” on a 4-point Likert scale, ranging from “0 = not at all” to “3 = nearly every day” (Cronbach’s alpha = 0.88). The total score of nine items were calculated (range 0-27), with a higher score indicating a severer level of depressive symptoms.

Loneliness was measured using the 10-item Chinese version of the Emotional and Social Loneliness Scale (ESLS-10) [53-54]. Participants were asked to answer how often the ten designated feelings occurred over the past year (e.g., “I feel as if nobody really understands me”). Responses were indicated on a 5-point Likert scale, ranging from “1 = not at all” to “5 = very often” (Cronbach’s alpha = 0.85). The total score of ten items were calculated (range 10-50), with a higher score reflecting a higher level of loneliness.

Covariates

Covariates were chosen in accordance with prior research [30,31,37] and included age, gender, place of residence (urban/ rural), educational attainment, marital status, chronic diseases (e.g., hypertension, cardiovascular diseases, stroke, osteoporosis, cancers, and type-2 diabetes), current smoking and alcohol consumption behaviors, and the economic status of municipalities (as determined by provincial GDP statistics) [55].

Statistical Analysis

Data analyses were implemented using SPSS 28.0 (IBM Armonk, NY, USA). Following the

exclusion of 248 cases for missing demographic details (73 cases lacking age and gender information), movement behaviors (73 cases), and physical and mental health outcomes (248 cases without BMI, PBF, physical fitness, and two mental health indicators data), along with 143 cases due to invalid or abnormal values in movement behaviors (122 cases) and health-related outcomes (76 cases, e.g., BMI, PBF) — particularly those cases with skewness and kurtosis absolute values beyond ±1.5 and z-scores exceeding the ±3 SD threshold [56] — data from 4,562 participants was retained for the final analysis. Based on a retrospective power estimate, the final sample size of 4,562 was adequate to detect an effect size (Cohen f^2) of 0.01, with an alpha of 0.05 and a statistical power (1-β) of 0.8, in the regression model [35,41]. Odds ratio (OR) of 1.68, 3.47, and 6.71 indicated a small, medium, and large effect size, respectively [57]. A statistical significance level of $P<0.05$ (two-tailed) with 95% confidence interval (CI) not covering 0 was used for all analyses.

Mean, SD, and percentage (%) were used to present the descriptive characteristics of the study sample. Considering the 24-hour movement guidelines propose different requirements for 60-64-year and 65+year groups, demographic characteristics were also reported for each subgroup. For main analyses, generalized linear mixed models were used to examine the correlates of meeting 24-hour movement guidelines as well as the associations of guideline adherence with physical and mental health outcomes.

Finally, sensitivity analyses were performed to examine the robustness of the study findings and alternative explanations. All the association analyses were reconducted with exclusion of participants who were obese (BMI≥28kg/m^2) or with moderate and severe depressive symptoms (PHQ scoring≥10) as suggested by previous studies [58-59]. Additionally, e-values were computed for the primary outcomes to assess the potential bias from unmeasured and residual confounding factors [58-60]. E-values estimate the magnitude of unmeasured or residual confounders that would need to be present to nullify the established relationships between independent and dependent variables, despite adjustments for all identified covariates [58-60]. E-values exceeding 1 suggest that only confounders of significant magnitude could challenge the observed relationships, including a greater robustness of these results against the influence of unmeasured confounders [58-60].

Results

Sample Characteristics

Of 4,953 participants, a total of 4,562 (retention rate of 92.1%) were included in the final data analyses (Figure 1). 69.2% of participants were aged 65 years and above, and the mean age of the total sample was 67.68±5.03 years. 55.8% of participants were female and 53% were lived in urban areas. Participants with an education level of middle and high school accounted for the largest percentage (46.4%), while only 12.2% of participants were educated in colleges. 86.9% of participants were married and 46.8% reported a history of chronic diseases. More details of the study sample are presented in Table 1.

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Table 1. Descriptive characteristics of the study sample (n=4,562).

