BASIC SCIENCES

Physical Activity Declines over a 12-Month Period in Parkinson's Disease: Considerations for Longitudinal Activity Monitoring

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ABSTRACT

ROSENFELDT, A. B., A. E. JANSEN, C. LOPEZ-LENNON, E. ZIMMERMAN, P. B. IMREY, L. E. DIBBLE, and J. L. ALBERTS. Physical Activity Declines over a 12-Month Period in Parkinson's Disease: Considerations for Longitudinal Activity Monitoring. *Med. Sci. Sports Exerc.*, Vol. 57, No. 4, pp. 738–745, 2025. **Purpose:** The purpose of this project was to evaluate physical activity trends in individuals with Parkinson's disease (PD) over a 12-month period using continuous activity monitoring. Environmental (temperature) and cultural factors (represented by day of the week) were evaluated as potential external sources of variability. It was hypothesized that physical activity would decline over the course of 12 months. Further, it was hypothesized that participants would exhibit greater physical activity on warmer days and that the day of the week would have minimal impact on physical activity as many participants were no longer in the workforce. **Methods:** Participants were part of the Usual and Customary Care arm (N = 119) of the CYClical Lower Extremity Exercise Trial for Parkinson's disease-II (CYCLE-II) at the Cleveland Clinic and University of Utah. Participants wore a Garmin Vivofit4® device daily for 12 months. A linear mixed effects model was created to model daily steps over 12 months. **Results:** Participants wore their activity monitors on 93% of study days. Steps per day declined by 6.1% over 12 months (95% confidence interval, 12.6% decline, 0.9% increase; P = 0.09). Steps per day were greater with warmer temperatures (P < 0.001), plateauing and declining between 75°F to 85°F (24–29°C). Participants took fewer steps on Sunday; this daily difference was more pronounced for Utah participants, who took 25% fewer steps on Sundays compared with other weekdays (P < 0.001). **Conclusions:** Most individuals live with PD for decades, and interventions should address the expected annual decline in daily step count. Environmental and cultural factors impact daily step count and should be adjusted for in short- and long-term monitoring of physical activity in individuals with PD. **Key Words:** ACTIVITY MONITORING, DAILY STEPS, PARKINSON'S DISEASE, SEASONALITY, TEMPERATURE, WEEKDAYS, WEEKENDS

Household and community ambulatory activity is an important metric of physical activity in individuals with Parkinson's disease (PD) (1). Individuals with PD experience a gradual decline in physical activity due to a variety of motor and nonmotor factors exacerbated by the disease (2). Reports of daily step accumulation in PD vary widely from approximately 2700 to 10,000 steps per day (3–7), and individual day-to-day step count variability is substantial (i.e., upwards of 50% of the mean) (8).

Intuitively, motor symptom severity would be a logical predictor of daily step count; however, multiple reports (9–11) and a recent meta-analysis (12) highlight the complexity of that relationship. Zajac and colleagues reported that walking capacity measured by gait speed via a 10-meter walk test, and endurance measured via a 6-min walk test, accounted for only 7% and 13% of daily step count variance, respectively (11). Similarly, other studies reported that motor symptom severity explained 4% of daily step count variance (9) and that the severity of motor fluctuations did not influence the mean time spent walking (10). Previous studies suggest that clinical measures of walking capacity provide limited insight into real-world activity performance in PD. A potential explanation for the weak relationship between clinical tests of motor performance and real-world activity is that individuals with PD tend to walk in short duration, low-intensity bouts with few instances of sustained walking in their natural living environments (6). Short-duration, low-intensity walking bouts are

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likely less impacted by gait speed, endurance, disease severity, and motor fluctuations.

