International Journal of Neurologic Physical Therapy
2023; 9(1): 1-9
http://www.sciencepublishinggroup.com/j/ijnpt
doi: 10.11648/j.ijnpt.20230901.11
ISSN: 2575-176X (Print); ISSN: 2575-1778 (Online)

Measures of Physical Activity in Parkinson's Disease (MAPD)

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To cite this article:

Jonathan Gilby, Camille Carroll, Jonathan Marsden. Measures of Physical Activity in Parkinson's Disease (MAPD). *International Journal of Neurologic Physical Therapy*. Vol. 9, No. 1, 2023, pp. 1-9. doi: 10.11648/j.ijnpt.20230901.11

Received: January 30, 2023; **Accepted**: February 16, 2023; **Published**: April 27, 2023

Abstract: *Background:* Previous research indicates that Physical Activity (PA) can help people with Parkinson's (PwP) to manage their symptoms but that they are less active than people of the same age and in relation to PA guidelines. Common PA measures include questionnaires or accelerometers. Accelerometers are not routinely used in clinical services. Little research has been conducted on PwP perceived feasibility and utility of using body-worn accelerometers. *Objective:* This quantitative, observational study assessed the concurrent validity, feasibility and perceived utility of a questionnaire and body-worn accelerometer to capture PA in people with newly diagnosed Parkinson's. *Methods:* Twenty-four participants were recruited from a service for newly diagnosed PwP at University Hospitals Plymouth NHS Trust, UK. The study was conducted remotely by postal, telephone and email correspondence. Participants used a wrist-worn accelerometer (GENEActiv™) for one week, completed the International Physical Activity Questionnaire (IPAQ-S) about that week's PA, and completed a Likert-style utility questionnaire on perceived feasibility and utility of using these PA measures. Energy expenditure (metabolic equivalents – METs) calculated from the PA measures were compared using Spearman's correlation. Descriptive statistics summarised PA levels in relation to WHO guidelines and feasibility of measures based on responses to utility questionnaire. *Results:* The sample (n=24, 17 males, 7 females; mean age 72.4 years, SD ± 9.7; mean disease duration 1 years) showed a significant moderate correlation between total weekly energy expenditure calculated from the PA measures (r_s = 0.55, n = 24, p =.003). Overall, the sample were above guidelines for moderate PA (IPAQ-S mean 453 mins per week, range 0 – 3010, SD ± 718); GENEActiv™ mean 265 mins per week, range 1 - 794, SD ± 217). Participants agreed 'the PA questionnaire was easy to fill in' (median response 2 = agree, IQR 2) but disagreed with the statement 'I would rather fill in a PA questionnaire about the previous week than wear the sensor for a week' (median response 4 = disagree, IQR 2). *Conclusion:* Findings suggest it is feasible to introduce a measure of PA to Parkinson's patients remotely. There was wide variation between the measures when determining levels of moderate PA. Validation of the GENEActiv™ device against gold standard measures of PA intensity in PwP is needed to establish criterion validity. *Impact:* This work contributes to the understanding of patient experience and preferences in remote monitoring of PA and the use of these measures to plan service provision to support PA.

Keywords: Parkinson's, Physical Activity, Accelerometer, Physical Activity Questionnaire

1. Introduction

Common impairments in Parkinson's such as bradykinesia, balance problems, and sleep behaviour disorder, can lead to activity and participation limitations and affect quality of life [1–3].

Physical activity (PA) is any bodily movement produced by the skeletal muscle that results in substantial increase over resting energy expenditure with exercise as a structured sub-type of PA [4]. The benefits of PA and exercise in the general population include lower rates of chronic disease, healthier body composition and bone health, and better cognitive functioning [5]. Exercise has additionally been shown to improve both motor and non-motor features of Parkinson's and potentially has a disease-modifying effect [6–9].

Previous research suggests that people with Parkinson's (PwP) have more sedentary lifestyles than age-matched controls; however, there is debate over the most appropriate measures of PA [10, 11]. A recent scoping review identified a lack of evidence of what levels of PA PwP currently achieve in studies of physical self-management [12]. An obstacle to designing appropriate PA interventions is this lack of knowledge of baseline activity habits [13].

Common methods of measuring PA have potential disadvantages. For example, self-report questionnaires require retrospective recall and can be affected by external factors such as social desirability; monitoring with devices (for example, accelerometers) can be expensive and require additional resources to return/collect [14].

Research-grade accelerometers are defined as those suitable for researchers and clinical scientists to estimate PA levels via regression equations, validated against gold-standard laboratory methods [15]. Research-grade accelerometers are likely to be more accurate than commercially available accelerometers, particularly in measuring changes in walking activity in PwP in the home [16, 17].

