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Title: Changes in objectively measured outdoor time and physical, psychological, and cognitive function among older adults with cognitive impairments

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Highlights

- This study targeted older adults with cognitive impairment.
- Their outdoor time was measured using a global positioning system.
- Changes in outdoor time were associated with changes in physical functioning.
- Changes in outdoor time were not associated with changes in cognitive functioning.
- Nor were they associated with changes in psychological functioning.

Abstract

Background: Older adults with cognitive impairment are at higher risk for various health problems. Although previous studies have suggested going outdoors more frequently might be effective to promote health, no longitudinal studies have examined objectively measured outdoor time in this population. This study examined the relationships between changes in objectively measured outdoor time and physical, psychological, and cognitive functions among older adults with cognitive impairments.

Methods: This study was a secondary analysis of a randomized controlled trial (n = 145). The baseline and 1-year follow-up data of outdoor time per day measured by the global positioning system, physical functions (6-minute walk test, 5-repetition chair stand test), psychological functions (Geriatric Depression Scale, simplified World Health Organization Five Well-being Index), and cognitive functions (tablet versions of the Trail-making Test, Symbol Digit Substitution Test, Word Memory Test, Story Memory Test) were used.

Results: Multiple regression analyses revealed that changes in outdoor time were significantly associated with changes in 6-minute walk (standardized beta = 0.20, $p = 0.048$) and 5-repetition chair stand tests (standardized beta = −0.19, $p = 0.032$) after adjusting for baseline data, basic factors, and trial allocation. However, significant relationships between changes in outdoor time and psychological and cognitive functions were not revealed.

Conclusions: The results indicate that maintaining or increasing outdoor time would be effective to prevent declines in physical functions but that a quantitative aspect of going outdoors would have limited impact on psychological and cognitive functions among older adults with cognitive impairment.

Keywords: Cognitive Dysfunction; Geographic Information Systems; Health Behavior; Homebound Persons; Mental Health; Physical Fitness

1. Introduction

Declines in cognitive functions are a common health problem associated with aging. Among community-dwelling older adults without dementia or limitations of activities of daily living, 31.4% have mild or global cognitive impairments (1). It is well known that older adults with cognitive impairment are at higher risk for dementia (2). Epidemiological studies have shown that they are also vulnerable to various health outcomes, such as mortality (3), disability (1), mobility impairment (4), fall experiences (5), and psychological health (6). Thus, development of effective strategies to prevent further decline of their health status is a public health priority.

To prevent further decline of health status among older adults with cognitive impairment, promotion of going outdoors more frequently might be effective. The concept of going outdoors is similar to that of homebound status and life-space mobility. Going outdoors usually involves certain levels of physical, cognitive, and/or social activities. Older adults go outdoors for various purposes such as shopping, social visits, running errands, and so on (7). Since going outdoors does not require any special knowledge, motivation, cost, or time, it would be easier for older adults to incorporate going outdoors into their daily lives than other health behaviors such as exercise and smoking cessation. Previous studies have reported that going outdoors, housebound status, and life space are associated with various health outcomes, including mortality (8, 9), instrumental/basic activities of daily living (10–13), cognitive function (14–16), and psychological health (10, 17). Some studies have also indicated that influences of going outdoors on health outcomes differ with older adults' characteristics, such as gender (13); their belief in personal control (14); and physical status (15). Thus, the findings from cognitively healthy older adults cannot necessarily be generalized to older adults with cognitive impairment. However, few studies have focused on older adults with cognitive impairments and investigated the associations of going outdoors with health status

(18).

Moreover, current findings about the health benefits of going outdoors, homebound status, and life-space mobility are predominantly obtained by self-reported measurements (8–17). Because a Global Positioning System (GPS) can accurately record the location of an individual at every moment, recent gerontology studies (18–23) have used it to measure transportation patterns among older adults. Some of these studies also have calculated objective outdoor time by overlaying GPS data and the home locations of each individual, and then they examined the relationships between objectively measured outdoor time and health outcomes (21–23). In addition to GPS, home infrared sensors have been also used to measure outdoor time (24–25). They found that objectively measured outdoor time was associated with physical function (21, 25), cognitive function (24,25), and psychological health (21, 22, 25) among older adults. However, except for one study (25), longitudinal associations have not been examined. To establish health benefits of going outdoors, longitudinal examinations measuring objective outdoor time are essential.