Annual declines in physical activity in PD have been reported between 7% (13) and 11% (4). These studies warn of a physical activity crisis in the PD population; however, several limitations should be noted. One of the studies was conducted with the goal of evaluating physical activity during the COVID-19 pandemic (13), and it is not clear if the decrease in steps was due to pandemic-related restrictions or disease progression. The sample size (n=33) and characteristics of the sample as PD patients were had daily step counts exceeding healthy peers (e.g., 10,000+ steps). (4). Both studies were conducted using cross-sectional 7-d monitoring periods at the beginning and end of the 12-month period. While 7 d provides a snapshot of activity (14,15), data from individuals without neurological disease suggest that a 7-d monitoring period may not adequately represent an individual's global physical activity (16). Twelve-month continuous activity data from healthy, middle-aged adults revealed that individuals took more steps in summer (vs. winter), on weekdays (vs. weekends), and workdays (vs nonwork days) (17). In addition, external events and deviations from routine behaviors, such as work or school, significantly impact step count (18). The findings in individuals without neurological disease suggest that environmental and cultural factors may impact daily step count in individuals with PD.

Commercially available activity monitors offer an inexpensive, noninvasive method of measuring free-living physical activity over short and long durations, (19,20) and have been used extensively for clinical research (21). Given the potential impact of weekly, monthly, and seasonal factors on daily step count and the relatively short duration of previous activity monitoring studies in PD, the purpose of this project was to evaluate physical activity levels in individuals with PD over a 12-month period via continuous monitoring. The primary hypothesis was that individuals with PD would exhibit a decline in physical activity over 1 yr. Environmental factors (temperature) and cultural factors (represented by day of the week) were evaluated as potential external sources of variability. Two secondary hypotheses were 1) individuals would be more physically active when temperatures were warmer, and 2) cultural factors (i.e., day of the week) would have minimal impact on physical activity, as most individuals are diagnosed in the sixth and seventh decades of life (22), a time when many have left the workforce.

METHODS

Participants completed a baseline enrollment evaluation and 12 months of activity monitoring as part of a pragmatic, multisite, randomized, controlled clinical trial, CYClical Lower Extremity Exercise Trial for Parkinson's disease-II (CYCLE-II) (23). The primary purpose of the CYCLE-II project was to determine the effects of aerobic exercise on PD progression over a 12-month period by randomizing participants into either a home-based aerobic exercise intervention or a Usual and Customary Care group. Briefly, participants were adults with a diagnosis of idiopathic PD (24) who were deemed safe from a cardiovascular (25) and physical safety perspective to participate in aerobic exercise should they be randomized to the exercise group. Participants were enrolled in the trial for approximately 12–13 months from late 2019 to mid 2023. All participants completed the informed consent process approved by the Cleveland Clinic and University of Utah Institutional Review Boards. Details of the full trial and inclusion/exclusion criteria are provided in a previous publication (23). Because of the potential impact of the prescribed aerobic exercise on daily step count, only individuals in the Usual and Customary Care group were included in the current analysis.

Enrollment evaluation. General demographics and disease-specific information were gathered at the enrollment evaluation. The Movement Disorder Society-Unified Parkinson's disease Rating Scale-III (MDS-UPDRS III) was used to characterize PD motor symptoms (26) and included the traditional Hoehn and Yahr scale (27). The Trail Making Test A & B was administered as an assessment of attention and set switching (28), and gait speed was assessed by the ten-meter walk test at a comfortable pace (29). Data presented in this report were collected in the on-medication state, operationally defined as ingesting antiparkinsonian medication 1 h before clinical testing.

Physical activity monitoring. Upon enrollment, participants received a Garmin Vivofit4® Fitness Activity Tracker (Garmin International, Inc., Olathe, KS) and were instructed to wear the device during all waking hours, except when bathing, around the ankle of their less affected lower extremity to minimize the potential noise that a lower extremity tremor may cause. The Garmin Vivofit4® was selected due to its cost-effectiveness (~$70 per unit), 12-month battery life, and ability to accurately capture steps in individuals with PD (30,31).

Participants downloaded the commercially available Garmin Connect mobile application to their smartphone and Bluetooth connected their Vivofit4® monitor. Participants were asked to synchronize their ankle-worn device to their smartphone application at least weekly. Data from the smartphone application was automatically available on the Garmin website, and activity data were pulled from the website weekly by a member of the study team. A member of the study team called each participant biweekly to ensure that physical activity data were being synced to the Garmin mobile application.