Variable	Total (n=4,562)	Aged 60-64 yrs. (n=1,405)	Aged 65+ yrs. (n=3,157)
Age (years), mean (SD)	67.68 (5.03)	62.12 (1.36)	70.15 (4.00)
Gender, n (%)			
Male	2018 (44.2%)	619 (44.1%)	1399 (44.3%)
Female	2544 (55.8%)	786 (55.9%)	1758 (55.7%)
Residence, n (%)			
Urban	2417 (53%)	782 (55.7%)	1635 (51.8%)
Countryside	2145 (47%)	623 (44.3%)	1522 (48.2%)
Education, n (%)			
Primary school and below	1892 (41.5%)	456 (32.5%)	1436 (45.5%)
Secondary school	2115 (46.4%)	753 (53.5%)	1362 (43.1%)
College and above	555 (12.2%)	196 (14%)	359 (11.4%)
Marital status, n (%)			
Married	3964 (86.9%)	1277 (90.9%)	2687 (85.1%)
Single/divorced/widowed	598 (13.1%)	128 (9.1%)	470 (14.9%)
Chronic disease, n (%)			
No	2428 (53.2%)	836 (59.5%)	1592 (50.4%)
Yes	2134 (46.8%)	569 (40.5%)	1565 (49.6%)
Smoking, n (%)			
Not currently	648 (14.2%)	235 (16.7%)	413 (13.1%)
Yes, but not everyday	184 (4.0%)	65 (4.6%)	119 (3.8%)
Yes, almost everyday	3730 (81.8%)	1105 (78.6%)	2625 (83.1%)
Alcohol, n (%)			
Never	3423 (75%)	1030 (73.3%)	2393 (75.8%)
Seldomly	627 (13.7%)	220 (15.7%)	407 (12.9%)
Often	512 (11.2%)	155 (11%)	357 (11.3%)
Municipality economic status, n (%)			
≥ 9th of provincial GDP	2344 (51.4%)	676 (48.1%)	1668 (52.8%)
< 9th of provincial GDP	2218 (48.6%)	729 (51.9%)	1489 (47.2%)
Physical health outcomes, mean (SD)			
BMI (kg/m^2)	24.36 (3.05)	23.91 (2.72)	24.55 (3.17)
Waist circumference (cm)	86.46 (9.38)	84.72 (8.48)	87.24 (9.65)
WHR	0.92 (0.07)	0.91 (0.07)	0.93 (0.07)
PBF (%)	27.92 (6.87)	27.14 (6.55)	28.27 (6.98)
SP (mmHg)	139.63 (18.52)	139.41 (18.49)	139.73 (18.55)
DP (mmHg)	82.67 (10.98)	82.81 (10.82)	82.61 (11.06)
Physical fitness	59.50 (11.91)	60.10 (10.06)	59.24 (12.64)
Mental health outcomes, mean (SD)			
Depression	2.59 (3.35)	1.99 (2.65)	2.86 (3.58)
Loneliness	21.59 (7.91)	20.61 (7.24)	22.03 (8.15)

Note. BMI=body mass index; WHR=waist-hip ratio; PBF=percentage body fat; SP= systolic pressure; DP=diastolic pressure; SD=standard deviation.

Prevalence of Adherence to 24-Hour Movement Guidelines

Only 1.8% of participants met all three movement guidelines, while the rates of adhering to none, one, and two movement guidelines were 24.7%, 50.5%, and 23.0%, respectively. In particular, the proportion of participants meeting individual movement guidelines was 32.1% for MVPA, 3.4% for SB, and 66.4% for sleep, respectively. Prevalence rates of meeting a combination of two movement behaviors ranged from 1.8% to 23.3%, while only 1.8% of participants met all three movement guidelines (Figure 2).

--- Insert Figure 2 Here ---

Correlates of Adherence to 24-Hour Movement Guidelines

Table 2 presents the correlates of meeting 24-hour movement guidelines in the study sample.

Participants who were older and who were females had a comparatively poorer adherence to either individual movement guidelines or the combinations of two or three behaviors (all $P<0.001$). The municipality economic status was positively associated with meeting all three movement guidelines. Participants lived in urban areas were more likely to adhere to the MVPA and sleep guidelines (all $P<0.05$). A higher education level and no chronic diseases were associated with a higher adherence to MVPA, sleep, and MVPA+SB guidelines, while marital status was not associated with guidelines adherence.

Associations of Adherence to 24-Hour Movement Guidelines with Physical and Mental Health Outcomes

The association between adherence to the movement guidelines (individual and in combination) and health-related outcomes are outlined in Tables 3-4. Adhering to either the MVPA or the sleep guidelines was associated with favorable physical and mental health outcomes (all $P<0.001$), except two blood pressure indicators ($P=0.08$-0.57). Similar results were also observed for adherence to the SB guidelines, except a significant correlation with systolic blood pressure ($P=0.017$).

Adhering to both MVPA and SB guidelines was associated with greater health-related outcomes (all $P<0.01$), except diastolic pressure ($P=0.88$). Adhering to MVPA+Sleep or SB+Sleep guidelines was associated with better performance of physical health (all $P<0.05$), except two blood pressure indicators ($P=0.09$-0.78). Adhering to MVPA+Sleep was associated with a lower level of both depressive symptoms and loneliness (both $P<0.001$), while SB+Sleep guideline adherence was not significantly associated with loneliness ($P=0.18$).

Relative to not meeting any movement guidelines, adherence to one, two or all three movement guidelines was associated with lower values of BMI, waist circumference, WHR, and PBF, alongside higher levels of physical fitness among participants (all $P<0.001$). However, this correlation did not extend to blood pressure (both systolic and diastolic) ($P=0.17$-0.89). For mental health outcomes, adhering one, two, or all three movement guidelines was significantly and inversely associated with both depressive symptoms and loneliness (all $P<0.001$) compared with not meeting any guidelines (Table 4). The dose-response associations between the number of guidelines adherence and health-related outcomes were also identified (all $P<0.01$), except blood pressure ($P=0.18$-0.64).

Table 2. Correlates of Adherence to 24-hour movement guidelines in the study sample (n =4,562).