The present study aimed to longitudinally examine whether changes in objectively measured outdoor time were favorably associated with changes in physical, psychological, and cognitive functions among older adults with cognitive impairments.

2. Methods

2.1. Participants and Procedures.

The present study was a secondary analysis of a community-based randomized control trial of exercise for older adults with global cognitive impairment. The primary purpose of this trial was to clarify the effect of exercise intervention on their further declines in cognitive functions. We are preparing to submit the main results of this trial as another manuscript. A protocol of this trial (ID: UMIN000013097) is available at the UMIN Clinical

Trials Registry website <http://www.umin.ac.jp/ctr/index.htm>. This website is accepted by the International Committee of Medical Journal Editors.

Participants were recruited from a sub-cohort of the National Center for Geriatrics and Gerontology-Study of Geriatric Syndromes (NCGG-SGS [26]) conducted in 2013 in the Midori Ward of Nagoya city, Aichi prefecture, Japan. Among those enrolled in this sub-cohort, 709 were selected as potential participants for the trial. Participants met the following inclusion criteria: 1) had global cognitive impairment as reflected by scores from 21 to 24 on the Mini-Mental State Examination (27), 2) normal walking speed was ≥ 1 m per second, 3) did not have serious health problems (e.g., stroke, Parkinson's disease, dementia), and 4) were not potential participants in other intervention studies. This trial provided community-based exercise programs at fitness centers. Thus, as risk management, we excluded individuals who exhibited inadequate gait functioning or serious health problems. We invited this subsample to participate in an exercise trial by postal mail. Among 709 individuals, 359 participated in the baseline assessment, when physical, psychological, and cognitive function and outdoor time were evaluated. Well-trained staff conducted these assessments. Among 359 individuals, 79 were excluded from the trial because they withdrew from participation (n = 24), had missing or abnormal data (n = 21), had serious health problems at the baseline assessment (e.g., brain tumor, new diagnosis of dementia and Parkinson's disease) (n = 27), or participated in fitness centers five or more days per week (n = 7). Thus, 280 individuals participated in the intervention trial and were assigned to either the intervention or control group.

For the intervention group, exercise programs were provided once a week for 40 weeks (40 times in total). For the control group, health education programs were provided once every three months (three times in total). Then, the follow-up assessment was conducted in both groups. The interval from baseline to follow-up was 12 months. Among the 280 individuals, 254 (90.7%) participated in the follow-up assessment. Similar to baseline, well-trained staff assessed physical, psychological, and cognitive function at follow-up. The reasons for dropout included health problems (n = 15), withdrawal of participation (n = 9), and death (n = 2).

Of 280 participants, 147 met the inclusion criteria of providing GPS data for outdoor time at both baseline and follow-up assessment; 133 did not meet the inclusion criteria and/or were dropped from the follow-up assessment. Furthermore, among 147 individuals, 2 did not participate in physical function assessment at follow-up due to poor physical condition at the time of assessment. Thus, data from 145 participants were analyzed in the present study. Figure 1 shows the detailed flow diagram of the 145 participants included in the present study.

The trial was approval by the Ethics Committee of the NCGG (No.637-3). Written informed consent was obtained from all participants. All procedures were conducted in accordance with the Helsinki Declaration.

2.2. Measures.

2.2.1. Outdoor time.

The methodology involving GPS data has not been standardized (28). Previous studies have used various procedures to handle GPS data (18-23). Detailed information concerning the methodology employed in this study was reported in our previous article (21). Outdoor time was measured by GPS monitors (Globalsat DG-200 Data Logger: GlobalSat WorldCom Corporation: Taipei, Taiwan). Individuals were asked to wear the GPS at all times except when sleeping and to complete a daily log. The log had an entry column to determine whether the device was worn all day.

In normal conditions of the connection, the GPS device can recode latitude and altitude every 30 seconds. Outdoor time per day was calculated as the times when the individual left and returned to the home area, which was defined as a 100-m radius from each home's representative point. Participants' data from each day were included if they 1) wore the device at least 10 hours, 2) started and ended the day in the home area, 3) had no poor connection during times when they left and returned to the home area, and 4) completed the log indicating the device was worn all day. Furthermore, we included the data of each individual who met these criteria for at least 8 of 14 days. Then, each participant's average daily outdoor time was calculated for both baseline and follow-up survey.