Participants wore the activity monitor daily for 52 wk ±10 d. To ensure full and complete datasets, the analysis was restricted to data from the first 50 wk.

Statistical analysis. Baseline data were summarized with means and standard deviations (SD) if continuous and approximately normally distributed, median and quartiles if continuous and skewed, and with frequency counts and percentages if categorical. Temperature data was retrieved from the National Oceanic and Atmospheric Administration from 2019 to 2023 (32). Daily maximum temperature for each participant was collected from the nearest weather station to the individual's residential zip code. If multiple weather stations were within one degrees of combined latitude and longitude to the participant's home, the mean of those stations was used.

A valid wear day was defined as a day in which the step count was at least 500 steps, as a value below 500 steps was likely incompatible with a full day of wear time (33). The median baseline steps per day was calculated using the first seven valid wear days for the purposes of population description. Analysis of changes in step count included participants with at least 175 d of valid step data within the 12-month period.

Median steps per day by calendar date for days with at least 10 participants with step data, with a locally estimated scatterplot smoothing trend was plotted. A linear mixed effects model (LMM) was created to model daily steps over the 12-month enrollment. The LMM included fixed effect terms for days since the start of monitoring, maximum daily temperature each day (°F/°C), clinical site, day of the week, and site by day of the week interactions. The effect of days since the start of monitoring was modeled linearly. To allow for a nonlinear relationship between temperature and steps per day, temperature was modeled using natural cubic splines, with the choice of number of knots determined via the best Akaike Information Criterion score. The model also included random effects for participant intercepts and slopes. The data were initially normalized by logarithmic transformation, thus making the modeled relationships of daily steps and predictors multiplicative rather than additive. To account for heteroscedasticity, we filtered the data by removing, for each calendar month, the lowest 2% of daily steps for each day of the week, ensuring removed data were distributed evenly throughout the months of the year. The model was fit by residual maximum likelihood estimation, and tests of significance were conducted using Wald statistics with the Kenward-Roger estimate for denominator degrees of freedom. To assess the relationship between individual's baseline level of steps and the change over time of steps, the correlation between the random intercepts and random slopes was calculated. Finally, to explore the potential confounding effect of secular trends in activity due to the fluctuating COVID-19 pandemic during the trial, a sensitivity analysis was conducted in which the fixed effect slope of steps with time was separately estimated for each tercile of CYCLE-II participants by enrollment date. The analysis was conducted using the R lme4 (34) and lmerTest (35) packages with RStudio 2023.12.1, R version 4.3.3.

RESULTS

One hundred twenty-seven individuals with PD were randomized into the Usual and Customary Care control group. Four participants withdrew from the study and were not included in the analysis. An additional four participants had fewer than 175 valid wear days (e.g., less than 500 steps per day) (Fig. 1A). Demographics for the remaining 119 individuals are provided in Table 1.

The data set contained 38,534 d with step data; 938 d (2.4%) were considered invalid due to a step count of less than 500 steps. The median [Q1, Q3] number of wear days was 328 [301, 343] out of 351 d (93%). The median number of steps per participant over the first seven days of monitoring ranged from 1170 to 17,378 steps per day with a median [Q1, Q3] of 5682 [3323, 7940] (Fig. 1B).

Daily step count declined over a 12-month period. The mixed model random intercept and slope variance components were both statistically significant ($P < 0.001$), reflecting considerable variability in individual participant daily step levels and slopes with time. After adjustment for temperature, site, and day of the week, daily steps declined on average by 6.1% over 12 months (95% confidence interval [CI], 12.6% decline, 0.9% increase, P = 0.09). The correlation between the baseline level of daily steps and the change over time in daily steps was low, r = −0.10 (95% CI, −0.28 to 0.09). In the sensitivity analyses, step counts declined on average by 12.9% (1.1%, 23.2%) annually in the 39 patients enrolled November 15, 2019, to July 16, 2020, declined 0.7% per year (12.4% decline, 12.5% increase) in the 40 patients enrolled from July 17, 2020, to March 16, 2021, and declined 4.5% per year (15.7% decline, 8.2% increase) in the 40 patients