Metabolic Equivalents (METs) represents a procedure for expressing the energy cost of physical activities as a multiple of the resting metabolic rate that can be estimated from both PA questionnaires and accelerometers [18]. One MET equals the energy expenditure at rest.

Measurement of PA levels in clinical practice may help to identify individuals who would benefit from input to promote PA. Examining the relationship between self-report and objective PA parameters is an important step in planning service provision to support PA in PwP. It would also help in exploring the potential for PA monitoring in longitudinal cohort studies. This could contribute to a better understanding of the interactions between PA and important disease outcomes such as cognition and quality of life [13, 19, 20].

Further, there is relatively little research into the acceptability of accelerometers to PwP and few studies have attempted to objectively measure PA in early Parkinson's [11, 21].

It is therefore important to ascertain what are the most acceptable methods of measuring PA in this population. The COVID-19 pandemic has also highlighted the importance of being able to gather this information remotely.

2. Aims and Objectives

This study examined the concurrent validity and acceptability of wrist-worn accelerometer and physical activity questionnaire to monitor PA in a population from a service for newly diagnosed PwP.

The objectives were to determine:

1) The correlation coefficient between PA questionnaire and accelerometer.
2) Proportion of participants below the minimum PA guidelines for health [6].
3) Acceptability of the use of the accelerometer and PA questionnaire for a period of seven days monitoring.

3. Materials and Methods

3.1. Patient and Public Involvement and Engagement

Patient and Public Involvement and Engagement (PPIE) was sought with a local Parkinson's support group. The group assisted in the choice of the International Physical Activity Questionnaire Short Form (IPAQ-S) [22], based on perceived readability and usability. The Participant Information Sheet and the utility questionnaire were also piloted with the group for comments on readability and usability and found to be acceptable.

3.2. Ethical Approvals

Ethical approval was sought and approved from the Health Research Authority through the Integrated Research Application System (IRAS) (IRAS ID: 265843) in line with the UK Policy Framework for Health and Social Care Research [23]. The sponsor for the study was the University of Plymouth. Additional approvals were received from the University Hospital Plymouth NHS Trust Research Office and the University of Plymouth Faculty Research Ethics and Integrity Committee (FREIC).

3.3. Participants

The aim was to recruit twenty-four participants were over a four-month period using a convenience-sampling approach from a single Parkinson's service for people newly diagnosed with Parkinson's (The New Patient Pathway (NPP)) in University Hospitals Plymouth NHS Trust, UK. This accounted for approximately ten percent of the annual enrolment to the NPP in this healthcare provider organisation.

Inclusion criteria were purposefully broad, in order to obtain as representative sample of the NPP as possible This mapped to the service inclusion criteria: a confirmed diagnosis of idiopathic Parkinson's Disease according to the UK Brain Bank Criteria [24]; within the first year of care post-diagnosis as per the NPP protocol. The only additional criteria were that participants were able to consent; ambulate (with or without walking aid); and, either independently or with the assistance of an appropriate carer, be able to conduct a telephone consultation, be able to fit an accelerometer device and fill in a PA and utility questionnaire.

3.4. Sample Size Calculation

Powering the study to 80 percent with a 0.05 significance level allowed the detection of correlations of 0.45 or greater between IPAQ-S and accelerometer. This was influenced by a review of measurement properties of PA questionnaires, which suggested that a minimal acceptable standard set against objective activity measuring devices is 0.50 [25]. This concurs with the moderate correlation threshold suggested by Ferguson [26] and the large correlation threshold suggested by Cohen [27].

3.5. Data Collection Methods

Correspondence was conducted remotely, via telephone, email and postal correspondence in line with a University of

Plymouth risk assessment and data management plan during the COVID-19 pandemic.

On enrolment to the NPP, patients were asked if they were willing to be contacted by members of the research team. Details of those who agreed were then passed, via secure email, to the research team who undertook telephone-based pre-screening.

A participant information sheet and consent form (with stamped addressed return envelope) was sent to eligible participants. Additional permissions to access baseline data (age; age at diagnosis; sex; past medical history; presence of tremor) from routine healthcare data were requested.

Once consented, participants were sent out the following information: study team contact information; pack containing instructions about the accelerometer device fitting and seven day wear protocol (wearing the device on the non-dominant wrist), care and cleaning; the GENEActiv™ device itself (pre-cleaned as per manufacturer instructions); the IPAQ-S questionnaire to be filled out retrospectively for the same seven day period; utility questionnaire; retrospective falls diary; pre-paid return envelope.

