



Article

Clinical Efficacy, Cost-Effectiveness, and Caregiver Satisfaction in Clinical Practice Compared to Standard Care: 12-Month Longitudinal Analysis of the Application of Parkinson's KinetiGraph

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Abstract

Background: Parkinson's disease (PD) is a progressive neurodegenerative disorder marked by both motor and non-motor symptoms. The home-based wearable sensor monitoring Parkinson's KinetiGraph (PKG) evaluates clinical efficacy, caregiver satisfaction, and cost-effectiveness in the clinical management of Parkinson's disease (PD) compared to prior usual standard care. **Methods:** We analyzed 50 patients with Parkinson's disease, comparing baseline clinical outcomes, healthcare utilization, and caregiver burden without PKG to follow-up data after 12 months with PKG. We used IBM SPSS Statistics for the analysis. Statistical significance was set at $p < 0.05$ for hypothesis testing. We employed the Wilcoxon signed-rank test to evaluate differences between the two time points, while exploratory bivariate associations between caregiver burden (Zarit score) and various outcomes were examined using Spearman's rank correlation. **Results:** Over a 12-month period following the implementation of PKG-guided care, significant improvements were observed in various clinical, functional, and economic areas for the patients. Key findings include the following: motor function improved, with UPDRS Part III scores showing a 20% median reduction (from 25 to 20); medication adjustments decreased by 40% (from 5 to 3); outpatient visits were reduced by 60% (from 5 to 2); hospital admissions decreased

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by 100% (from 1 to 0); caregiver burden, as measured using the Zarit caregiver burden score, declined by 37.5% (from 48 to 30); and total direct medical costs decreased by 17.9% (from AED 261,800 to AED 215,000). Conclusions: These findings indicate substantial reductions in healthcare utilization, costs, and caregiver burden following the integration of PKG monitoring into clinical practice.

Keywords: Parkinson's disease; UAE; PKG; remote monitoring; caregiver burden; cost-effectiveness

1. Introduction

Parkinson's disease (PD) represents a chronic neurodegenerative disorder characterized by a spectrum of motor and non-motor symptoms (NMS) [1,2]. Traditional management of PD relies heavily on regular clinical visits, which provide a snapshot of the patient's condition and may not capture the full spectrum of symptom fluctuations experienced in daily life [1]. This limitation can lead to suboptimal treatment adjustments and increased use of healthcare resources [3]. Home monitoring devices offer a paradigm shift in PD management by enabling continuous, real-time assessment of patients' symptoms in their natural environment [4,5]. Furthermore, with disease progression, patients become increasingly dependent on their caregivers, and subsequently, there is a cost not only to the service but also to the well-being of caregivers [6]. Caregiver burden in PD has been well documented, reflecting the physical, emotional, and financial stress experienced by those providing care, often family and friends. Caregivers usually face high levels of stress, anxiety, and depression, affecting their quality of life (QoL) [7]. Studies have found that caregiver burden is correlated with increasing disability and symptom progression of PD [6,8]. To reduce this burden, one must consider methods that reduce the patient's disease burden and provide quick and effective treatment plans [9]. The implementation of home monitoring systems in PD management could generate significant cost savings through several mechanisms. While data on cost-saving applications for PD are emerging, evidence from other chronic conditions suggests promising economic benefits [10–12]. There was a 19% cost reduction compared to standard hospital care when applying a home monitoring program for COVID-19 patients [13]. Despite the growing burden of PD worldwide, research on Middle Eastern and Emirati populations still needs to be conducted. Middle East and North African studies account for only 9.52% of PD prevalence studies in low-to-middle-income countries [14]. This underrepresentation is further highlighted by the EmPark study, which in 2022 revealed that Emiratis with PD are younger (48.5 ± 13.1 years), experience a high NMS burden (27.9 ± 24.0), and lack awareness of advanced therapies [15]. These findings underscore the need for tailored management approaches that address the Emirati PD population's unique demographic and clinical characteristics.