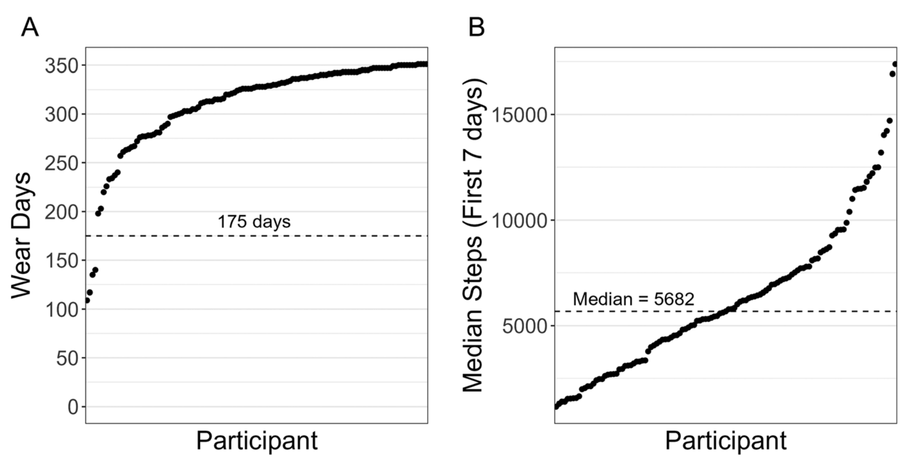

FIGURE 1—(A) Number of valid wear days for the 123 participants with PD over the 50 wk monitoring period. Four individuals were compliant less than 50% of wear days (below the dashed line) and were excluded from the analysis. Of the 119 remaining participants, the median number of activity monitor wear days was 328 out of 351 d (93%). (B) Median [IQR] number of steps per day per participant (N = 119) over the first seven wear days was 5682 [3323, 7940] with a range from 1170 to 17,378.

TABLE 1. Participant demographics.

	Cleveland Clinic (n = 63)	University of Utah (n = 56)	Overall (N = 119)
Age, yr	66 (8)	65 (9)	65 (8)
Race			
Asian	1 (1.6%)	0 (0%)	1 (0.8%)
Black	1 (1.6%)	0 (0%)	1 (0.8%)
Two or more races	1 (1.6%)	2 (3.6%)	3 (2.5%)
White	60 (95.2%)	54 (96.4%)	114 (95.8%)
Ethnicity			
Not Hispanic or Latino	63 (100%)	55 (98.2%)	118 (99.2%)
Hispanic or Latino	0 (0%)	1 (1.8%)	1 (0.8%)
Sex			
Female	19 (30.2%)	21 (37.5%)	40 (33.6%)
Male	44 (69.8%)	35 (62.5%)	79 (66.4%)
Years since PD diagnosis	5.4 (4.6)	4.4 (3.6)	4.9 (4.2)
Education, yr	16 (2)	16 (3)	16 (2)
Employment			
Employed full-time	16 (25.4%)	19 (33.9%)	35 (29.4%)
Employed part-time	7 (11.1%)	4 (7.1%)	11 (9.2%)
Homemaker	1 (1.6%)	1 (1.8%)	2 (1.7%)
Retired by choice	27 (42.9%)	20 (35.7%)	47 (39.5%)
Retired/disabled due to PD	12 (19.0%)	12 (21.4%)	24 (20.2%)
Living Situation			
Resides alone	4 (6.3%)	5 (8.9%)	9 (7.6%)
Resides with family member or friend	4 (6.3%)	1 (1.8%)	5 (4.2%)
Resides with significant other	55 (87.3%)	50 (89.3%)	105 (88.2%)
MDS-UPDRS III, on-medication, score	33 (13)	24 (12)	28 (13)
Hoehn & Yahr, on-medication			
I	13 (20.6%)	3 (5.4%)	16 (13.4%)
II	31 (49.2%)	49 (87.5%)	80 (67.2%)
III	19 (30.2%)	4 (7.1%)	23 (19.3%)
Median daily steps, first 7 d	6138 [3680, 8633]	5652 [3299, 7581]	5682 [3323, 7940]
Gait velocity during the Ten Meter Walk Test (comfortable pace, 10MWT), m·s^{-1}	1.24 (0.22)	1.28 (0.20)	1.26 (0.21)
Trail Making Test A (TMT A), s	31.5 (10.7)	36.9 (16.8)	34.0 (14.1)
Trail Making Test B (TMT B), s	52.4 (26.5)	60.0 (33.2)	56.0 (29.9)
Levodopa equivalent daily dose (LEDD)*	661 (357)	737 (391)	696 (374)

