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Journal of Sport and Health Science 8 (2019) 376–385
www.jshs.org.cn

Original article

Levels and correlates of 24-hour movement behaviors among South Koreans: Results from the Korea National Health and Nutrition Examination Surveys, 2014 and 2015

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Received 11 July 2018; revised 31 August 2018; accepted 17 September 2018
Available online 1 December 2018

Abstract

Purpose: This study aimed to examine the levels and correlates of 24-h movement behaviors (i.e., physical activity, sedentary time, and sleep), and different patterns of these behaviors in a nationally representative sample of South Koreans aged 12 years and older. This study also aimed to examine the sociodemographic correlates of 24-h movement behaviors stratified by age groups.

Methods: Self-reported, repeated cross-sectional data from 10,708 participants in the 2014 and 2015 Korea National Health and Nutrition Examination surveys were used. Key variables included moderate-to-vigorous intensity physical activity, muscular strengthening exercises, walking, active transportation, sedentary time, and sleep. Sociodemographic variables included age, sex, household income, area of residence, and education level. Descriptive statistics by sex and age as well as general linear models by age group were performed.

Results: The proportions of individuals meeting the moderate-to-vigorous intensity physical activity, muscular strengthening exercises, and sleep guidelines were, respectively, 21.6%, 22.1%, and 32.5% in male youth; 6.9%, 4.5%, and 22.8% in female youth; 55.5%, 30.8%, and 54.0% in male adults; 48.8%, 14.4%, and 57.6% in female adults; 44.0%, 30.6%, and 45.5% in male older adults; and 29.5%, 8.9%, and 37.3% in female older adults. The proportions of individuals showing the most ideal combinations of 24-h movement behaviors were only 3.2% in youth, 0.4% in adults, and 0 in older adults. Universally, older age, female sex, or living in metro Seoul were associated with unfavorable patterns of 24-h movement behaviors across different age groups. However, the associations of income and education with movement behaviors were mixed across age groups.

Conclusion: Overall, the proportion of South Koreans with a healthy 24-h movement behavior pattern is low. The sociodemographic correlates of different types of 24-h movement behaviors should be considered when designing targeted interventions for the promotion of healthy active living for South Koreans.

Keywords: 24-h movement behavior; Behavioral epidemiology; Guideline adherence; Health behavior surveillance

1. Introduction

Engaging in sufficient levels of physical activity (PA), limiting sedentary behavior (SB), and obtaining adequate sleep throughout the day is beneficial for health across the lifespan.[1–4] Given that a 24-h period consists of 3 types of movement behaviors (i.e., PA, SB, sleep),[3] regularly monitoring the levels and patterns of these behaviors is important for population health surveillance and for developing future preventative health strategies. Also, identifying those at risk owing to unhealthy movement behavior patterns can inform targeted interventions as well as the equitable allocation and provision of resources.[5,6]

As part of such efforts, the World Health Organization (WHO)[7] and the National Sleep Foundation[8] offer recommendations for PA, separately for moderate-to-vigorous intensity PA (MVPA) and muscular strengthening exercises (MSE),

Peer review under responsibility of Shanghai University of Sport.
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https://doi.org/10.1016/j.jshs.2018.11.007
Cite this article: Lee E-Y, Carson V, Jeon JY, Spence JC, Tremblay MS. Levels and correlates of 24-hour movement behaviors among South Koreans: Results from the Korea National Health and Nutrition Examination Surveys, 2014 and 2015. *J Sport Health Sci* 2019;8:376–85.

and sleep for different age groups. Although no specific benchmark is available for sedentary time, it is generally advised to minimize time spent being sedentary, particularly screen-based SB.[3,9] To date, limited evidence is available to understand the levels of movement behaviors in the South Korean (Korean/Korea hereafter) population based on the internationally recognized benchmarks such as global PA guidelines[7] or international sleep recommendations.[8]

Although 2 major health surveillance surveys are conducted annually in Korea (Korea National Health and Nutrition Examination Survey (KNHANES); Korea Youth Risk Behavior Web-based Survey), it was not included in a recent comparison of adolescent and adult PA and SB across 122 countries.[10] Based on national data collected in 2013, only 4.9% of youth (12−18 years) met the WHO's PA guidelines, with an average MVPA of 29.7 min/day and the average sitting time was 8.9 h/day.[11] Although adherence to the internationally recognized sleep guidelines[8] has not been assessed in Korea, the greatest portion of adolescents (30%−49%) across studies spent 6−7 h/day sleeping.[12,13] Finally, prevalence estimates and the important correlates of movement behaviors among Korean adults older than 18 years have rarely been reported.

Therefore, the purposes of this study were to (1) describe the levels of PA by different domains (MVPA, walking, active transportation), sedentary time, and sleep duration, (2) examine adherence to the international recognized guidelines for PA (MVPA and MSE, separately)[7] and sleep,[8] (3) examine the proportions of individuals showing the ideal patterns of 24-h movement behaviors, and (4) investigate the sociodemographic correlates of these behaviors in a nationally representative sample of Koreans.