A notably promising instrument within this context is the Parkinson's KinetiGraph (PKG), a wearable device meticulously designed to continuously monitor Parkinson's disease (PD) motor symptoms objectively. The PKG system offers comprehensive data regarding patients' motor fluctuations and adherence to medication, and aids in personalizing Parkinson's care [16] and overall disease progression, facilitating more informed and timely clinical decisions [17]. With many such devices now being offered in the healthcare market, evaluation of the cost impact is essential. Recently published a systematic review analyzing the cost-effectiveness of five devices for monitoring PD [18–20]. They concluded that PKG has the most evidence for application in clinical practice and validity in its outputs while also having a significant cost benefit [18,21]. Incorporating the PKG into the

standard care protocol at Emirates hospitals could enhance patient outcomes through personalized treatment adjustments and realize substantial cost savings. These savings may arise from decreased hospital admissions, fewer emergency visits, and optimized utilization of healthcare resources through precise symptom management [22,23]. Moreover, the adoption of PKG aligns with the broader trend towards digital health and remote patient monitoring, accelerated by the COVID-19 pandemic [24]. The ability to remotely track and manage PD symptoms can lead to increased patient autonomy, improved quality of life [25–27] and greater satisfaction with care, all of which contribute to the overall economic efficiency of the healthcare system [5,18,28]. For caregivers, the insight provided by using PKG in clinical practice can alleviate some of the uncertainties and anxieties associated with managing the disease. This is achieved through the reassurance of continuous monitoring of symptoms, which provides objective evidence rather than subjective evidence alone [29,30].

“The EmPark-PKG study hypothesizes that the integration of the PKG system for managing Parkinson’s disease will demonstrate superior cost-effectiveness, result in reduced caregiver burden, and yield better clinical outcomes compared to standard care. By conducting a comprehensive cost–benefit analysis, the study aims to identify financial efficiencies and inform healthcare policymakers with evidence-based recommendations, ultimately improving management strategies for Parkinson’s disease and ensuring sustainable, high-quality care for the Emirati population.”

2. Methodology

2.1. Study Design

This 12-month longitudinal observational cohort study was conducted at King’s College Hospital in Dubai, UAE, from August 2023 to August 2024. Patients were recruited and invited to attend a baseline visit for assessments, accompanied by their caregivers. After this initial visit, participants were instructed to wear a PKG wrist device on their symptom-dominant side for seven consecutive days. To facilitate the return of the device, each participant received a pre-paid envelope to send the device back to the hospital for analysis. A neurologist typically reviewed the PKG data within 24 h of its return. Following this review, a virtual consultation with the neurologist was arranged within two weeks to discuss the findings and make any necessary adjustments to the management plan. The effectiveness of these adjustments was assessed during follow-up visits at three months, six months, and twelve months, during which all assessments were repeated, including another seven-day PKG recording.

2.2. Participant Population

50 patients with Parkinson’s disease were recruited from the King’s College Hospital Dubai, diagnosed with idiopathic Parkinson’s Disease (PD), following the criteria established by the UK Parkinson’s Disease Brain Bank. Participants were required to be at least 40 years old and exhibit conditions suitable for PKG monitoring, including unstable PD management, wearing-off phenomena, nocturnal akinesia, dyskinesia, motor and non-motor fluctuations, as well as sleep disturbances. Individuals with significant co-existing neurological or psychiatric disorders were excluded from the study, as were those who were unable or unwilling to provide informed consent. To participate, patients needed to wear the PKG watch continuously for seven days. Any patients who were unable to comply with this requirement or who withdrew from the study before completing the full week of data collection were also excluded.

Inclusion criteria were a confirmed diagnosis of PD using the UK Parkinson’s Disease Brain Bank criteria, at least 40 years of age, ability to tolerate PKG monitoring, clinical

signs of unstable PD with wearing-off phenomena, nocturnal akinesia, dyskinesia, motor and non-motor fluctuations, as well as sleep disturbances. Patients with significant co-existing neurological or psychiatric disorders, and those who were unable or unwilling to provide informed consent, were excluded. To participate, patients needed to wear the PKG watch continuously for seven days. Any patients who were unable to comply with this requirement or who withdrew from the study before completing the full week of data collection were also excluded.