Data presented as mean (SD), median [Q1, Q3] or n (%).
*N = 118, LEDD dose missing in one participant.

enrolled from March 17, 2021, to March 21, 2022. The observed variation in rates of decline between the three groups of patients was not statistically significant (P = 0.33).

Lower temperatures were associated with fewer daily steps. Median daily steps are plotted by calendar date in Figure 2A. Daily steps were significantly (P < 0.001) and nonlinearly (P < 0.001) associated with temperature. Daily step counts were generally higher at moderate and warmer temperatures and lower during colder temperatures. Figure 2B displays the LMM predicted steps per day as a smooth function of temperature, with predicted steps per day presented as the percentage of predicted steps at a given temperature compared with predicted steps at a reference value of 59°F (15°C), the median temperature over the course of the entire CYCLE-II project. Steps per day increased almost linearly with rising temperatures below the median value.; Above the median, the rate of increase slowed, plateaued, and then declined around 75°F to 85°F (24–29°C). A temperature adjustment factor is included in Supplemental Table 1 (Supplemental Digital Content, http://links.lww.com/MSS/D142).

Daily step count was dependent on day of the week and site. At both locations, median steps per day was largely consistent across all days of the week except Sunday, when steps per day were lowest at both sites. In the model, day of the week and its interaction with location were both statistically significant (P < 0.001), although the main effect of location was not (P = 0.44). After adjustment for temperature and other factors from the model, the Utah cohort exhibited a dramatic decrease in step count on Sundays, with a median of 3855 steps per day (95% CI, 3287–4521) or approximately 25% fewer steps than on weekdays (Fig. 3). The Cleveland participants also exhibited a reduction in steps per day on Sundays, with 4890 steps per day on Sundays (95% CI, 4207–5684) or 10% fewer steps than on weekdays: however, the reduction was significantly less than observed with the Utah group (P < 0.001). In contrast, the reduction of steps on Saturday compared with weekdays was smaller and not significantly different by site (P = 0.68).

Practical application of applying a temperature adjustment factor. As a practical example, all participants who began the CYCLE-II study in the month of February (N = 14) were analyzed. Evaluating the first 7 d of their enrollment, participants walked a median of 5807 steps per day, and the average temperature was 33°F (0°C). Looking 6 months ahead to the warmer month of August, the median steps per day in the first 7 d of the month was 6076 and average temperatures were significantly higher at 84°F (29°C). Taken in isolation, it appears that the participants who began the study in February increased their step count by 5%. However, from the model estimates of temperature, the expected change from 33°F (0°C) to 84°F (29°C) is a 15% increase due to temperature alone (Supplemental Table 1, Supplemental Digital Content, http://links.lww.com/MSS/D142). When the temperature adjustment factor is applied to the same data set, by dividing physical activity at the endpoint by the ratio of expected change