Variable	MVPA	SB	Sleep	MVPA+SB	MVPA+Sleep	SB+Sleep	MVPA+SB+Sleep
	***OR* (95%CI)**	***OR* (95%CI)**	***OR* (95%CI)**	***OR* (95%CI)**	***OR* (95%CI)**	***OR* (95%CI)**	***OR* (95%CI)**
Age	0.97 (0.95, 0.98) ***	0.93 (0.90, 0.97) ***	0.97 (0.96, 0.98) ***	0.94 (0.90, 0.97) ***	0.97 (0.96, 0.99) ***	0.94 (0.89, 0.98) **	0.94 (0.89, 0.98) **
Gender							
Male (Ref.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Female	0.55 (0.47, 0.64) ***	0.40 (0.27, 0.60) ***	0.55 (0.47, 0.64) ***	0.39 (0.26, 0.59) ***	0.56 (0.47, 0.66) ***	0.36 (0.21, 0.61) ***	0.35 (0.21, 0.61) ***
Residence							
Urban (Ref.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Countryside	0.75 (0.66, 0.86) ***	0.83 (0.59, 1.16)	0.78 (0.69, 0.89) ***	0.80 (0.57, 1.13)	0.77 (0.66, 0.89) ***	0.82 (0.52, 1.32)	0.83 (0.52, 1.33)
Education							
Primary school and below (Ref.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Secondary school	1.19 (1.03, 1.37) *	0.93 (0.64, 1.35)	1.06 (0.92, 1.22)	0.96 (0.66, 1.39)	1.21 (1.03, 1.43) *	1.38 (0.80, 2.39)	1.40 (0.81, 2.41)
College and above	1.41 (1.13, 1.75) **	0.81 (0.47, 1.40)	1.86 (1.46, 2.38) ***	0.82 (0.47, 1.42)	1.54 (1.22, 1.95) ***	1.46 (0.71, 3.01)	1.50 (0.73, 3.07)
Marital status							
Married (Ref.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Single/divorced/widowed	1.15 (0.95, 1.39)	1.03 (0.61, 1.74)	1.11 (0.92, 1.33)	0.88 (0.50, 1.55)	1.22 (0.99, 1.51)	0.74 (0.31, 1.72)	0.96 (0.45, 2.03)
Chronic diseases							
No (Ref.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yes	0..87 (0.76, 0.99) *	1.20 (0.86, 1.67)	0.60 (0.53, 0.69) ***	1.20 (0.86, 1.67)	0.85 (0.74, 0.99) *	1.03 (0.66, 1.62)	1.04 (0.66, 1.63)
Smoking							
Not currently (Ref.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Yes, but not everyday	0.63 (0.43, 0.90) *	0.59 (0.19, 1.30)	1.15 (0.79, 1.67)	0.50 (0.19, 1.29)	0.78 (0.52, 1.16)	0.42 (0.10, 1.83)	0.42 (0.10, 1.85)
Yes, almost everyday	1.13 (0.92, 1.38)	0.90 (0.58, 1.40)	1.05 (0.85, 1.30)	0.89 (0.57, 1.38)	1.18 (0.95, 1.47)	0.94 (0.51, 1.72)	0.95 (0.52, 1.74)
Alcohol							
Never (Ref.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Seldomly	1.33 (1.09, 1.63) **	1.12 (0.69, 1.81)	0.93 (0.76, 1.15)	1.13 (0.70, 1.82)	1.24 (1.01, 1.54) *	0.94 (0.48, 1.81)	0.94 (0.49, 1.81)
Often	1.24 (0.99, 1.54)	1.43 (0.89, 2.28)	0.82 (0.66, 1.04)	1.42 (0.89, 2.28)	1.07 (0.84, 1.35)	1.12 (0.89, 2.13)	1.13 (0.59, 2.15)
Municipality economic status							
< 9th of GDP	N/A	N/A	N/A	N/A	N/A	N/A	N/A
≥ 9th of GDP (Ref.)	0.93 (0.82, 1.07)	1.49 (1.06, 2.09) *	0.83 (0.73, 0.94) **	1.50 (1.06, 2.10) *	0.94 (0.82, 1.09)	1.67 (1.05, 2.67) *	1.67 (1.04, 2.66) *
R^2	0.06	0.05	0.07	0.05	0.05	0.06	0.06

Note. Ref.=reference group; MVPA= moderate-to-vigorous physical activity; SB=sedentary behavior; 95%CI=95% confidence interval; N/A=not applicable; $^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$.

Table 3. Associations of Adherence to 24-hour movement guidelines with physical outcomes (n=4,562).