Data were collected at baseline and at a 12-month follow-up outpatient clinic appointment. The data, namely, demographics and clinical characteristics including age, gender, ethnicity, disease duration, and levodopa equivalent daily dose (LEDD), were collected at both time points. Motor function was assessed using the Hoehn and Yahr (HY) staging system from 1 to 5, and the Unified Parkinson's Disease Rating Scale (UPDRS) parts 3 (UPDRS3) and 4 (UPDRS4). UPDRS3 was used to collect data on motor symptoms of PD, ranging from tremor to gait, while UPDRS4 was used to collect data on motor complications such as dyskinesia and early morning dystonia. Nonmotor function was assessed using the validated *Nonmotor Symptoms Questionnaire (NMSQ)*, covering symptoms ranging from depression to neuropsychiatric manifestations. This was a patient self-completed questionnaire, completed in the waiting room prior to the baseline and follow-up consultation. The Montreal Cognitive Assessment (MOCA) scores are categorized into distinct ranges to evaluate cognitive function effectively. A score of 26 or higher is considered indicative of normal cognitive abilities. Scores between 19 and 25 suggest mild cognitive impairment, while scores ranging from 10 to 18 may indicate moderate cognitive impairment. Scores below 10 are associated with severe cognitive impairment. All clinical assessments were conducted by a movement disorder specialist, a certified neurology registrar, and a Parkinson's disease nurse specialist. While the majority of evaluations were performed in person, some assessments were conducted online for patients who were unable to attend the clinics.

Caregivers were invited to participate in the Zarit Caregiver Burden Interview (ZCBI), a comprehensive 22-item scale designed to assess caregiver burden. Each item is rated on a 5-point scale, ranging from "Never" (0) to "Nearly Always" (4). Higher total scores on the ZCBI reflect a greater level of caregiver burden. This widely utilized self-report questionnaire effectively captures the subjective experiences of family caregivers who support dependent individuals. Patients were asked to wear a 7-day PKG wrist-worn watch on their symptom-dominant side and return it in a pre-paid envelope. Within 1 month of the PKG being received, the clinician conducted a virtual appointment, adjusting management plans, if indicated, by interpreting the PKG report with the results of the clinical scales from baseline. Patients received the PKG quarterly and at 12 months, the patient and caregivers were asked to complete all the assessments again as before, and the patient was required to wear a PKG watch again for 7 days.

2.3. Ethical Considerations

All Participants underwent neurological evaluations and specific assessments for Parkinson's Disease (PD), conducted by qualified healthcare professionals. This study received ethical approval from King's College Hospital in Dubai (REC/K19/1024) and was aligned with the ongoing UK portfolio of the NILS cohort study at the National Parkinson's Centre of Excellence at King's College Hospital, London. It was also carried out in compliance with the General Data Protection Regulation (GDPR) as endorsed by the UAE Parkinson's expert group and the Parkinson's Association UAE. Patients recruited for the study were invited to attend a baseline visit for assessments alongside their caregivers. Caregivers were required to provide informed consent and maintain regular contact with the patient for a minimum of 20 h per week.

2.4. Data Analysis

All statistical analyses were performed using IBM SPSS Statistics, Version 29 (IBM Corp., Armonk, NY, USA). The level of statistical significance was set at $p < 0.05$ (two-tailed) for all hypothesis tests. Descriptive statistics were calculated for all study variables. Continuous variables were summarized using mean values and standard deviations, and medians and interquartile ranges (IQRs) to account for non-normal distributions. Frequencies and percentages were used to describe categorical variables. Prior to inferential testing, the distribution of continuous variables was assessed by visually inspecting histograms and Q–Q plots, as well as the Shapiro–Wilk test of normality. Given the small sample size and the non-normal distribution of multiple outcome variables, non-parametric tests were selected for pre–post comparisons. Specifically, the Wilcoxon signed-rank test was used to evaluate differences between baseline and 12-month follow-up across all clinical, PKG-derived, economic, and caregiver burden measures. Effect sizes (r) were calculated for each Wilcoxon test using the formula $r = Z/\sqrt{N}$, where Z is the test statistic and N is the number of paired observations. Boxplots were generated using R version 4.5.0 (R Core Team, Vienna, Austria, 2024) with the ggplot2 package (version 3.4.0) to visualize pre–post changes in key outcomes and to support interpretation of the distributional properties of the data. Additionally, exploratory bivariate associations between caregiver burden (Zarit score) and selected clinical, PKG, and patient-reported outcomes were examined using Spearman’s rank correlation. These correlations were computed separately for baseline and 12-month follow-up values.