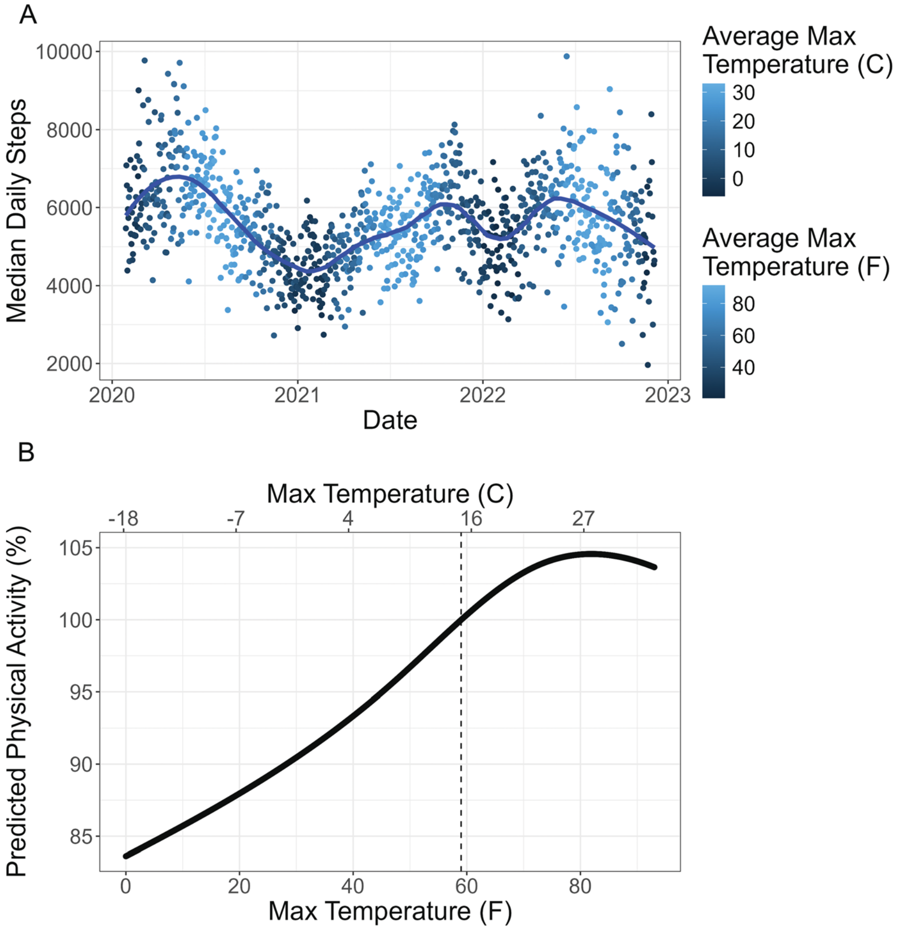

FIGURE 2—(A) Observed median steps per day as a function of temperature on days with a minimum of 10 participants with valid step data. The color gradient represents the average daily maximum temperature for all participants' locations; warm days are denoted with a lighter blue color and colder days with a darker blue/black color. The blue line represents the temperature trendline. In general, warmer temperature days resulted in a greater number of steps compared with colder days. (B) Predicted median steps per day as a function of temperature. The 100% reference value was selected as the median temperature across all recorded step days, 59°F (15°C) (dashed vertical line). As temperature increased, the number of steps per day also increased. The number of steps per day began to plateau and then decline around 75°F to 85°F (24–29°C).

by temperature, median steps per day is estimated to have decreased by 9%. This example highlights the practical application of controlling for temperature in this patient population.

DISCUSSION

To gain insight into the progression of gait-related disability and the influence of environmental and cultural factors on community ambulatory activity, this study evaluated trends in physical activity over a 12-month period using continuous activity monitoring in individuals with PD. Although not reaching conventional statistical significance, our estimated 6.1% decline in daily stepping activity over a 12-month period is consistent with our hypothesis and similar to prior reports of PD decreasing activity levels. (4,13). As hypothesized, an environmental factor, daily temperature, influenced physical activity levels. In contrast to our a priori null hypothesis, cultural factors, characterized by days of the week, did influence daily step count.

The 6.1% decline was observed despite the majority of our participants being characterized as having mild PD (Hoehn