2. Materials and methods

2.1. Study participants

Data from the 2014−2015 KNHANES were used for this study. The KNHANES is an annual, repeated cross-sectional survey, consisting of 3 components (i.e., health examination, health interview, and nutrition survey), that monitors health and health behaviors among a nationally representative sample of Koreans older than 1 year.[14] The self-administered health interview data collected at the mobile examination center for the 2014 and 2015 KNHANES were used for this study. Using stratified multistage clustered sampling, a total of 14,930 participants were recruited in 2014 ($n = 7550$) and 2015 ($n = 7380$). Among those sampled, children aged younger than 12 years (2014, $n = 1023$; 2015, $n = 852$) were removed from the analyses because they did not participate in the health interview. The final sample included 13,055 Koreans aged 12 years or older. Before being released, the data in the KNHANES were de-identified by the Korea Center for Disease Prevention and Control. All participants provided informed consent[14] and the survey protocol was approved by the Korea Center for Disease Prevention and Control Ethics Committee Board (approval numbers: 2013-12EXP-03-5C for the 2014 cycle; 2015-01-02-6C for the 2015 cycles) (available at: https://knhanes.cdc.go.kr/knhanes/sub03/sub03_06_mod.do). A detailed description of the survey methodology can be found elsewhere.[14]

2.2. Measures

2.2.1. PA

Self-reported PA (i.e., work (school-related for those 12−18 years old)/transport/leisure during the past week) was assessed using the Global Physical Activity Questionnaire.[15] The average number of min per day of overall MVPA (i.e., work/leisure only) was calculated for the analysis. Acceptable reliability ($\kappa = 0.42-0.67$; Spearman's $\rho = 0.62-0.76$), validity against accelerometer (Spearman's $\rho = 0.34$), and other self-report PA questionnaires ($r = 0.60-0.68$) on the Korean-Global Physical Activity Questionnaire have been reported.[15] The frequency and duration of walking (3 items) and the frequency of participating in MSE (1 item) were also self-reported.

For youth, MVPA values were dichotomized into meeting (≥60 min/day) or not meeting (<60 min/day) the PA guidelines.[7] Additionally, engaging in 3 or more days per week of MSE was classified as meeting, whereas engaging in fewer than 3 days/week was classified as not meeting the guidelines.[7] For adults/older adults, metabolic equivalent of task (MET)-min values were obtained using the following equation: total PA MET-min/week = ((work-related vigorous-intensity PA (VPA) frequency × work-related VPA duration × 8) + (work-related moderate-intensity PA (MPA) frequency × work-related MPA duration × 4) + (active transportation frequency × active transportation duration × 4) + (leisure-related VPA frequency × leisure-related VPA duration × 8) + (leisure-related MPA frequency × leisure-related MPA duration × 4)).[16] Those obtaining 600 MET-min/week or more of MVPA were classified as meeting the guidelines whereas those obtaining less than 600 MET-min/week were classified as not meeting the guidelines.[16] Additionally, engaging in 2 or more days/week MSE was classified as meeting the guidelines while engaging in less than 2 days/week was classified as not meeting the guidelines.[7]

2.2.2. Sedentary time

Self-reported sedentary time was assessed using 1 item from the Korean-Global Physical Activity Questionnaire[15] for which participants were asked to report the time spent (h and min) sitting or reclining on a typical day (e.g., sitting at a desk, sitting with friends, traveling by car/bus/train, reading, playing cards/video games, web surfing, or watching television, but not time spent sleeping). To allow comparisons, total sedentary time was converted to hours and categorized as less than 9 h/day *vs.* 9 h/day or more (defined as high sitting time) for analysis based on a previous study.[17]

2.2.3. Sleep duration

Self-reported sleep duration was assessed using 1 item, which asked participants to report the time spent sleeping (h) on a typical day. Sleep duration values were dichotomized into meeting or not meeting the sleep recommendation based on the age-specific sleep recommendations in our samples: 9−11 h/day for those 12−13 years old, 8−10 h/day for those

14−17 years old, 7−9 h/day for adults (18−64 years old), and 7−8 h/day for older adults (≥65 years old).[8]

2.2.4. Sociodemographic factors

Self-reported age, sex, household income, area of residence, and education level (for adults only) were included as sociodemographic factors. Age was estimated by the KNHANES based on the self-reported birth date and the examination date of the respondents. The response options for sex included male or female. Household income was collected by asking respondents to report their monthly earnings directly. Age- and sex-standardized monthly income scores were calculated by dividing total monthly household income by number of household members. The standardized income values were then grouped into quartiles (low, low-middle, middle-high, and high) before the Korea Center for Disease Prevention and Control released the data.[18] Area of residence was divided into metro Seoul (Seoul, Incheon metropolitan city, and Gyeonggi province) and nonmetro Seoul, given that social and health inequalities between these 2 categories have been reported.[11,19] For adults and older adults only, information on educational attainment was obtained with the following response options: elementary or less (≤6 years), middle school (7−9 years), high school (10−12 years), and college and above (≥13 years). Education level was then grouped into less than post-secondary graduate or post-secondary graduate or more.