The IPAQ-S is one of the most widely used PA questionnaires and is validated in many age ranges and clinical populations (although not Parkinson's) (IPAQ-S) [28–30]. The IPAQ-S asks about time spent in four activity types undertaken during any work, travel, housework or leisure activity: vigorous intensity; moderate intensity; time spent walking; and time spent sitting [31]. Further, the ability to calculate Metabolic Equivalent Units (METs) from the IPAQ-S allows a comparison to accelerometer outcomes.

The choice of accelerometer was partly pragmatic, due to the availability of device to the Parkinson's service and the need for remote set up during the COVID-19 pandemic as the GENEActiv™ requires virtually no setup on the part of participant with a single on and off button press to start and stop the monitoring period. It can record continuously for seven days or longer (depending on monitoring frequency). The GENEActiv™ has been used in other studies of Parkinson's populations [32, 33]. It has the advantage of being lightweight (16g), fully waterproof, and allowing the collection of raw acceleration data (range ±8g) on three orthogonal planes [34].

The gold-standard for estimating energy expenditure in free-living environments is the doubly-labelled water method [35, 36]. This method is expensive and cannot provide information about the frequency, intensity and pattern of PA [37, 38]. As PA is a multidimensional exposure it is difficult to find an absolute measure [37]. This study therefore uses data derived from the accelerometer to assess the concurrent validity of self-report PA questionnaire.

A Likert-Style participant utility questionnaire was adapted from a previous study in PwP [39]. This was checked for readability by PPIE representatives.

3.6. Data Analysis

The automatic report available from www.ipaq.ki.se was used to calculate total MET minutes per week from the IPAQ-S. This is the preferred continuous variable suggested by the IPAQ group [22]. The automatic report assigns a MET value for walking, moderate and vigorous activity (3.3, 4 and 8 METs respectively). All minutes at each level of activity were multiplied by the corresponding MET value to allow comparison to the GENEActiv™ data for calculation of the correlation coefficient (Objective one).

Using GENEActiv™ post-processing software (version 3.3), raw 75Hz accelerometer data was summarized into a signal vector magnitude (Gravity subtracted) (SVMgs) using one second epochs (1):

$$SVMgs = \Sigma \left|\sqrt{x^2 + y^2 + z^2} - g\right| \quad (1)$$

$SVMgs$ = Signal Vector Magnitude gravity subtracted, x = x axis, y = y axis, z = z axis, g = gravity where 1 g = acceleration due to gravity.

This derivative of vector magnitude favoured by the original GENEActiv™ validation study [40], removes the gravity component from the signal in order to isolate the activity-related acceleration component. In the present study, 75 Hz was chosen as the closest available setting on the current GENEActiv™ software (version 3.3) to the 80Hz on the post-processing software (version 1.2.1) used in the validation study [40].

Summary GENEActiv™ data was converted into METs taking cutoffs from the Esliger *et al.* (2011) protocol [40] (See table 1) and linearly scaling SVMgs data to its corresponding MET to calculate total MET minutes per week. Missing data was accounted for by determining the average MET minutes per day from the available data and multiplying by seven to obtain MET minutes per week. A cutoff of less than 15 percent of the predicted data (i.e., less than one complete day of data) was set for exclusion from analysis. Percentage recording time was also presented as indicator of user fidelity.

Table 1. *GENEActiv™ cutpoints.*

Intensity	GENEActiv™ Cutpoints (SVMgmin) Left Wrist	GENEActiv™ Cutpoints (SVMgmin) Right Wrist	Metabolic Equivalent (MET)
Sedentary	≦216	≦385	≦1.49
Light	217-644	386-439	1.5-3.99
Moderate	645-1809	440-2097	4-6.99
Vigorous	≧1810	≧2098	≧7

SVMgmin = Signal Vector Magnitude gravity subtracted in one minute epoch intervals

Acknowledging the concern that the Parkinson's motor feature of tremor could be a confounding variable in a wrist-worn

accelerometer wear protocol for PwP [41], we performed a sensitivity-analysis excluding all of those identified from clinic letter with a tremor on the GENEActiv™ worn wrist.

Data was analysed using Microsoft® Excel for Mac version 16.44 and SPSS® version 25 software [42]. The level of significance was set at α=0.05. Scatterplots allowed visual inspection of the general trend of the data and examination for outliers. The association between the MET minutes per week from the GENEActiv™ and IPAQ-S total was assessed using non-parametric Spearman's Rank Correlation (Objective One testing).

The MET minutes per week at moderate and above intensity from both the GENEActiv™ (Using MET thresholds defined in Table 1) and IPAQ-S were compared to the recommended minimum guidelines for health of 150 minutes Moderate Physical Activity [5] using descriptive statistics (mean ± 95%CIs) (Objective Two testing).