3. Results

Over the 12-month period following the implementation of PKG-guided care, substantial changes were observed across multiple clinical, functional, and economic domains. Analyses focused on evaluating motor and non-motor symptom severity, medication burden, wearable-derived motor parameters, healthcare utilization, direct medical costs, and caregiver-reported burden. All pre–post comparisons were assessed using Wilcoxon signed-rank tests due to the non-parametric distribution of the data. Effect sizes were calculated for each outcome to quantify the magnitude of change. Additionally, Spearman’s correlation analyses were conducted to explore the relationship between caregiver burden and relevant clinical, PKG-based, and patient-reported outcomes at both baseline and 12-month follow-up.

As shown in Table 1 results of Wilcoxon signed-rank tests assessing clinical outcomes in Parkinson’s patients before and after 12 months of PKG-guided care. The Hoehn and Yahr stage improved significantly from 3.00 to 2.25, a 25% reduction ($Z = -5.36$, $p < 0.001$, $r = 0.76$). Additionally, motor function, measured by UPDRS Part III, showed a significant decrease in scores from 25.00 to 20.00, a 20% reduction ($Z = -6.19$, $p < 0.001$, $r = 0.87$). The UPDRS Part IV scores remained stable at 7.00, but there was reduced variability in motor complications, especially in the upper range ($Z = -5.25$, $p < 0.001$, $r = 0.74$). Additionally, the levodopa equivalent daily dose (LED) was reduced from 735.00 mg/day to 600.00 mg/day, an 18.4% decrease ($Z = -3.54$, $p < 0.001$, $r = 0.50$). Medication adjustments decreased significantly from a median of 5 to a median of 3, representing a 40% reduction ($Z = -6.27$, $p < 0.001$, $r = 0.89$). Additionally, Epworth Daytime Sleepiness (EDS) scores dropped from a median of 14 at baseline to a median of 10 after 12 months, reflecting a 28.6% decrease ($Z = -4.89$, $p < 0.001$, $r = 0.69$). There was also a significant improvement in patient-reported quality of life.

Table 1. Pre–post comparison of clinical efficacy outcomes following 12 months of PKG-guided care.

Variable	Statistic	Pre-PKG (Baseline)	Post-PKG (12 Months)	% Change	<i>r</i> (Effect Size)
Hoehn and Yahr	<i>M</i> ± <i>SD</i>	2.73 ± 0.49	2.26 ± 0.43	−17.2%	0.76 ***
	<i>Mdn</i> (<i>IQR</i>)	3 (2.5, 3)	2.25 (2, 2.5)	−25.0%	
UPDRS Part III	<i>M</i> ± <i>SD</i>	25.82 ± 4.11	19.04 ± 3.34	−26.3%	0.87 ***
	<i>Mdn</i> (<i>IQR</i>)	25 (24, 30)	20 (16, 22)	−20.0%	
UPDRS Part IV	<i>M</i> ± <i>SD</i>	9.60 ± 5.47	6.00 ± 3.00	37.5%	0.74 ***
	<i>Mdn</i> (<i>IQR</i>)	7 (4, 12)	7 (4, 8)	0%	
LED (mg/day)	<i>M</i> ± <i>SD</i>	739.40 ± 243.16	642 ± 120.02	−13.2%	0.50 ***
	<i>Mdn</i> (<i>IQR</i>)	735 (500, 900)	600 (600, 700)	−18.4%	
Med. adjustments	<i>M</i> ± <i>SD</i>	5.10 ± 1.07	2.56 ± 0.61	−49.8%	0.89 ***
	<i>Mdn</i> (<i>IQR</i>)	5 (4, 6)	3 (2, 3)	−40.0%	
Epworth (EDS)	<i>M</i> ± <i>SD</i>	15.24 ± 5.49	10.48 ± 1.90	−31.2%	0.69 ***
	<i>Mdn</i> (<i>IQR</i>)	14 (10, 20)	10 (10, 10)	−28.6%	
PDQ-8	<i>M</i> ± <i>SD</i>	18.92 ± 6.81	12.52 ± 3.70	−33.8%	0.81 ***
	<i>Mdn</i> (<i>IQR</i>)	16 (16, 24)	12 (10, 16)	−25.0%	
NMSQ	<i>M</i> ± <i>SD</i>	13.58 ± 2.33	10.16 ± 0.65	−25.2%	0.85 ***
	<i>Mdn</i> (<i>IQR</i>)	14 (12, 14)	10 (10, 10)	−28.3%	