A geographic information system (ArcGIS for Desktop 10.3: Esri Japan Incorporation: Tokyo, Japan) was utilized for GPS data analysis.

2.2.2. Physical function.

Cardiorespiratory fitness and lower-extremity strength were measured using the 6-minute walk test and five-repetition chair stand test, respectively. The 6-minute walk test asks participants to walk as fast as possible in 6 minutes along a straight 10 m course. The total distance (in meters) walked in 6 minutes was recorded. Longer distance indicates higher cardiorespiratory fitness. The 6-minute walk test has sufficient reliability and validity and can be easily conducted in clinical settings (29).

The five-repetition chair stand test requires participants to stand up and sit down in a chair five times as fast as possible with their arms folded across their chest. The times (in seconds) in which they complete the task are measured. Lower times represent better lower-extremity strength status. The chair stand test has sufficient reliability (30) and is a predictor of older adults' mortality (31).

2.2.3. Psychological function.

Depression and psychological well-being were measured using the Geriatric Depression Scale—Japanese 15-item version (32) and the simplified Japanese version of the WHO—Five Well-Being Index (33), respectively. Regarding the depression scale, the participants answered each item with yes or no. The range of this version is 0–15, and higher scores represent higher depressive symptoms.

For the psychological well-being scale, a four-point Likert scale was utilized to answer each item. The range of this version is 0–15, and higher scores indicate higher psychological well-being.

2.2.4. Cognitive function.

The NCGG-Functional Assessment Tool (NCGG-FAT [34]) was utilized to assess cognitive function. The NCGG-FAT is a multidimensional neurocognitive functional assessment tool using a tablet personal computer. The NCGG-FAT has high test–retest reliability and moderate to high validity (34). The variables used in the present study were attention and executive function (tablet version of Trail-Making Test—part A and B), processing speed (tablet version of the Symbol Digit Substitution Test; SDST), word memory (immediate recognition, delayed recall), and logical memory (story memory; immediate recall, delayed recognition). For Trail-Making Tests, lower scores represent better cognitive functions. For other tests, higher scores represent better cognitive functions.

2.2.5. Basic factors.

Sex (male, female), age (years), educational background (years), living alone (yes, no), overweight (25 or more for body max index), presence of body pain (yes, no), presence of chronic disease (hypertension, hyperlipidemia, or diabetes: yes, no), and allocation of randomization (intervention group, control group) were treated as basic factors in the present study.

2.3. Analyses.

The baseline characteristics of those included in (n = 145) and excluded from (n = 135) the present study were examined using chi-squared tests for sex, living alone, overweight, body pain, chronic disease, and allocation of randomization and t-tests for age, education, physical, psychological and cognitive function variables, and outdoor time per day.

Paired t-tests were conducted to examine whether physical, psychological, and cognitive function variables and outdoor time per day were significantly changed from baseline to follow-up assessment.

Then, multiple linear regression analyses were performed with changes in each physical, psychological, and cognitive function (follow-up minus baseline) as the dependent variables. The independent variable was changes in outdoor time per day. Furthermore, the present study made two models. In Model 1, outdoor time/day and baseline value of each dependent variable were adjusted. Then, in Model 2, baseline outdoor time/day, baseline value of each dependent variable, gender, age, education, living alone, overweight, body pain, chronic disease, and allocation group were adjusted.

Statistical significance was set at $p < 0.05$. The Statistical Package for the Social Sciences (SPSS) for Windows 21.0 (IBM Japan, Ltd., Tokyo, Japan) was used to perform all analyses.

3. Results

3.1. Participant Characteristics.

Participant characteristics at baseline are summarized in Table 1. The results of chi-squared tests and t-tests revealed that the individuals included in the present study had significantly higher psychological well-being and went outdoors for shorter times than those excluded at baseline. Other variables at baseline were not significantly different between those included and excluded.

Table 2 represents longitudinal changes of each variable. Paired t-tests indicated that the scores on the five-repetition chair stand test, SDST, and story memory tests were significantly and favorably changed from baseline to follow-up assessment. Outdoor times were significantly decreased from baseline to follow-up assessment.