Meeting movement guidelines[a]	BMI (kg/m^2)	WC (cm)	WHR	PBF (%)	SP (mmHg)	DP (mmHg)	Physical fitness
	B **(95%CI)**	***B*** **(95%CI)**	***B*** **(95%CI)**	***B*** **(95%CI)**	***B*** **(95%CI)**	***B*** **(95%CI)**	***B*** **(95%CI)**
Meeting individual guideline[b]							
At least MVPA	-1.22 (-1.41, -1.04)***	-3.84 (-4.40, -3.27)***	-0.02 (-0.02, -0.01)***	-2.44 (-2.75, -2.12)***	-1.05 (-2.22, 0.12)	-0.20 (-0.90, 0.50)	2.99 (2.64, 3.34)***
At least SB	-0.84 (-1.32, 0.36)***	-2.80 (-4.25, -1.35)***	-0.01 (-0.02, -0.003)[e] *	-2.37 (-3.19, -1.56)***	-3.61 (-6.57, -0.64)*	-0.01 (-1.77, 1.76)	2.80 (1.90, 3.71)***
At least sleep	-0.51 (0.70, -0.32)[e] ***	-1.40 (-1.97, -0.83)[e] ***	-0.01 (-0.01, -0.005)***	-0.66 (-0.98, -0.34)[e] ***	0.36 (-0.80, 1.53)	-0.06 (-0.75, 0.64)	1.65 (1.30, 2.00)***
Meeting specific guidelines combinations[c]							
At least MVPA+SB	-0.86 (-1.34, -0.38)***	-2.95 (-4.41, -1.49)***	-0.02 (-0.03, -0.004)[e] **	-2.42 (-3.25, -1.61)***	-3.98 (-6.96, -0.99)**	-0.13 (-1.91, 1.65)	2.80 (1.89, 3.72)***
At least MVPA+Sleep	-0.97 (-1.17, -0.76)***	-3.06 (-3.68, -2.43)***	-0.01 (-0.02, -0.01)***	-1.82 (-2.17, -1.47)***	-1.12 (-2.40, -.17)	-0.22 (-0.99, 0.54)	2.76 (2.37, 3.14)***
At least SB+Sleep	-0.89 (-1.54, -0.24)**	-2.75 (-4.72, -0.79)**	-0.02 (-0.03, -0.002)*	-2.53 (-3.63, -1.43)***	-3.98 (-8.00, 0.03)	0.33 (-2.06, 2.73)	3.49 (2.27, 4.72)***
The number of guidelines met[d]							
Meeting one	-0.93 (-1.14, -0.71)***	-5.48 (-7.47, -3.48)***	-0.02 (-0.02, -0.01)***	-1.50 (-1.86, -1.13)***	0.86 (-0.50, 2.21)	0.02 (-0.79, 0.83)	2.26 (1.86, 2.66)***
Meeting two	-1.64 (-1.89, -1.38)***	-4.97 (-5.75, -4.20)***	-0.02 (-0.03, -0.02)***	-2.91 (-3.34, -2.47)***	-0.55 (-2.16, 1.06)	-0.29 (-1.25, 0.67)	4.30 (3.82, 4.77)***
Meeting three	-1.84 (-2.50, -1.18)***	-2.56 (-3.21, -1.91)***	-0.03 (-0.05, -0.02)***	-4.13 (-5.25, -3.01)***	-3.64 (-7.79, 0.51)	0.28 (-2.20, 2.75)	5.90 (4.67, 7.13)***
Trend analysis	-0.77 (-0.89, -0.65)***	-2.35 (-2.72, -1.99)***	-0.02 (-0.02, -0.01)***	-1.44 (-1.64, -1.23)***	-0.51 (-1.27, 0.24)	-0.11 (-0.56, 0.34)	2.11 (1.89, 2.33)***

Note. All models were adjusted for age, gender, residence, education, marital status, chronic diseases, smoking, alcohol, and municipality economic status; [a] Independent variables were meeting movement guidelines and dependent variables were health outcomes; [b] Not meeting individual guideline as reference group; [c] Not meeting specific guideline combinations as reference group; [d] Not meeting any guideline as reference group; [e] The analysis was not robust in the sensitivity analysis with excluding participants who were obese or with moderate and severe depressive symptoms; MVPA= moderate-to-vigorous physical activity; SB=sedentary behavior; BMI = body mass index; WC = Waist circumference; SP= systolic pressure; DP=diastolic pressure; 95%CI=95% confidence interval; $^{***}P<0.001$, $^{**}P<0.01$.

Table 4. Associations of Adherence to 24-hour movement guidelines with mental health outcomes (n=4,562).

Meeting movement guidelines[a]	Depression	Loneliness
	***B* (95%CI)**	***B* (95%CI)**
Meeting individual guideline[b]		
At least MVPA	-1.99 (-2.18, -1.80)***	-3.57 (-4.04, -3.09)***
At least SB	-2.05 (-2.55, -1.54)***	-1.95 (-3.19, -0.71)[e] *
At least sleep	-2.60 (-2.79, -2.42)***	-4.00 (-4.47, -3.53)***
Meeting specific guidelines combinations[c]		
At least MVPA+SB	-2.04 (-2.54, -1.53)***	-1.89 (-3.14, -0.64)[e] **
At least MVPA+Sleep	-2.01 (-2.23, -1.80)***	-3.53 (-4.05, -3.00)***
At least SB+Sleep	-1.76 (-2.45, -1.08)***	-1.14 (-2.82, 0.54)
The number of guidelines met[d]		
Meeting one	-3.28 (-3.48, -3.07)***	-5.11 (-5.65, -4.58)***
Meeting two	-4.43 (-4.67, -4.19)***	-7.35 (-7.99, -6.72)***
Meeting three	-4.75 (-5.37, -4.14)***	-5.95 (-7.59, -4.32)***
Trend analysis	-2.05 (-2.16, -1.93)***	-3.28 (-3.58, -2.98)***