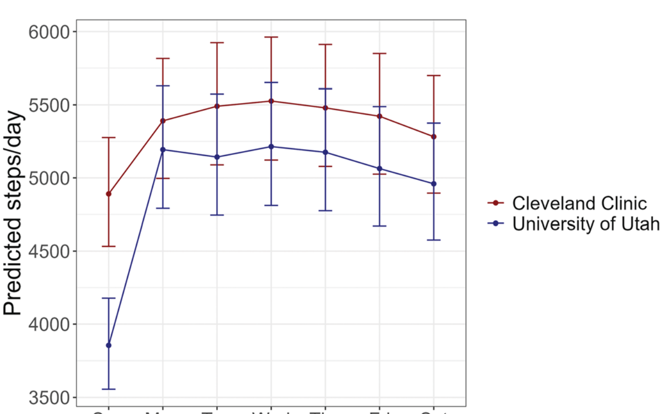

FIGURE 3—Predicted median steps per day and standard error by day of the week and site. There was a significant interaction between location and day of the week with participants at both sites taking significantly fewer steps on Sunday than the rest of the days of the week. The Utah cohort exhibited a more dramatic decrease in step count on Sundays, with a predicted median of 3855 steps per day (95% CI, 3287–4521), or approximately 25% fewer steps than on weekdays.

and Yahr I-II). Importantly, the decline was present regardless of baseline number of steps, suggesting that those with high or low physical activity are susceptible to declining physical activity over time. Considering most individuals live with PD for decades (36), an annual 6.1% decline in daily step count represents a downward trend that may have a meaningful impact on physical activity patterns and community participation. This furthers the call for rehabilitation, fitness, and medical professionals to search for interventions that curb activity decline in PD (37).

Intuitively, one would expect on warmer days individuals are more likely to partake in outdoor activities and have higher step counts compared with colder days. In fact, a systematic review in primarily healthy adults concluded that physical activity appears to be higher in spring and summer months and decreases in winter months (38). Individuals reported that adverse weather makes them up to 50% more likely to engage in sedentary behaviors such as watching television (39). The data presented in this manuscript demonstrate that individuals with PD also engage in less physical activity on colder days. In addition to the cold weather, Cleveland, Ohio and Salt Lake City, Utah experience snow and ice in the winter. Data with healthy middle-aged adults demonstrated the number of steps per day decreased by 3.6% for every 10 cm of snow accumulation (40). It is likely that individuals with PD are less physically active not just due to the cold, but also the snow and ice which increase the probability of a fall within a population with known postural instability and gait dysfunction.

With an average age of 65 yr and the majority of participants being retired or working part time, we hypothesized that the day of the week would not influence step accumulation. This held true during the weekdays and Saturday; however, in contrast to the hypothesis, the data revealed a significantly lower step count on Sunday at both sites, with a profound (25%) decrease in the Utah cohort. Such a substantial difference likely reflects the impact of a cultural factor, religion, influencing activity. In a cross-sectional survey conducted in Utah, members of the Church of Jesus Christ of Latter-day Saints (LDS) were less likely to exercise regularly than those not affiliated with LDS (41). While our project did not record religious affiliation, approximately 60% of people in Utah claim LDS affiliation (42). On Sunday, the LDS Sabbath, it is common to attend several hours of religious events and refrain from common daily activities such as working and shopping. This finding highlights the impact of cultural factors on physical activity and further illustrates why motor performance such as walking speed, walking endurance, and motor fluctuations in PD explain a small amount of daily step accumulation (9–11). The 25% reduction in step count on Sundays in Utah participants is consistent with previous research demonstrating situational and cultural influences on community ambulatory activity. Work by Wang and colleagues suggests the amount of physical activity and daily step count depends on both internal and external factors; for example, having an extroverted personality and being surrounded by supportive peers were associated with a higher daily step count (18). A simple example is provided by a large cohort of University of Notre Dame students who increased their physical activity by over 2800 steps on days of a home football game (18). External factors powerfully influence daily step count, and health and medical providers should further examine how to leverage external factors to increase daily step count in both healthy and disease populations.

As demonstrated by the results from this project and others (8), daily step count in individuals with PD is highly variable. However, much of that variability may not be random, but rather explainable by external environmental and cultural factors. Since most activity monitoring studies consider a valid wear week to be three to five complete days of data (15), one of those days being a Sunday or coinciding with an out-of-routine external event such as a religious or sporting event (18) may skew results. Information gained about the variability in step data in healthy adults and now PD, gives reason for pause when making inferences about trends in physical activity based on cross-sectional, short bouts of physical activity monitoring and when making inferences on interventional studies examining preactivity to postactivity data over short to moderate duration (i.e., 2–6 months). If activity monitoring is performed in different seasons, for example a pretest being performed in the February and a posttest in August as illustrated by the practical application example, variance in step count may be primarily due to the change in temperature rather than an intervention. The temperature adjustment factor provided above and illustrated in Figure 2B provides a potential solution to correct for preintervention to postintervention temperature changes.