The utility questionnaire was reported using descriptive statistics (median, IQR) on a question-by-question basis (Objective Three testing).

4. Results

4.1. Sample

Of the 32 potential participants highlighted by the clinical team, five declined meaning 27 participants were recruited to the study (84 percent). Average recruitment rate was 6.5 per month in a four month recruitment window. Three participants were lost to follow-up, withdrawing for personal reasons and returning the accelerometer before commencing the monitoring period.

The recruited 24 participants (17 males, 2 females) were aged 60 to 89 (Mean age 72.4 years, SD ± 9.7), mean disease duration one year (SD ± 0.7), Hoehn and Yahr Stages one to three (median 1.5). All were of White, British ethnic origin.

4.2. GENEActiv™ Recording Time

Most participants (N=16) achieved the full recording time with the GENEActiv™. Mean recording time was 96.74 percent of the seven days and nights monitoring period (Range 44.59 to 100 percent).

4.3. Correlation Between Physical Activity Questionnaire and Accelerometer (Objective One Testing)

There was a significant moderate positive correlation (rs = 0.55, n = 24, p = 0.003) between MET minutes per week derived from the IPAQ-S and accelerometer. This significant correlation persisted following removal of eight datasets of patients with identified tremor on the GENEActiv™ worn wrist (rs = 0.50, n = 16, p = 0.024).

4.4. Proportion of Participants Below the Minimum PA Guidelines for Health (Objective Two Testing)

According to IPAQ-S self-report, 50 percent (n=12) of participants were below the PA guidelines for health of 150 minutes moderate PA per week. According to GENEActiv™ monitoring this proportion was 42 percent (n = 10) (Figure 1).

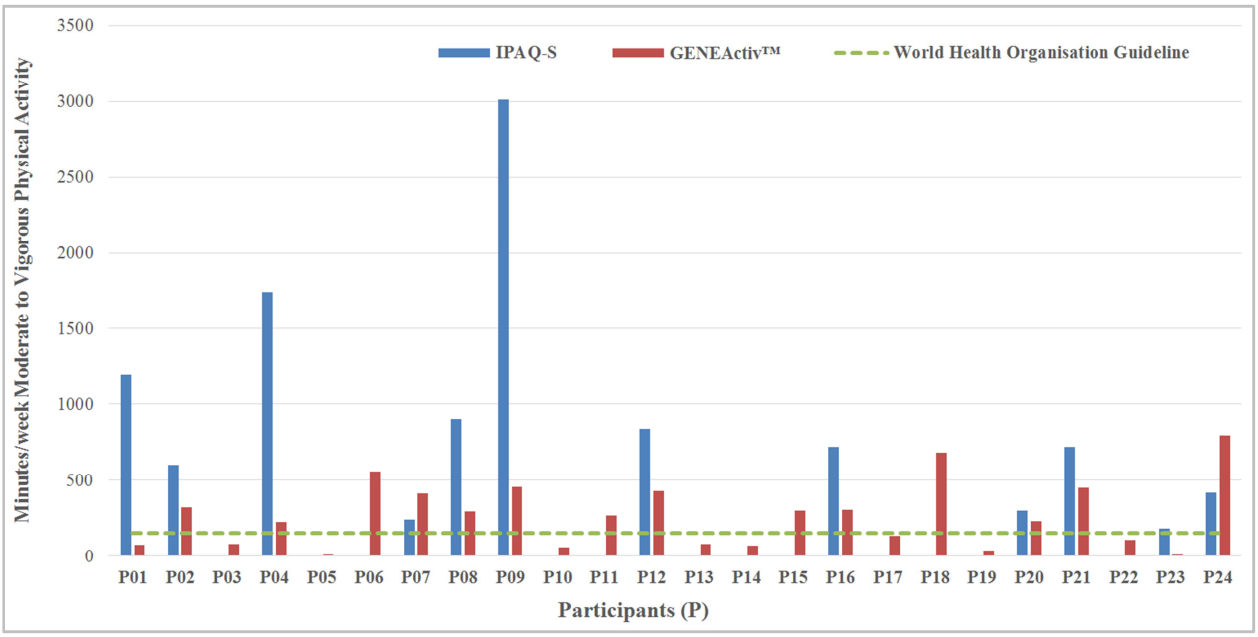

Figure 1. *Minutes per week moderate to vigorous physical activity.*

The average minutes of moderate and above PA were above guidelines (IPAQ-S mean 453 mins per week, range 0 – 3010, SD ± 718); GENEActiv™ mean 265 mins per week, range 1 - 794, SD ± 217). The effect of including and excluding data for the IPAQ-S self-reported minutes of moderate and above PA per week in the analysis for one participant (P011) was examined as their self-reported minutes were more than two standard deviations from the mean. Excluding P011 reduced the IPAQ-S mean by 110 minutes but the sample, as a whole, were still well above

guidelines (IPAQ-S mean 342 mins per week, range 0 – 1740, SD ± 479, P011 excluded).