2.3. Statistical analysis

Analyses were weighted to account for the multistage cluster sampling design of the KNHANES and performed separately by 3 age groups: youth (12−17 years), adults (18−64 years), and older adults (≥65 years) based on the age groupings in the WHO's PA recommendations.[7] Descriptive statistics were calculated for the sociodemographic variables, as well as the levels of MVPA, walking, active transportation, sedentary time, and sleep duration by sex. Proportions of participants meeting the PA and sleep guidelines and engaging in high sitting time (≥9 h/day) by sex were also calculated. Different patterns of 24-h movement behaviors were also calculated. Specifically, the most ideal pattern included meeting PA and sleep recommendations and not engaging in high sitting time, whereas the least ideal pattern included meeting neither PA nor sleep recommendation and engaging in high sitting time. Additionally, the proportions of participants showing ideal patterns in at least 2 behaviors (MVPA + sleep, MVPA + sitting, or sleep + sitting) and 1 behavior (MVPA only, sleep only, or sitting only) were also calculated. General linear models were performed to examine associations of sociodemographic factors with MVPA, walking, active transportation, sitting, and sleep. A significance level was set at $p < 0.05$, and unstandardized coefficients (B) and 95% confidence intervals (CIs) were estimated. All statistical analyses were performed using the IBM SPSS Version 20.0 Complex Samples Procedures (IBM Corp., Armonk, NY, USA).

3. Results

Of the 13,055 eligible participants 2347 (2014, $n = 1251$; 2015, $n = 1096$) had missing data on the key variables, leaving a total of 10,708 for the analytic sample. Regardless, no significant differences existed in sociodemographic factors between the included ($n = 10,708$) and excluded ($n = 2347$) samples. A summary of the sample characteristics is provided in Table 1.

Among 845 youth, the total average daily MVPA, walking, and active transportation were 38.2 min/day, 32.8 min/day, and 24.6 min/day for males and 17.5 min/day, 33.0 min/day, and 21.9 min/day for females, respectively (Fig. 1A). Total

Table 1
Sample characteristics—Korean National Health and Nutrition Examination Surveys, 2014 and 2015.

	Youth (12−17 years)	Adults (18−64 years)	Older adults (≥65 years)
Total (*n*)	845	7481	2382
Age (mean ± SE)	14.6 ± 0.1	40.8 ± 0.2	72.5 ± 0.1
Sex (%)			
Male	51.6	50.0	44.4
Female	48.4	50.0	55.6
Household income (%)			
Low	10.2	9.0	44.6
Low-middle	24.3	23.6	27.7
Middle-high	36.6	33.0	16.7
High	28.9	34.4	11.0
Area of residence (%)			
Metro Seoul	53.4	52.5	42.8
Nonmetro Seoul	46.6	47.5	57.2
Education (%)			
≥Post-secondary graduate	NA	41.4	9.2
<Post-secondary graduate	NA	58.6	90.8
Sedentary time (%)			
<9 h/day	24.4	59.1	63.1
≥9 h/day	75.6	40.9	36.9

Abbreviations: NA = Not available; SE = standardized errors.

sedentary time was 10.1 h/day for males and 11.0 h/day for females (Fig. 2A). Males and females slept for 7.3 h/day and 7.0 h/day, respectively (Fig. 2A). The proportions of male and female youth meeting the MVPA and MSE recommendations within the WHO's PA guidelines were 21.6% and 6.9% for MVPA, and 22.1% and 4.5% for MSE, respectively (Fig. 3A). The proportions of male and female youth meeting the sleep recommendation were 32.5% and 22.8%, respectively (Fig. 3A). The proportions of youth showing the most ideal and the least ideal 24-h movement behavior pattern were 3.2% and 14.1%, respectively (Fig. 4). Among youth (Table 2), being male or having a middle-high or high income compared with a low income was significantly associated with greater MVPA. Older age was the only significant correlate of longer time spent walking and taking active transportation. For sedentary time, being older age, being female, or living in metro Seoul was a significant correlate of time spent sitting. In addition, being younger age, being male, or having a middle-high or high income compared with a low income was associated with longer sleep duration.

Among 7481 adults, the total average daily MVPA, walking, and active transportation were, respectively, 32.3 min/day, 49.7 min/day, and 20.6 min/day for males and 21.2 min/day, 46.3 min/day, and 20.5 min/day for females (Fig. 1B). Among adults, the average sedentary time per day was 7.9 h for males and 7.6 h for females, and the average sleep duration was 6.8 h/day for males and 6.9 h/day for females (Fig. 2B). A total of 55.5% of males and 48.8% of females met the MVPA recommendation, whereas 30.8% of males and 14.4% of females met the MSE recommendation. The