The excellent wear adherence (93% of possible study days) in 119 individuals with PD confirms the feasibility of long-term activity monitoring via a commercially available product and supports the validity of the results. Several factors likely contributed to the high adherence to the activity monitor. The Garmin Vivofit4® does not require charging (12-month battery life) and has a user-friendly interface. The device stores approximately 4 wk of data, so the risk of data loss is minimized, even if a participant did not synchronize the watch to the phone frequently. A survey of individuals with PD regarding their attitudes toward digital technologies revealed that they prefer design simplicity, minimal charging requirements, and passive monitoring (43). The choice of technology in this project satisfied those requirements and was critical to project success. Second, biweekly phone calls may have facilitated adherence to wearing and synching the device, as the participants were aware their data were being monitored and likely felt accountable. Other projects should consider the specific needs of the population of interest and use those needs to guide technology selection.

Our study has limitations. Nonlocomotive physical activity, such as yoga or resistance training, is typically not accounted for in activity monitors that capture only steps, and future projects should contemplate accurately accounting for various types of nonlocomotor physical activity. The two study sites have widely varying seasons with mean monthly high and low temperatures at each spanning a 40- to 50+-degree range over the year. Future research in long-term activity monitoring should consider validating a temperature adjustment in other geographical regions that have different temperature patterns, such extremely warm or cold temperatures or a lack of temperature variation. Our observational period coincided with the COVID-19 pandemic. The pandemic's length, successive waves from new SARS-COV-2 variants, the emergent vaccine response, and personal preferences/behaviors influenced by regional culture and politics may pose challenges to data analysis over this period. A 2022 systematic review of 14 cross-sectional and 11 cohort studies published in 2020 and 2021 concluded that "The level of physical activity in the elderly population decreased during the quarantine period of COVID-19 worldwide" (44). However, the majority of these studies relied on self-reported activity data, subject to bias, rather than direct measurement. The complexity of activity monitoring during this time was evident in a large (N = 5036) study combining two cross-sectional surveys of adults in the United States near the pandemic's start in April 2020, in which 24% of respondents reported both being highly active and also sitting for over 8 hours per day, and another 21% being highly active and sitting for over 6 hours per day (45). This suggests that the pandemic's effect on physical activity in the United States may have been much more complex than simple reduction. Consistent with Oliveira and colleagues (44), sensitivity analysis showed greatest decline in activity by the first third of our enrolled patients, observed early in the pandemic, but then stable activity in the middle third and gradual decline, similar to the overall trend, in the last third of our enrollees. This pattern suggests superimposition on an overall PD-related decline of a temporary dampening of activity due to COVID-19 restrictions followed by a recovery with vaccine availability and lifting of societal restrictions. Nevertheless, without non-PD controls we cannot exclude a pandemic-induced decline in activity in the age demographic of CYCLE-II patients but not otherwise associated with PD.

CONCLUSIONS

In conclusion, a 6.1% decline in daily step count over a 12-month period in individuals with PD was observed. An environmental factor (temperature) significantly impacted daily step count, and a correction factor was implemented to account for temperature changes. The impact of cultural factors (religious commitments) was evident in the significant reduction in step count in the Utah cohort on Sundays. Taken together, results of this study suggest progressive diminution of ambulatory activity in individuals with PD, add nuance to the interpretation of cross-sectional step counts of short duration, and suggest caution when interpreting comparisons between preintervention and postintervention short duration step count data.

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The study has received approval from the Institutional Review Boards of the Cleveland Clinic (IRB of record) and the University of Utah. Before initiation of the study protocol, all participants completed the informed consent process.

The study is registered on ClinicalTrials.gov, trial identifying number NCT04000360.

The authors declare no conflicts of interest. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

The data sets analyzed during the current study are available upon request from the corresponding author.

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