Note: *n* = 50; *M* = mean; *SD* = standard deviation; *Mdn* = median; *IQR* = interquartile range, defined as the range between the first quartile (Q1) and third quartile (Q3). LED = levodopa equivalent daily dose; EDS = Epworth Daytime Sleepiness; PDQ-8 = Parkinson's Disease Questionnaire—8; NMSQ = Non-Motor Symptoms Questionnaire. All comparisons were conducted using Wilcoxon signed-rank tests (two-tailed). *r* = effect size, calculated as $Z/\sqrt{N}$. % Change reflects the percentage difference in median scores from baseline to 12 months, calculated as $((\text{Pre} - \text{Post})/\text{Pre}) \times 100$. $p < 0.001$ ***.

The PDQ-8 scores showed a decrease from a median of 16.00 to a median of 12.00, reflecting a 25.0% reduction in median scores. Additionally, the burden of non-motor symptoms, as assessed by the Non-Motor Symptoms Questionnaire (NMSQ), decreased from a median of 14.00 to a median of 10.00, indicating a 28.3% reduction in median scores. Overall, these findings demonstrate statistically significant improvements across all evaluated clinical efficacy outcomes after 12 months of PKG-guided care. This suggests consistent and meaningful clinical changes in motor function, medication burden, sleepiness, patient-reported outcomes, and quality of life (see Figure 1). Following 12 months of PKG-guided care, significant improvements were observed across all domains. Bradykinesia scores declined at baseline and follow-up, reflecting a 22.6% reduction. Dyskinesia scores showed a decrease in distribution, with the range narrowing, indicating reduced variability. Similarly, tremor burden decreased, demonstrating a 25.0% reduction. All changes were statistically significant. PKG immobility scores showed a decline, indicating a 28.6% reduction in time immobile. Clinician-rated resting tremor severity also decreased, reflecting an overall reduction of 50.8%. Additionally, early morning dystonia severity improved significantly, with a 50.0% reduction. Together, these findings demonstrate statistically significant reductions in motor dysfunction, tremor activity, and symptom severity following PKG-guided care, with large effect sizes observed across all parameters, indicating consistent objective and clinical improvements in motor control.

Table 2 summarizes changes in healthcare resource utilization, direct medical costs, and caregiver burden over the 12-month period following the implementation of PKG-guided care. Statistically significant reductions were observed across all parameters: Out-patient follow-up visits decreased from 5 at baseline to 2 post-PKG, reflecting a 60.0% reduction ($Z = -6.26$, $p < 0.001$, $r = 0.89$). Hospital admissions declined from 1 to 0, resulting in a complete reduction of 100.0% ($Z = -4.95$, $p < 0.001$, $r = 0.70$). The number of imaging scans required including MRI and CT, showed a significant decline from a median of 2.00 to a median of 1.00, reflecting a 50.0% reduction ($Z = -6.19$, $p < 0.001$, $r = 0.88$).