Note. All models were adjusted for age, gender, residence, education, marital status, chronic diseases, smoking, alcohol, and municipality economic status; [a] Independent variables were meeting movement guidelines and dependent variables were health outcomes; [c] Not meeting specific guideline combinations as reference group; [d] Not meeting any guideline as reference group; [e] The analysis was not robust in the sensitivity analysis with excluding participants who were obese or with moderate and severe depressive symptoms; MVPA= moderate-to-vigorous physical activity; SB=sedentary behavior; 95%CI=95% confidence interval; $^{***}P<0.001$, $^{**}P<0.01$.

Sensitivity analyses

The outcomes of sensitivity analyses, which excluded participants with obesity or moderate to severe depressive symptoms, aligned with the primary findings, except for seven discrepancies (Supplementary Materials 1). In particular, the association between adherence to the SB guidelines and loneliness (P=0.06) was not significant in the sensitivity analysis. Similarly, adhering to the sleep guideline was not significantly associated with BMI (P=0.49), waist circumference (P=0.78), and PBF (P=0.42). Furthermore, the correlation between adherence to MVPA+SB guidelines and WHR (P=0.10) and loneliness (P=0.07) was not statistically significant among participants, excluding those with obesity or moderate to severe depressive symptoms. The e-values showed that the main findings of the association examination are unlikely to be nullified by unmeasured confounders (all the e-values were >1) (Supplementary Materials 1).

Discussion

Principal Results

This study provides timely evidence on the prevalence and correlates of adherence to 24-hour movement guidelines as well as its associations with physical and mental health outcomes among older adults. Results showed that only 1.8% of participants met all three movement guidelines, while 32.1%, 3.4% and 66.4% met individual behavioral guidelines for MVPA, SB and sleep, respectively (Aim 1). Participants, who were older, female and lived in the municipalities with a lower economic status, were less likely to comply with all three movement guidelines, while living in urban areas, higher education levels, no chronic diseases were associated with a higher adherence to specific individual

or combination of movement guidelines (Aim 2). For Aim 3, adherence to either the individual or combined movement guidelines was associated with a higher level of physical fitness and lower levels of BMI, waist circumference, WHR, PBF, depressive symptoms and loneliness. This did not extend to the relationship between adherence to SB+Sleep and loneliness. Furthermore, adherence to movement guidelines did not correlate with two blood pressure indicators, except when adhering to the SB or MVPA+SB guidelines.

Regarding guideline adherence (Aim 1), the percentage of Chinese older adults meeting all three movement guidelines was lower than other age groups as reported in previous national surveys (e.g., Chinese children and adolescents: 2.1%; Chinese caregivers of preschoolers: 15.1%; Canadian adults: 7.1%, and Thailand adults: 21.3%) [36,38,41,42]. This is consistent with previous studies, which indicate a poorer adherence of 24-hour movement guidelines among older adults compared to other age groups [30,37,38]. Age-related decrease in PA and sleep and increase in sedentary time have been demonstrated by previous studies [61-62]. This is not surprising, as older adults generally experience physical and cognitive hypofunction with age, coupled with worries of life transition, diseases and death [63], which to some extent may weaken the antecedents of behavioral initiation (e.g., perceived capability, motivation), eventually leading to the unhealthy patterns of movement behaviors (e.g., physical inactive, prolonged sedentary, insufficient sleep) [64]. In addition to this explanation, the time frame of data collection should also be considered. The data in our study was gathered during the COVID-19 period, where local preventive measures were still being undertaking (e.g., mandatory quarantine, physical distancing, emergent closures of some public areas); and this might contribute to the low adherence rate of meeting 24-hour movement guidelines among Chinese older adults [65-66]. Overall, the above findings underline the long-term requirement of effective behavioral promotion strategies and policymaking. In addition, as there is a lack of evidence on older adults' adherence of 24-hour movement guidelines, we are not able to make a comparison with previous studies using the same age group, which implies that more surveillance studies on this topic are warranted.

Regarding the correlates of movement guideline adherence among Chinese older adults (Aim 2), we found that participants who were female and who were older were less likely to comply with movement guidelines, which is in accordance with previous studies with children and adults [35-38]. Interestingly, we also found a lower adherence of all three movement guidelines among participants who lived in the municipalities ranking at <9th of GDP. This might reflect the fact that compared with those who lived in the cities with a lower level of economy and modernization, Chinese older adults who lived in the cities with a higher GDP were apt to having a healthy lifestyle. For other covariates, some were only associated with specific guideline adherence (e.g., a higher adherence of MVPA and sleep was found in participants living in urban areas, yet residence was not associated with SB guideline adherence), where mixed results were also demonstrated in previous studies with children and adults [30,35,42,67]. Overall, the above findings imply that future health promotion programs and policymaking should take age, gender, and municipality economic status difference into account. For example, more effective strategies for motivating females and older-aged groups are needed (e.g., designing programs based on participants' preference, tailoring the intervention content based on pre-identified psychosocial determinants targeting these samples, more supportive policy

for these economic disadvantaged municipalities). In addition, more research on examining the role of other demographic factors is warranted.