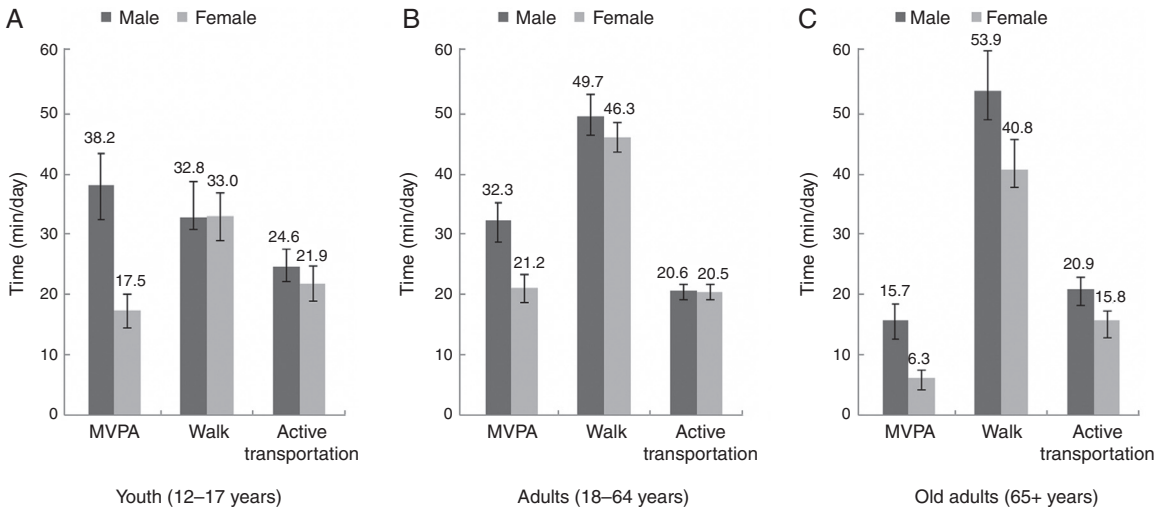

Fig. 1. Time spent in MVPA, walking, and active transportation by sex among youth (12−17 years), adults (18−64 years), and older adults (≥65 years)—Korean National Health and Nutrition Examination Surveys, 2014 and 2015. MVPA = moderate-to-vigorous intensity physical activity.

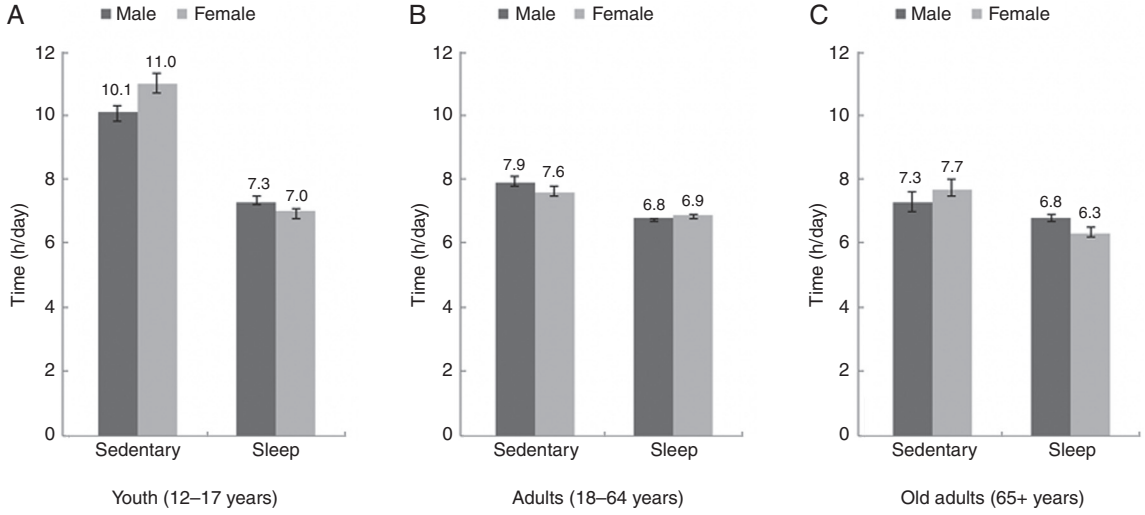

Fig. 2. Sedentary time and sleep duration by sex among youth (12−17 years), adults (18−64 years), and older adults (≥65 years)—Korean National Health and Nutrition Examination Surveys, 2014 and 2015.