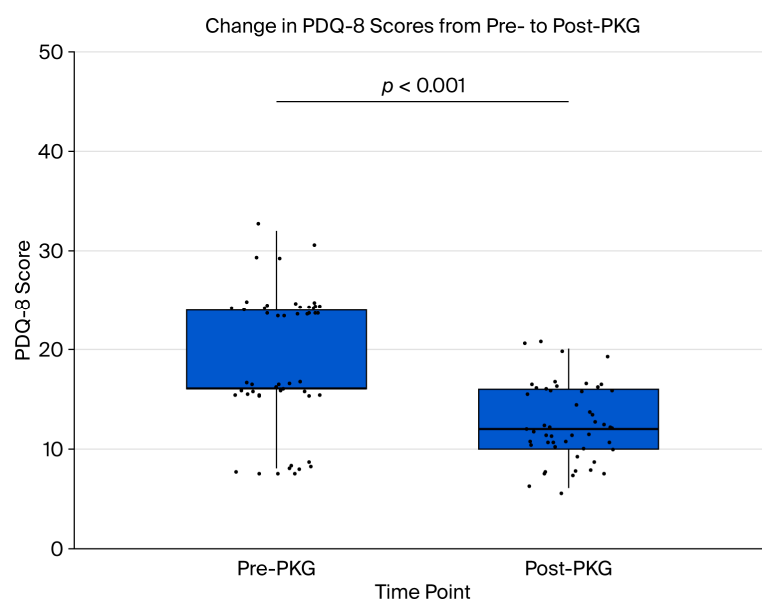


Figure 1. Change in Parkinson’s Disease Questionnaire—8 (PDQ-8) Scores From Pre- to Post-PKG. *Note:* Boxplots depict PDQ-8 scores at baseline (Pre-PKG) and at 12-month follow-up (Post-PKG) following EmPark-PKG-guided care. Median values are indicated by horizontal lines within each box; boxes represent the interquartile range (IQR), and whiskers denote the 1.5× IQR. Individual patient scores are overlaid. A Wilcoxon signed-rank test indicated a statistically significant reduction in PDQ-8 scores from pre to post intervention ($p < 0.001$), reflecting improved patient-reported quality of life. PKG = Parkinson’s KinetiGraph.

Additionally, carer-accompanied visits decreased from a median of 2.00 to a median of 1.00, also indicating a 50.0% reduction ($Z = -5.63$, $p < 0.001$, $r = 0.80$). Furthermore, the Zarit caregiver burden score improved significantly, decreasing from a median of 48.00 at baseline to a median of 30.00 at follow-up, which corresponds to a 37.5% reduction in caregiver burden ($Z = -5.73$, $p < 0.001$, $r = 0.81$). The total direct medical cost in AED showed a significant decrease, changing from 261,800.00 AED (IQR: 236,400.00–286,200.00) to 215,000.00 AED (IQR: 200,000.00–230,000.00), representing a 17.9% reduction. This change was statistically significant ($Z = -6.16$, $p < 0.001$, $r = 0.87$) (Figure 2).

Table 2. Healthcare utilization, direct medical cost, and caregiver burden before and after 12 months of PKG-guided care.

Variable	Statistic	Pre-PKG (Baseline)	Post-PKG (12 Months)	% Change	r (Effect Size)
OP follow-ups	$M \pm SD$	5.08 ± 1.05	2.26 ± 0.53	−55.5%	0.89 ***
	Mdn (IQR)	5 (4, 6)	2 (2, 3)	−60.0%	
Hospital admissions	$M \pm SD$	1.60 ± 1.58	0.54 ± 0.71	−66.2%	0.70 ***
	Mdn (IQR)	1 (0, 2)	0 (0, 1)	−100%	
Imaging scans	$M \pm SD$	2.12 ± 0.44	0.64 ± 0.48	−69.8%	0.88 ***
	Mdn (IQR)	2 (2, 2)	1 (0, 1)	−50.0%	
Carer-accompanied	$M \pm SD$	2.2 ± 0.88	1.16 ± 0.55	−47.3%	0.80 ***
	Mdn (IQR)	2 (2, 3)	1 (1, 1)	−50.0%	
Zarit burden score	$M \pm SD$	49.58 ± 21.04	27.52 ± 10.40	−44.5%	0.81 ***
	Mdn (IQR)	48 (44, 66)	30 (20, 30)	−37.5%	
Total cost (AED)	$M \pm SD$	$270,640.8 \pm 96,424.05$	$224,603.2 \pm 71,351.46$	−17.0%	0.87 ***
	Mdn (IQR)	261,800 (236,400, 286,200)	215,000 (200,000, 230,000)	−17.9%	