Regarding the association between movement guidelines adherence and health-related outcomes among Chinese older adults (aim 3), we found that adherence to movement guidelines, individually or in combination, was associated with greater physical health indicators, including BMI, PBF, waist circumference, WHR and physical fitness. These findings are consistent with previous findings from children and adult populations [37-42], suggesting the broader applicability of these guidelines. Notably, our research showed that only adherence to SB or MVPA+SB guidelines was associated with a lower level of systolic pressure, contrasting with the lack of association between other guidelines adherence and blood pressure indicators. The limited evidence on the relationship between 24-hour movement guidelines adherence and health of older adults constrains a comprehensive comparison with existing studies. Notably, current research on movement behaviors and their relationship with blood pressure indicators (e.g., using a compositional data analysis) presents mixed findings among older adults [68-70]. This discrepancy may be attributed to different types of PA (e.g., muscle strength training, aerobic exercise) and dietary factors (e.g., sodium intake) [71-72]. Particularly, in relation to blood pressure among older adults, the quality of PA (e.g., specific modality) and dietary patterns may serve as more sensitive and significant correlates than the quantity of PA (e.g., minutes per week). Moreover, age-related physiological changes may reduce the sensitivity of blood pressure to movement behaviors [73], and the prevalent use of antihypertensive medications within the elderly population could also obscure the potential benefits of adhering to movement guidelines (e.g., achieving the recommended levels of MVPA) [74]. Nevertheless, these assumptions were not explored in our study, highlighting a need for systematic investigation in future research.

For mental health outcomes, we found that adherence to movement guidelines was associated with lower levels of depressive symptoms and loneliness, except adherence to SB+Sleep guidelines, which showed no significant relationship with loneliness. Engaging in a variety of physical activities, especially peer-based or group-oriented ones, significantly benefits the emotional and social well-being of the elderly [75]. The influence of SB and sleep duration on loneliness among older adults have not been convincingly demonstrated by prior research [70,76-77]. It is important to recognize that not all sedentary activities exert the same effect on mental well-being; engaging in socially interactive sedentary activities (e.g., internet-based social activities, playing chess with friends) may actually contribute to reducing depressive symptoms and feeling of loneliness [77-78]. The findings of our study support the connection between adherence to movement guidelines and mental health outcomes among older adults. However, evaluating activity solely by its duration does not provide a comprehensive understanding of its effect on mental health. Future research is needed to investigate the specific mechanisms by which movement behaviors contribute to the improvement of mental health, thereby informing the development of more effective health promotion initiatives.

Finally, the results of sensitivity analyses corroborate the robustness of our data analyses, with certain exceptions noted in the associations between adherence to SB guidelines and loneliness, adherence to sleep guidelines and BMI, waist circumference, and PBF,

adherence to MVPA+SB guidelines and WHR, and adherence to MVPA+Sleep guidelines and loneliness. These exceptions suggest that weight status and the severity of depressive symptoms might affect the solidity of our findings, warranting further investigation in future studies. Additionally, our e-value analyses consistently yielded values exceeding 1, affirming the resilience of our findings against the influence of unmeasured confounders and therefore strengthening the stability of our results. These findings validate the integrity of the associations identified in our study. It is worth noting that our observations also reveal that lower adherence to movement guidelines corresponds with reduced e-values, suggesting a comparatively increased susceptibility to unobserved confounders. This discrepancy implies the importance of cautious interpretation and necessitates further exploration of potential unmeasured confounders, such as social and environmental factors, to enhance our comprehension of the intricate relationships between adherence to 24-hour movement guidelines and health-related outcomes.

Limitations

Several limitations should be noted. First, although our study applied stratified random sampling with a large sample size, the study findings to some extent could only reflect the behavioral profiles of Chinese older adults living in the center region of China and the generalizability to other regions (e.g., north and south of China) and different cultural contexts should be further examined. Second, the causal relationship between movement behaviors and health outcomes could not be well-supported by the cross-section design. A further examination using longitudinal and experimental designs is warranted. Moreover, all the movement behaviors were evaluated by self-reported items. Although these kinds of measures have been well validated and showed advantages in several aspects (e.g., could reach wider participants and be more feasible in a large sample surveillance), it might lead to measurement biases (e.g., recall-bias and social disabilities). Objective measures for movement behaviors are warranted in future research. In addition, for the correlates of movement guideline adherence, our findings could only explain a small percentage of the variance. Further examination of the potential correlates (e.g., psychosocial and environmental factors) is deserved in future studies.