3.2. Longitudinal Associations of Changes in Outdoor Time with Physical, Psychological, and Cognitive Function.

Table 3 indicates the results of multiple regression analyses for longitudinal associations of changes in outdoor time with physical, psychological, and cognitive functions. Changes in outdoor time were significantly associated with changes in 6-minute walk tests and in five-repetition chair stand test after adjusting for baseline outdoor time, baseline value of each dependent variable, basic factors, and the allocation of the intervention group. However, significant relationships between changes in outdoor time and changes in psychological and cognitive functions were not revealed.

4. Discussion

To our knowledge, this is the first study to examine longitudinal relationships between objectively measured outdoor time and health outcomes among older adults with cognitive impairments. The major finding of the present study was that changes in objectively measured outdoor time were associated with changes in physical function variables among older adults with cognitive impairments. This finding indicates that maintaining or increasing outdoor time would be effective to prevent declines in physical functions in this population. Most previous studies indicating the health benefits of going outdoors have measured going outdoors only by self-report (8–17). Except for one study (25), the associations of objective outdoor time and health outcomes were examined using cross-sectional designs (21–24). Although older adults with cognitive impairments are at higher risk for various health problems than those without cognitive impairments (1–6), no longitudinal studies have examined the influences of going outdoors on health outcomes among this population. Thus, our objective and longitudinal data support and strengthen the previous findings.

As for a potential mechanism of the relationship between outdoor time and physical function, physical activity might mediate this relationship. A previous cross-sectional study (21) indicated that going outdoors is indirectly associated with physical function through physical activities. It was also revealed that life-space mobility, a concept similar to outdoor time, is associated with physical activity level (35, 36). The desirable influences of physical activity on the physical functions among older adults are well established (37). Thus, considering this indication (21), it can be speculated that increase in outdoor time would elevate physical activity level, and this elevation would lead to desirable changes of physical functions in older adults.

The present study found that changes in objectively measured outdoor time were not significantly associated with changes in all variables of psychological and cognitive functions. These results indicate that a quantitative aspect of going outdoors—i.e., duration of going outdoors—would have limited impact on psychological and cognitive functions among older adults with cognitive impairments. For the non-significant relationships, the present study speculated that the qualitative aspects of going outdoors, such as type of destinations, modes of transportations, and degree of social interactions, should be considered to reveal the impact of going outdoors on these functions as well as the quantitative aspect. Since lower frequency of going outdoors was associated with decreased social interactions (38), and lack of social interactions can increase risk of depression (39), it can be assumed that going outdoors might provide psychological benefits for older adults mediated by social interactions. Although previous studies have indicated that self-reported frequency of going outdoors (10), life-space mobility (17), and objective outdoor time (21, 22, 24, 25) are associated with psychological and cognitive functions, none of them have investigated qualitative aspects of going outdoors. The present study also did not investigate the qualitative aspect. Failure to measure these qualitative aspects might cause inconsistencies in the findings between the previous and the present studies. Further examinations would be necessary to establish the influences of quantitative and qualitative aspects of going outdoors on psychological and cognitive health status.

The strengths of the present study were its objective measurements of going outdoors and employment of a longitudinal design. However, the present study includes some limitations. First, the sample size was small. Second, GPS device adherence was low, and individuals included in the present study showed better psychological well-being and went outdoors for a shorter time than those excluded. This would limit the internal validity of the present study. Third, since standardized methodology of handling GPS data is not available (28), the methodological details of the present study were not the same as was the case with previous GPS studies (18–23). Fourth, the present study was a secondary analysis of a randomized controlled trial. The potential effects of providing the programs might exist. Larger studies using a more representative sample are required to more conclusively examine the effects of outdoor time on health status among older adults with cognitive impairments. Nonetheless, this study contributes to better understanding the beneficial effects of going outdoors on health outcomes among older adults with cognitive impairments.

In conclusion, the present study found that changes in objectively measured outdoor time were favorably associated with changes in physical functions among older adults with cognitive impairments. This finding indicates that maintaining or increasing going outdoors would be effective to prevent declines in physical functions in this population. Further research on the determinants of effective strategies to promote going outdoors among these individuals is expected.