Note: $n = 50$; M = mean; SD = standard deviation; Mdn = median; IQR = interquartile range, defined as the range between the first quartile (Q1) and third quartile (Q3). PKG = Parkinson’s KinetiGraph; AED = United Arab Emirates Dirham. All comparisons were conducted using Wilcoxon signed-rank tests (two-tailed, $\alpha = 0.05$). r = effect size, calculated as $Z/\sqrt{N}$. % Change reflects the percentage difference in median scores from baseline to 12 months, calculated as $((\text{Pre} - \text{Post})/\text{Pre}) \times 100$. Cost data were obtained from individual patients’ health insurance records. $p < 0.001$ ***.

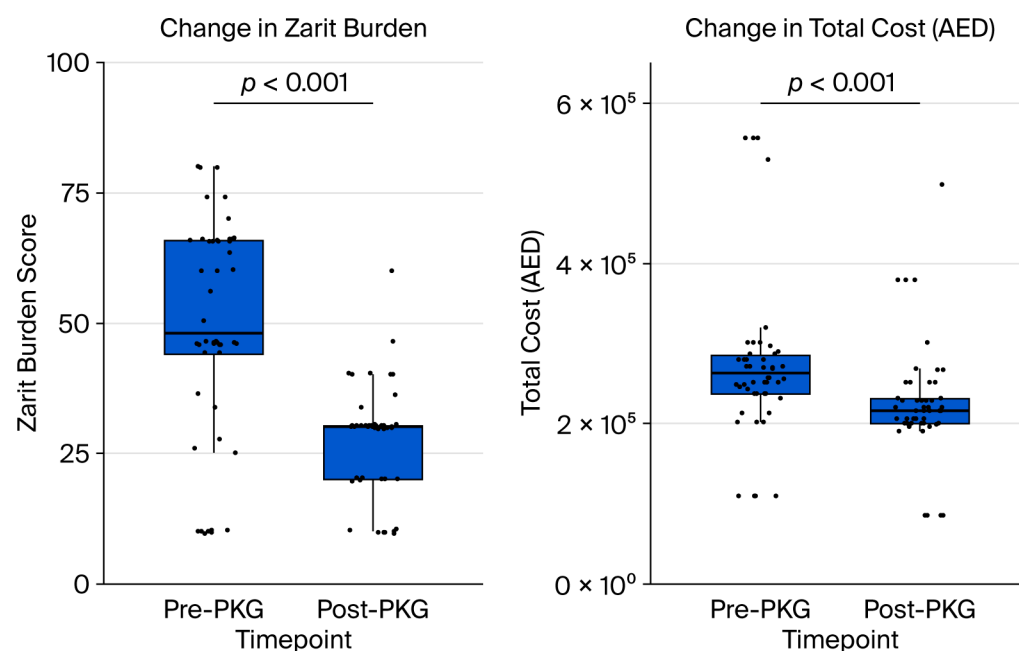


Figure 2. Changes in caregiver burden and total direct medical cost following 12 months of EmPark-PKG-guided care. *Note:* Boxplots depict changes in Zarit caregiver burden scores and total direct medical cost (AED) before (Pre-PKG) and after (Post-PKG) the EmPark-PKG intervention. Boxes represent the interquartile range (IQR), lines indicate medians, whiskers denote 1.5× IQR, and individual patient-level data are overlaid. Wilcoxon signed-rank tests indicated statistically significant reductions in both caregiver burden and total cost ($p < 0.001$ for both). AED = United Arab Emirates Dirham; PKG = Parkinson’s KinetiGraph.