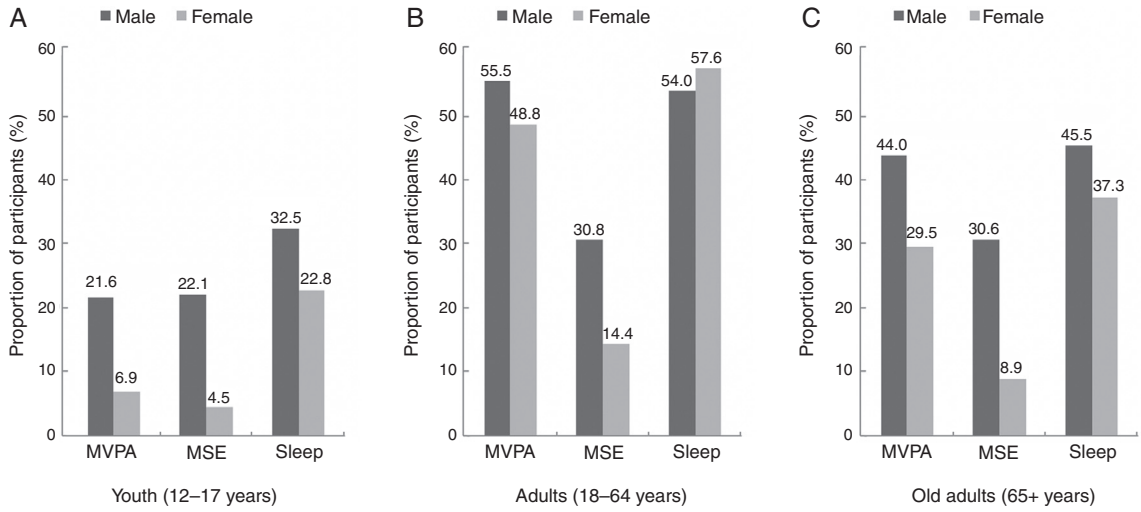

Fig. 3. Proportion of participants meeting the MVPA, MSE, and sleep recommendations by sex among youth (12−17 years), adults (18−64 years), and older adults (≥65 years)—Korean National Health and Nutrition Examination Surveys, 2014 and 2015. Meeting the MVPA recommendation[7]: ≥60 min/day for youth; ≥600 MET min/week for adults and older adults. Meeting the MSE recommendation[7]: ≥3 days/week for youth; ≥2 days/week for adults and older adults. Meeting the sleep recommendation[8]: 9−11 h/day for 12−13 years old, 8−10 h/day for 14−17 years old, 7−9 h/day for adults, and 7−8 h/day for older adults. MET = metabolic equivalent; MSE = muscular strengthening exercises; MVPA = moderate-to-vigorous intensity physical activity.

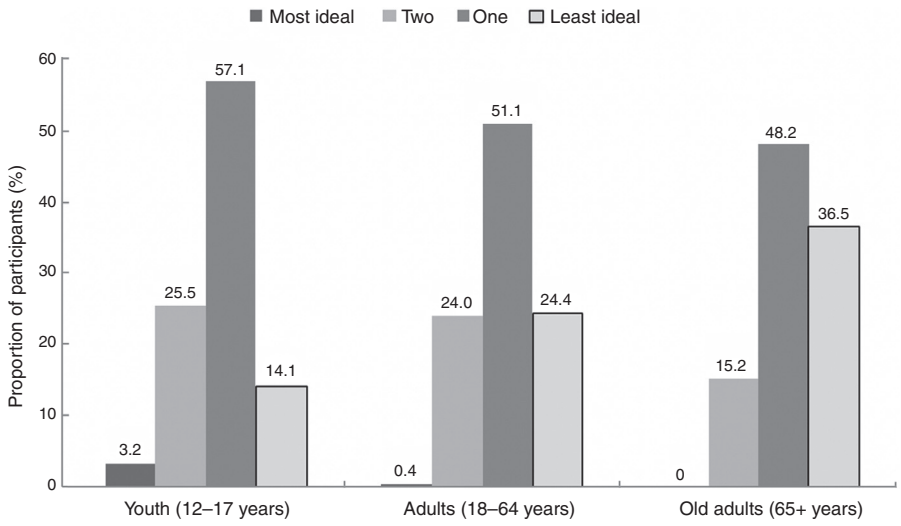

Fig. 4. Proportion of participants showing from the most ideal to least ideal patterns of 24-h movement behaviors among youth (12−17 years), adults (18−64 years), and older adults (≥65 years)—Korean National Health and Nutrition Examination Surveys, 2014 and 2015. Most ideal: Meeting MVPA and sleep recommendations and not showing high sitting time (≥9 h/day); Two: meeting the MVPA and sleep recommendations or meeting the MVPA recommendation and not showing high sitting time (≥9 h/day) or meeting the sleep recommendation and not showing high sitting time (≥9 h/day); One: meeting MVPA only, meeting sleep only, or not showing high sitting time (≥9 h/day) only; Least ideal: not meeting any of the recommendations and showing high sitting time (≥9 h/day). Meeting the MVPA recommendation[7]: ≥60 min/day for youth; ≥600 MET min/week for adults and older adults. Meeting the MSE recommendation[7]: ≥3 days/week for youth; ≥2 days/week for adults and older adults. Meeting the sleep recommendation[8]: 9−11 h/day for 12−13 year olds, 8−10 h/day for 14−17 year olds, 7−9 h/day for adults, and 7−8 h/day for older adults. MSE = muscular strengthening exercises; MVPA = moderate-to-vigorous intensity physical activity.

sleep recommendation was met by 54.0% of males and 57.6% of females (Fig. 3B). Only 0.4% of adults showed the most ideal 24-h movement behavior pattern, whereas 24.4% of adults showed the least ideal 24-h movement behavior pattern (Fig. 4). Among adults (Table 2), being younger, being male, or living in nonmetro Seoul was associated with a longer time spent in MVPA. As for walking, being a high school graduate or less was associated with more time spent walking. Being younger, having a low income, or being a high school graduate or less was associated with taking more active transportation. As for sedentary time, being younger, being male, having a high income, living in metro Seoul, or

Table 2
Associations between demographic variables and time spent in MVPA, walking, active transportation, sedentary time, and sleep duration—Korean National Health and Nutrition Examination Surveys, 2014 and 2015.