Conclusions

This study found that only 1.8% of Chinese older adults adhere to 24-hour movement guidelines. Older age, being female, and lower municipality economic levels were associated with a poorer adherence of movement guidelines among Chinese older adults. Importantly, adherence to either individual or combined movement guidelines correlated with better physical and mental health outcomes. These findings suggest the potential benefits of promoting a holistic lifestyle, encompassing adequate MVPA, reduced SB, and sufficient sleep, on improving the physical and mental well-being of elderly populations.

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Authors' Contribution

Design and methodology: WL and YD; Investigation and data management: YW, QH, BS, LZ and NS; Data screening and analysis: WL and YW; First draft writing: WL; Manuscript revision: WL, RER, NS, LZ, and YD; Language editing: RER and JSB. All authors read and approved the final manuscript.

Conflicts of Interest

None declared.

Abbreviations

PA: physical activity
MVPA: moderate-to-vigorous physical activity
SB: sedentary behavior
BMI: body mass index
WHR: waist-hip ratio
PBF: percentage body fat
SP: systolic pressure
DP: diastolic pressure
HSHC: health surveillance of Hubei China
PAR-Q: Physical Activity Readiness Questionnaire
SD: standard deviation
OR: odds ratio
CI: confidence interval

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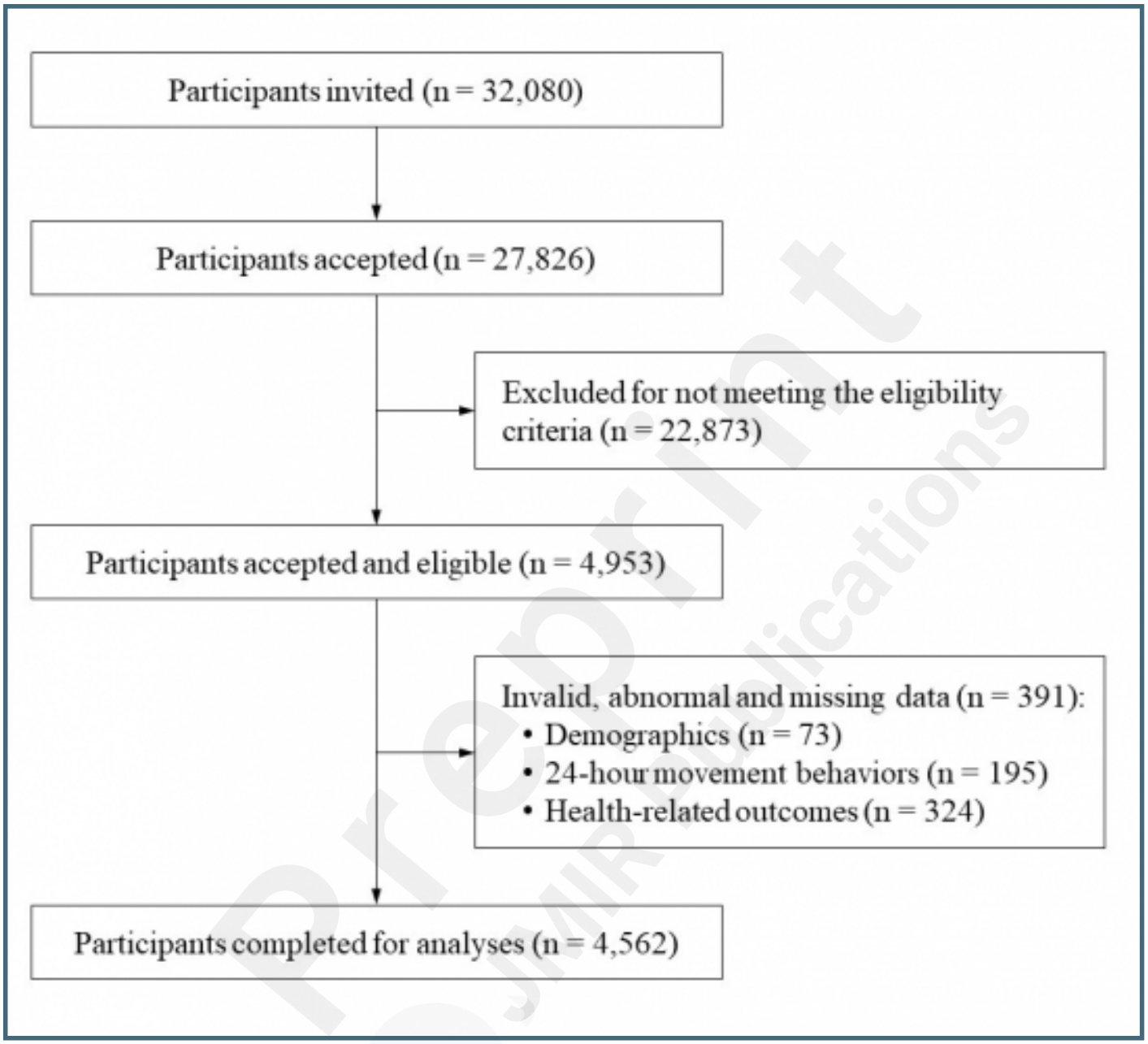
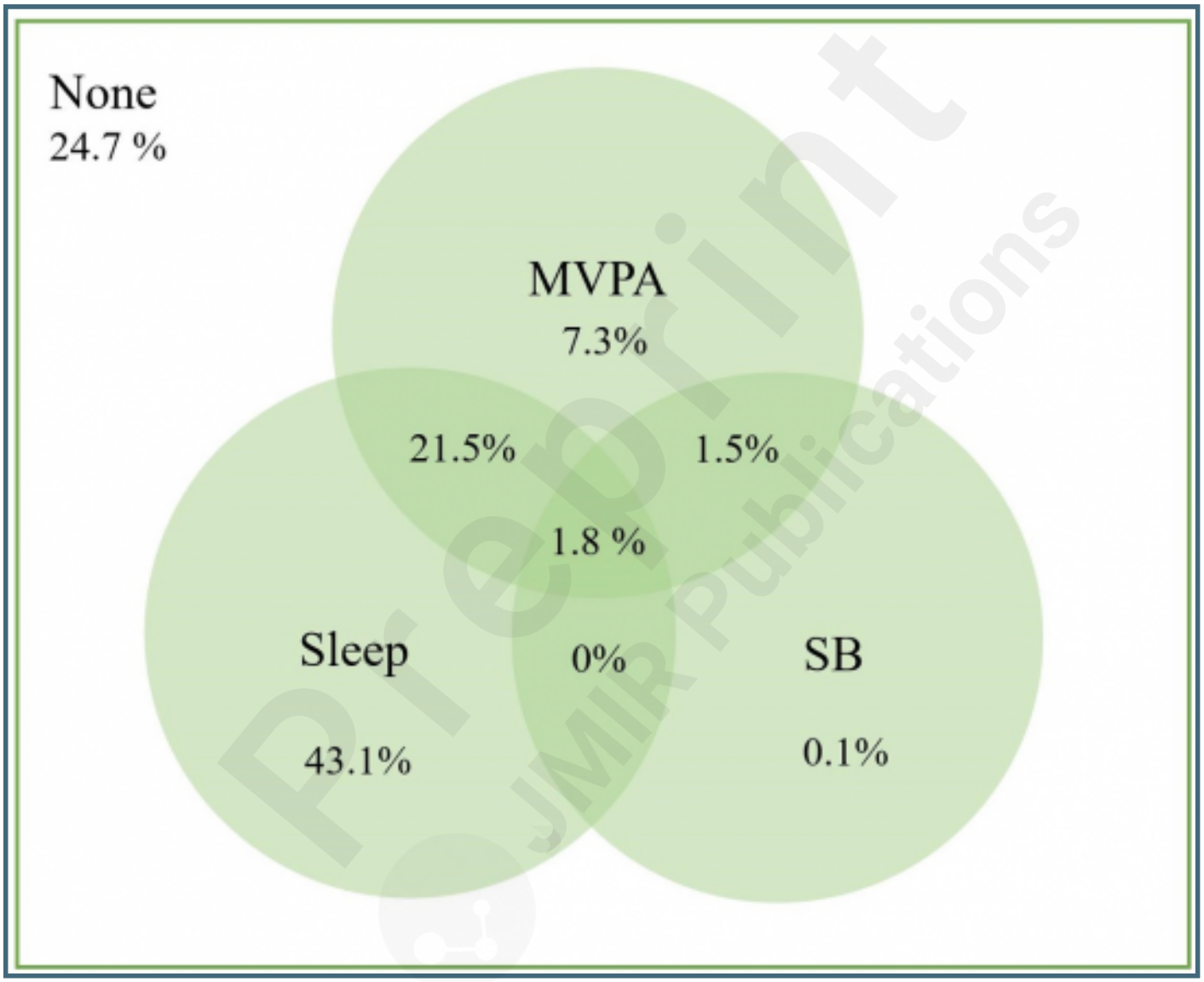
Supplementary Files

Figures

SROBE diagram of study process.



Adherence to the 24-hour movement guidelines among the study participants. Note. SB = sedentary behavior; MVPA = moderate to vigorous physical activity; The number within each circle are added to the percentage of participants meeting each individual guideline (i.e., 32.1% for MVPA, 3.4% for SB and 66.4% for sleep); The overall non-overlapped area of each circle refers to the percentage of participants meeting one of the three guidelines (i.e., 7.3% + 0.1% + 43.1% = 50.5%); The overall overlapped areas of two circles refer to the percentage of participants meeting two movement guidelines (i.e., 21.5% + 1.5% + 0% = 23%); The overlapped area of three circles refers to the percentage of participants meeting all three movement guidelines (i.e., 1.8%); The outside area of the circle refers to the percentage of participants meeting none of the guidelines (i.e., 24.7%).



Multimedia Appendixes

Results of sensitivity analyses.
URL: http://asset.jmir.pub/assets/1bc51b58b80ea73537d6c9e2dc048990.pdf