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the authors have no competing interests to declare.

Conflict of interests

The authors declare that they have no conflict of interests.

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Table 1. Baseline characteristics of the participants

	Analysis of the present study		
	Excluded (n = 135)	Included (n = 145)	
	n (%) or M (SD)	n (%) or M (SD)	p-value
Basic factors			
Sex (male), n (%)	82 (60.7)	87 (60.0)	0.903[a]
Age (years), M (SD)	76.3 (4.1)	76.4 (4.2)	0.777[b]
Education (years), M (SD)	11.9 (2.4)	11.9 (2.7)	0.870[b]
Living alone (yes), n (%)	16 (11.9)	10 (6.9)	0.216[a]
Overweight (yes), n (%)	32 (23.9)	26 (17.9)	0.240[a]
Body pain (yes), n (%)	68 (50.4)	83 (57.2)	0.249[a]
Chronic disease (yes), n (%),	99 (73.3)	91 (62.8)	0.073[a]
Allocation (intervention group), n (%)	63 (46.7)	77 (53.1)	0.339[a]
Physical functions			
6-minute walk test (m), M (SD)	449.1 (57.8)	454.2 (56.3)	0.461[b]
5-repetition chair stand test (sec), M (SD)	7.8 (1.9)	7.7 (2.2)	0.588[b]

Psychological functions			
GDS 15-item version (score), M (SD)	2.8 (2.3)	2.5 (2.2)	0.206[b]
Simplified Japanese version of WHO-5 (score), M (SD)	9.7 (3.2)	10.7 (3)	0.005[b]
Cognitive functions			
Trail-making test—A (sec), M (SD)	21 (5.1)	20.9 (5)	0.858[b]
Trail-making test—B (sec), M (SD)	44.9 (23.1)	40.9 (15.4)	0.091[b]
Symbol digit substitution task (score), M (SD)	52 (10.2)	52.2 (9.9)	0.876[b]
Word memory: immediate recognition (score), M (SD)	7.3 (1.4)	7.4 (1.2)	0.513[b]
Word memory: delayed recall (score), M (SD)	3.6 (2.1)	3.8 (2.1)	0.331[b]
Story memory: immediate recall (score), M (SD)	5.5 (2.1)	5.3 (1.9)	0.550[b]
Story memory: delayed recognition (score), M (SD)	6.4 (1.9)	6.6 (1.9)	0.406[b]
Outdoor time per day (time), M (SD)	4:14:45 (2:32:34)[c]	3:22:57 (1:55:20)	0.013[b]

Note.

M, mean; SD, standard deviation; GDS, Geriatric Depression Scale; WHO-5, World Health Organization Five Well-being Index.

[a]chi-squared test, [b]t-test, [c]n=49

Table 2. Changes from baseline to follow-up for physical, psychological, and cognitive functions.

	Changes from baseline to follow-up		
	M	SD	p-value[a]
Physical functions			
6-minute walk test (m)	3.7	33.8	0.189
5-repetition chair stand test (sec)	−0.4	1.5	<0.001
Psychological functions			
GDS 15-item version (score)	−0.3	1.6	0.062
Simplified Japanese version of WHO-5 (score)	0.1	2.9	0.623
Cognitive functions			
Trail-making test—A (sec)	0.3	5.6	0.586
Trail-making test—B (sec)	1.8	17.1	0.217
Symbol digit substitution task (score)	1.0	4.7	0.014
Word memory—immediate recognition (score)	0.1	1.0	0.241
Word memory—delayed recall (score)	0.0	1.7	0.765
Story memory—immediate recall (score)	0.5	1.8	0.001
Story memory—delayed recognition (score)	0.3	1.7	0.028
Outdoor time per day (time)	−00:13:07	1:02:16	0.012

Note.

M, Mean; SD, Standard Deviation; GDS, Geriatric Depression Scale; WHO-5, World Health Organization Five Well-being Index.

[a]paired t-test comparing baseline and follow-up.

Table 3. Multiple regression analyses for changes in outdoor time and changes in physical, psychological, and cognitive functions.