Demographic variable	MVPA (min)	Walking (min)	Active transportation (min)	Sedentary time (min)	Sleep (h)
Youth (12−17 years)					
Age	2.9 (−5.1 to 10.9)	7.7 (1.4 to 14.0)*	6.1 (1.4 to 10.8)*	101.8 (67.9 to 135.7)***	−1.4 (−1.6 to −1.2)***
Sex					
Male	Reference	Reference	Reference	Reference	Reference
Female	−20.7 (−26.8 to −14.6)***	0.1 (−4.4 to 4.6)	−2.7 (−6.4 to 1.0)	51.0 (28.9 to 73.1)***	−0.3 (−0.5 to −0.1)**
Household income					
Low	Reference	Reference	Reference	Reference	Reference
Low-middle	10.2 (−0.6 to 21.0)	−2.2 (−14.7 to 10.3)	9.0 (−10.3 to 7.7)	−6.4 (−54.4 to 41.6)	0.5 (−0.1 to 1.1)
Middle-high	10.0 (0.2 to 19.8)*	−8.9 (−19.8 to 2.1)	−4.2 (−12.6 to 4.2)	3.5 (−40.2 to 47.2)	0.6 (0.2 to 1.0)**
High	10.8 (1.0 to 20.6)*	−11.1 (−22.5 to 0.3)	−3.8 (−7.7 to 0.1)	25.7 (−19.4 to 70.8)	0.6 (0.2 to 1.0)**
Area of residence					
Metro Seoul	Reference	Reference	Reference	Reference	Reference
Nonmetro Seoul	0.4 (−6.5 to 7.3)	−4.2 (−9.7 to 1.3)	−3.8 (−7.7 to 0.1)	−44.2 (−69.9 to −18.5)**	0.0 (−2.0 to 2.0)
Adults (18−64 years)					
Age	−40.2 (-52.5 to −27.9)***	−6.2 (−19.7 to 7.3)	−19.9 (−25.6 to −14.2)***	−312.2 (−351.4 to −273.0)***	−1.2 (−1.4 to −1.0)***
Sex					
Male	Reference	Reference	Reference	Reference	Reference
Female	−11.1 (−14.8 to −7.4)***	−3.4 (−7.1 to 0.3)	−0.1 (−1.7 to 1.5)	−19.4 (−31.3 to −7.5)**	0.1 (0.1 to 0.1)**
Household income					
Low	Reference	Reference	Reference	Reference	Reference
Low-middle	4.7 (−2.0 to 11.4)	3.3 (−3.8 to 10.4)	−2.0 (−6.0 to 1.9)	−15.6 (−42.1 to 10.9)	−0.0 (−2.0 to 2.0)
Middle-high	4.7 (−1.8 to 11.2)	0.1 (−6.4 to 6.6)	−4.7 (−8.8 to −0.6)*	5.7 (−19.4 to 30.8)	−0.1 (−0.3 to 0.1)
High	4.7 (−1.4 to 10.8)	1.5 (−1.5 to 4.5)	−5.6 (−9.5 to −1.7)*	43.6 (17.9 to 69.3)**	−0.2 (−0.4 to 0.0)
Area of residence					
Metro Seoul	Reference	Reference	Reference	Reference	Reference
Nonmetro Seoul	9.1 (4.8 to 13.4)***	1.0 (−3.5 to 5.5)	1.1 (−1.1 to 3.3)	−89.6 (−104.5 to −74.7)***	0.1 (0.1 to 0.1)
Education					
≥Post-secondary graduate	Reference	Reference	Reference	Reference	Reference
<Post-secondary graduate	−0.4 (−4.1 to 3.3)	5.0 (1.1 to 8.9)*	4.0 (2.2 to 5.8)***	−60.5 (−72.7 to −48.3)***	0.0 (0.0 to 0.0)
Older adults (≥65 years)					
Age	−26.8 (−31.7 to −21.9)***	−47.8 (−63.9 to −31.7)***	−17.5 (−26.5 to −8.5)***	234.2 (70.0 to 398.5)**	2.7 (2.0 to 3.5)***
Sex					
Male	Reference	Reference	Reference	Reference	Reference
Female	−9.4 (−12.7 to −6.1)***	−13.1 (−19.8 to −6.4)***	−5.1 (−8.2 to −2.0)**	21.6 (−0.4 to 43.6)	−0.4 (−0.6 to −0.2)***
Household income					
Low	Reference	Reference	Reference	Reference	Reference
Low-middle	5.5 (1.0 to 10.0)*	3.9 (−3.4 to 11.2)	1.2 (−2.3 to 4.7)	−10.7 (−35.0 to 13.6)	−0.0 (−0.2 to 0.2)
Middle-high	4.0 (−1.3 to 9.3)	6.6 (−2.2 to 15.4)	−0.1 (−3.6 to 3.4)	−1.9 (−33.1 to 29.2)	−0.1 (−0.3 to 0.1)
High	7.7 (3.6 to 11.8)***	8.9 (−1.9 to 19.7)	3.5 (−4.5 to 11.5)	−5.9 (−43.9 to 32.1)	0.0 (−0.2 to 0.2)
Area of residence					
Metro Seoul	Reference	Reference	Reference	Reference	Reference
Nonmetro Seoul	4.6 (1.5 to 7.7)**	−5.3 (−12.0 to 1.4)	2.7 (−0.8 to 6.2)	−107.6 (−131.3 to −83.9)***	0.1 (0.0 to 0.2)
Education					
≥Post-secondary graduate	Reference	Reference	Reference	Reference	Reference
<Post-secondary graduate	−10.9 (−17.0 to −4.8)**	−12.6 (−20.0 to −4.8)**	−1.7 (−6.6 to 3.2)	−4.2 (−43.4 to 35.0)	−0.2 (−0.4 to 0.0)

Note: Values are unstandardized beta coefficients (95% confidence interval).
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
Abbreviation: MVPA = moderate-to-vigorous intensity physical activity.

being a post-secondary graduate or more was associated with more time spent sitting. Being younger or being female was associated with longer sleep.