4. Discussion

We comprehensively evaluated the clinical outcomes, cost-effectiveness, and caregiver burden by comparing PD management outcomes between the integration of wearable sensor PKG-guided remote monitoring into routine clinical management of Parkinson’s disease and standard care. Over a 12-month period following the introduction of Parkinson’s KinetiGraph (PKG)-guided care, significant improvements were observed in clinical, functional, and economic outcomes. Analyses focused on motor and non-motor symptoms, medication use, healthcare utilization, associated costs, and caregiver burden, utilizing non-parametric statistical methods.

Our study demonstrated significant clinical improvements in Parkinson’s patients following 12 months of PKG-guided care. Notably, there was a 20% reduction in motor scores as measured by the UPDRS Part 3, along with a decrease in the severity and unpredictability of motor complications, reflected in the UPDRS Part 4 scores. PKG-guided care not only benefited patients across various disease stages and motor functions, but it also led to an 18.4% reduction in the overall levodopa equivalent daily dose (LED), indicating a decrease in medication overload. Furthermore, the frequency of medication adjustments by healthcare providers diminished, suggesting enhanced treatment stability. Additionally, there was a significant improvement in daytime alertness, with a 28.6% reduction in Epworth Daytime Sleepiness (EDS) scores, indicating that patients experienced less daytime drowsiness, which in turn enhanced their daily functioning and overall well-being. These findings collectively highlight the impactful effects of PKG-guided care. Notably, representing a remarkable 50% reduction in carer-accompanied visits, not only reflects improved efficiency in care delivery but also suggests a potential easing of the demands placed on caregivers. Additionally, the Zarit caregiver burden score saw a significant improvement of 37.5% reduction in caregiver burden, as it correlates with an overall

enhancement in the quality of life for both patients and their caregivers. This evidence supports the notion that PKG-guided care not only streamlines care processes but also alleviates the emotional and physical strain on caregivers and loved ones. The implementation of PKG-guided care has led to noteworthy improvements in several areas of healthcare resource utilization over a 12-month period. One of the most striking outcomes has been the 60% reduction in outpatient follow-up visits and a significant decrease in acute hospital admissions; the 50% decline in unwarranted imaging and overall total direct medical expenses saw a substantial decrease of 17.9%, indicating that PKG-guided care streamlines patient management and enhances efficiency in healthcare delivery. Overall, our study evidence points toward the effectiveness of PKG-guided care in enhancing healthcare efficiency and reducing costs, but also lessens the burden on caregivers, which could inform future practices and policies in patient management.

5. Limitations

Our study has several limitations that should be acknowledged. First, the lack of a control group restricts our ability to conclusively attribute the observed changes to the implementation of PKG-guided care. Second, the relatively small sample size may limit the statistical power to detect subtle effects and could hinder the generalizability of our results to broader populations. Additionally, the cost data were sourced from insurer records, which may not capture indirect or unreimbursed expenses, such as transportation or informal caregiving. To enhance the validity and applicability of our findings, future research should focus on larger, controlled, multicenter studies that incorporate additional objective monitoring parameters.

6. Conclusions

Integrating PKG-guided remote monitoring into the standard clinical management of Parkinson's disease led to significant and meaningful improvements in motor symptoms, medication burden, quality of life, and the severity of non-motor symptoms over a year. Objective data from wearable devices showed marked reductions in bradykinesia, dyskinesia, tremor, and immobility, aligning with reports from patients and clinicians. Additionally, there was a notable decrease in healthcare resource use, including fewer outpatient visits, hospital admissions, and imaging scans, resulting in lower medical costs. Caregiver burden also decreased significantly, positively impacting both caregivers' quality of life and motor complications.

Author Contributions: V.M. and K.R.C. conceptualized the project. V.M., H.H., and A.N. performed the analysis, manuscript initial draft, and research. H.I., S.A., H.T.S.B., T.L., P.K., V.G., R.M., G.C.-F., M.O., G.T., R.B. and R.K.D. have contributed by providing insights, writing, editing and made revisions. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement: The datasets generated and analyzed during the EmPark-PKG study are available from the corresponding author upon reasonable request. Please email vinod.metta@nhs.net.

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