	Standardized beta of changes in outdoor time/day			
	Model 1[a]		Model 2[b]	
Dependent variable	Beta	p-value	Beta	p-value
Changes in physical functions				
Δ6-minute walk test	0.22	0.027	0.20	0.048
Δ5-repetition chair stand test	−0.19	0.038	−0.19	0.032
Changes in psychological functions				
ΔGDS 15-item version	−0.04	0.647	−0.04	0.640
ΔSimplified Japanese version of WHO-5	0.02	0.828	0.00	0.906
Changes in cognitive functions				
Δtrail-making test—A	0.09	0.307	0.06	0.475
Δtrail-making test—B	0.01	0.927	−0.02	0.652
Δsymbol digit substitution task	0.02	0.804	0.00	0.966
Δword memory—immediate recognition	−0.01	0.877	0.01	0.959
Δword memory—delayed recall	0.06	0.503	0.07	0.567
Δstory memory—immediate recall	−0.04	0.666	−0.01	0.828
Δstory memory—delayed recognition	0.02	0.803	−0.02	0.671

Note.

GDS, Geriatric Depression Scale; WHO-5, World Health Organization Five Well-being Index.

[a]Adjusted for baseline outdoor time/day and baseline value of each dependent variable.

[b]Adjusted for baseline outdoor time/day, baseline value of each dependent variable, gender, age, education, living alone, overweight, body pain, chronic disease, and allocation group.

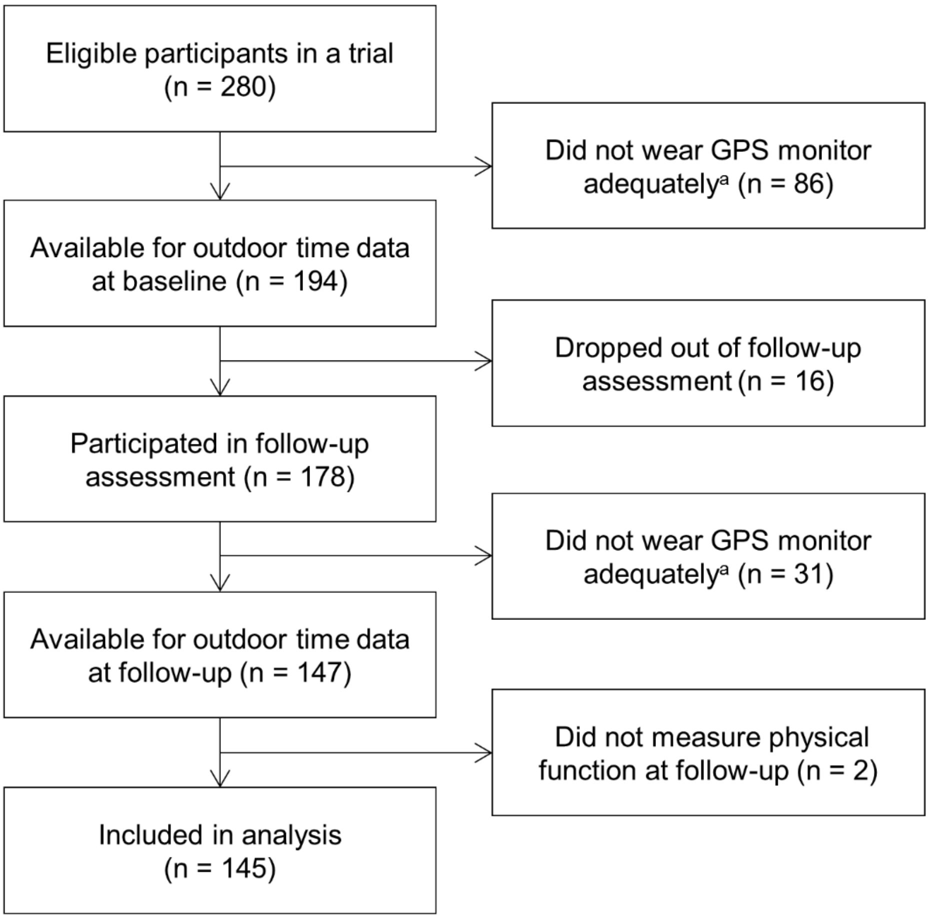

Figure 1. Flow diagram of process from original participants of a trial to inclusion of analysis in the present study.

[a]They did not wear the monitor of Global Positioning System for at least eight eligible days.

GPS, Global Positioning System.