Among 2382 older adults, total average daily MVPA, walking, and active transportation were, respectively, 15.7 min/day, 53.9 min/day, and 20.9 min/day for males and 6.3 min/day, 40.8 min/day, and 15.8 min/day for females (Fig. 1C). The average sedentary time was 7.3 h/day for males and 7.7 h/day for females, and the average sleep duration was 6.8 h/day for males and 6.3 h/day for females (Fig. 2C). In addition, a total of 44.0% of males and 29.5% of females met the MVPA recommendation, and 30.6% of males and 8.9% of females met the MSE recommendation. For sleep, 45.5% of males and 37.3% of females met the sleep recommendation (Fig. 3C). None of the older adults showed the most ideal 24-h movement behavior pattern, and 36.5% showed the least ideal 24-h movement behavior pattern (Fig. 4). In the older adult group (Table 2), being younger, being male, having a high income compared with a low income, living in nonmetro Seoul, or being a post-secondary graduate or more was associated with higher MVPA. Similarly, being younger, being male, or being a post-secondary school graduate or more was associated with longer daily walking. Being older and female were associated with spending less time in active transportation. Being older or living in metro Seoul was also associated with more time spent sitting. Last, being older or being male was associated with longer sleep.

4. Discussion

This study is the first to concurrently provide an overview of the levels and sociodemographic correlates of PA, sedentary time, and sleep in a nationally representative sample of Koreans. Overall, regardless of age, the large majority of Koreans showed less than ideal 24-h movement behavior patterns. The proportion of individuals meeting the PA recommendation was the lowest among Korean youth with sex being the most consistent and strongest correlate. In addition, the proportion of individuals engaging in ≥9 h/day of sitting ranged from 36.9% to 75.6%. Adherence rates to the sleep guidelines ranged from 22.8% to 57.6% across different age and sex groups. Overall, female youth were the least active and most sedentary. Also, female youth showed the lowest adherence rate to the sleep recommendation.

Among youth, only 3.2% showed the most ideal 24-h movement behavior pattern, with noticeable age and sex differences in individual movement behaviors. These results are largely consistent with the findings from Western developed countries[20–22] and from other studies conducted in Korea.[11,23] Unequal and unequitable opportunities for PA between genders in Korea are well-known, particularly in school settings.[24] Furthermore, Korean society places a strong emphasis on educational excellence; thus, many parents invest in their children's education in and out of school (e.g., private academic institutes), and this becomes intensified as children progress toward higher grades in school.[25,26] In addition, living in metro Seoul or having a lower income was also associated with high sedentary time and short sleep duration. Although it is unclear what type of SB (e.g., studying, screen-based activities) contributes to the high sedentary time among youth living in metro Seoul, the emphasis on education is often amplified in metro Seoul, where many high-income neighborhoods with good schools (called elite *Hakgun* [학군[學群], i.e., a school district) within a commutable distance are located.[25] Also, many Korean students reported experiencing at least 1 sleep problem (e.g., sleep disturbance, sleep deprivation, excessive daytime sleepiness, low sleep satisfaction) owing to academic workload.[27] Promoting healthy movement behavior patterns for a 24-h period is needed for all youth; however, more resources and support should be targeted at older youth, girls, those living in metro Seoul, and individuals with low-income backgrounds because they seem to be consistently less active, more sedentary, and/or get less sleep.

Only 0.4% of Korean adults showed the most ideal patterns of 24-h movement behaviors. In particular, Korean adult women seem to lag behind in PA compared with their international counterparts.[28,29] Correlates of PA among Korean adults varied by type; however, our results generally support the literature suggesting that younger age and male sex are the key correlates of PA among adults in high-income countries.[5] Living in nonmetro (*vs.* metro) Seoul was also associated with more MVPA. Urban−rural differences in MVPA may be due to variation in the occupational characteristics between the 2 geographical areas. Specifically, other than agriculture, the majority of Korea's economic activity typically takes place in metro Seoul. Thus, adults living in nonmetro Seoul will be more likely to have physically demanding jobs (e.g., farming, fishing) compared with those living in metro Seoul. This assumption is also supported by our data. Specifically, the urban−rural divide in MVPA was most apparent in occupation-related PA (67 min/day in metro Seoul *vs.* 126 min/day in nonmetro Seoul; data not shown).

The proportion of individuals sitting for ≥9 h/day was approximately 40% in our adult sample, which far exceeds the corresponding proportions in 20 other countries (2.6%−34.9%) included in the work of Bauman et al.[17] The correlates of high sedentary time identified in adults may be explained by the labor market characteristics of the nation. Males, compared with females, are more likely to be in high-paying, office-based workplaces in metro Seoul where higher education is required.[30–32] The sleep duration of our adult sample also compares unfavorably with the results from earlier studies that have included Korean adults,[33,34] as well as to the findings from international samples.[35–38] Given that short sleep duration across the lifespan of Koreans has been reported in separate studies,[39,40] Korean adults may obtain shorter sleep than the recommended level and than their counterparts in different countries because they simply do not require longer sleep. The optimal sleep duration needed for health benefits may differ across cultures;[39–41] thus, it may be worthwhile to explore optimal sleep duration cutoffs across different cultures with different health indicators. That said, short sleep duration reported among Korean adults may be due to bias associated with using self-reported measures (e.g., recall bias, overreporting or underreporting based on social desirability); therefore, more replication is needed to confirm our findings.

Although 14% of the entire population in Korea is over the age of 65 years,[42] the levels and correlates of 24-h movement behaviors among Korean elders are largely unknown. Our findings suggest that the proportion of older adults who are physically active is lower than that of adults; however, the guideline compliance rate of Korean older adults was not far off from the international average (approximately 37%).[43–47] In addition, Korean older adults seem to engage in more light-intensity PA (e.g., walking) than PA at higher intensities. Consistent with correlates identified in different countries,[5,48] males and those who are younger engaged in more PA than their respective counterparts consistently across different types of PA. Income, area of residence, and education level were significantly correlated with MVPA only. Older adults living in nonmetro Seoul seem to have more opportunities for habitual PA than their peers living in metro Seoul. Also, older adults who are more educated and have a higher income may place greater value on healthy active living, and thus engage in more MVPA than those who are less affluent.[49] Other than age and sex, only education level was correlated with walking. Similar to MVPA, more educated older adults may tend to understand and value the importance of PA and have adequate resources (e.g., access to walking trails, social support) available to them.[5,50]

In parallel with the correlates of low MVPA, older age and living in metro Seoul were the correlates of longer sedentary time among in the older adult group. The associations between MVPA, sedentary time, and age are intuitive given that physical function and mobility decrease with increasing age and this factor may subsequently prevent active living.[48] Efforts to delay the onset of physically inactive habits may help Korean elderly people to stay active, and thus to stay healthier. Similar to Korean youth and adults, older adults sleep less than their counterparts in other countries.[37,51] Although extremely short sleep duration (≤5 h/day) has been shown to be associated with negative health outcomes among Korean elderly,[33,52] identifying a population-specific optimal sleep duration range that is associated with health benefits may be needed, given that Koreans regardless of age generally sleep less than their counterparts in other countries.

To the authors' knowledge, this study is the first to describe the levels, patterns, and correlates of 24-h movement behaviors, individually and collectively, among Koreans. Based on our findings, to promote healthy levels and patterns of 24-h movement behaviors among young people, future interventions should target older youth, females, those with a low-income background, and those living in metro Seoul. Among adults, target population groups should include individuals who are older, female, have high incomes, live in metro Seoul, and have a higher education background. For older adults, the focus should be on those who are older, female, live in metro Seoul, and have no post-secondary education background. In addition to providing locally specific information that can help in developing national health promotion strategies, this study provides information that will enable international comparisons of 24-h movement behavior levels, patterns, and their correlates. For instance, our findings among youth will inform the development of the future national report card on PA for children and youth as part of the global initiatives in promoting PA.[53,54] Thus, the results will provide important information for local- and international-level efforts in promoting healthy active living.

The KNHANES and other publicly available national health surveillance data rely on self-reported measures that are subject to reporting bias. Although the KNHANES collects accelerometry-based PA and sedentary time data from a subsample of participants, the data are not available publicly. More studies using objective measures of movement behaviors (e.g., actigraphy) are needed to further support our findings. However, it is important to note that the use of a large, nationally representative sample of Koreans is a major strength of this study and that objective measures are often not feasible in large-population health surveillance.[55] Children younger than 12 years old were removed from the analyses because no PA or SB data were collected. Nevertheless, a need exists for monitoring 24-h movement behaviors among young children because these behavioral patterns can be established in the early years.[56,57] Last, given that different types of SB (e.g., reading *vs.* screen time) may be associated with different health outcomes,[58] and that health risks may vary by different domains of sitting (e.g., work, leisure, transport, home),[17] SB should be measured within specific types and domains.

5. Conclusion

Many Koreans are not practicing healthy 24-h movement behavior patterns, and when these behaviors were considered together and separately, youth, compared with adults and older adults, were the least engaged. This finding is a concern for the current and future health of Korean youth given that behavioral patterns during adolescence continue into adulthood.[59] Furthermore, regardless of age, females underperformed compared with their male counterparts in meeting the MVPA, MSE, and sleep recommendations (except for adult women). Although some efforts have been made at the school level to promote PA among school-aged girls,[24] much room exists for creating cultural and societal environments that encourage different types of PA at varying intensities and providing more opportunities and resources that will lead to sustainable healthy active living for female Koreans. Replication using a similar methodology is required to confirm and build on our findings.

Acknowledgments

The Korea Centers for Disease Control and Prevention conducted the KNHANES and produced the database used in this study. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. VC is supported by a Canadian Institutes of Health Research New Investigator Salary Award.

Authors' contributions

EYL obtained the data and designed the study, performed the statistical analysis and data interpretation, and drafted the manuscript; VC, JYJ, JCS, and MST participated in the design

of the study and contributed to the data interpretation. All authors have read and approved the final version of the manuscript, and agreed with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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