Six participants recorded a 'don't know/not sure' answer to at least one of the sections of the IPAQ-S. In line with the IPAQ Group (2005) guidance, they automatically scored zero for that section. Three of these six participants recorded no moderate to vigorous PA on the IPAQ-S but at least some minutes moderate to vigorous PA on the GENEActiv™ device (Range 81 – 679).

4.5. Acceptability of the Use of the Accelerometer and PA Questionnaire for a Period of Seven Days Monitoring (Objective Three Testing)

The utility questionnaire indicated that participants tended to agree with the positively worded statements relating to the GENEActiv™ device and disagree with the negatively worded statements. For example, participants disagreed with the statement 'I would rather fill in a PA questionnaire about the previous week than wear the sensor for a week' (Statement 5: median response 4 = disagree, IQR 2). Participants did, however, agree that 'the PA questionnaire was easy to fill in' (Statement 8: median response 2 = agree, IQR 2). This contrasts with the answers to Statement 9, 'I found it difficult to remember how much PA I had done for the week when completing the PA questionnaire', which were more evenly spread between strongly agree and strongly disagree answers (Median response 3 = neither agree or disagree, IQR 2) (Figure 2).

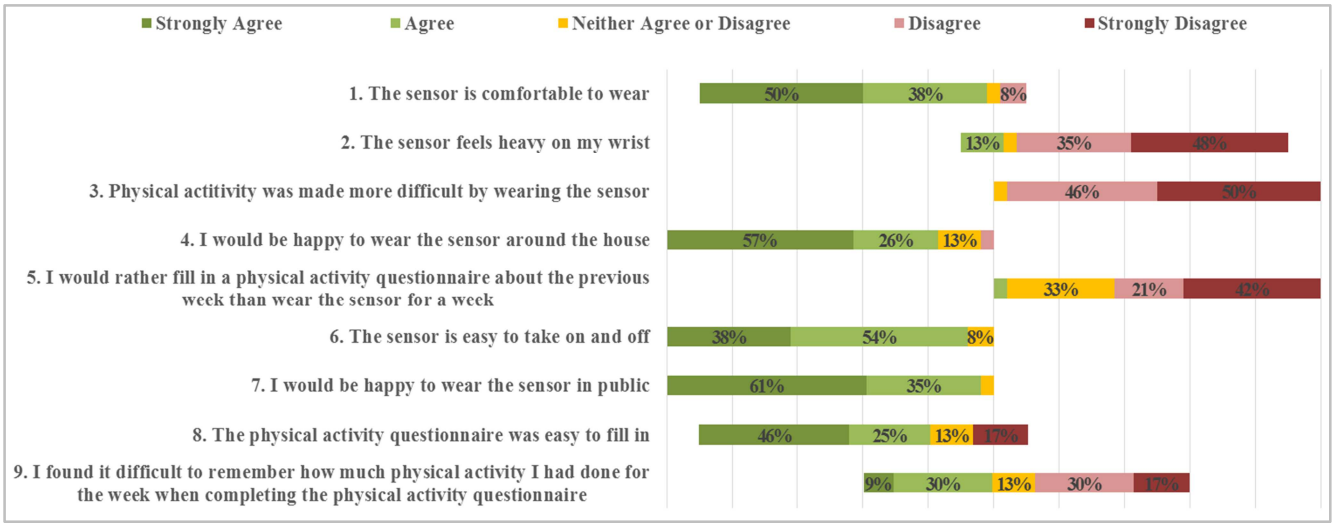

Figure 2. *Utility Questionnaire* [Smaller percentages (<5%) removed as merging with adjacent data labels in original].

5. Discussion

The correlation coefficient between MET minutes per week recorded by the IPAQ-S questionnaire and the GENEActiv™ accelerometer was moderate and statistically significant. It was above the 0.5 level recommended as a minimal acceptable level by a review into measurement properties of PA questionnaire when compared to objective PA measures [25]. It is also above the correlations reported in a systematic review of PA questionnaires. The systematic review included an analysis of 41 studies using accelerometers as comparison measures in a range of clinical populations and found a moderate correlation of 0.41 for questionnaires asking about the past week [29]. An important distinction is that none of the studies included in the systematic review involved PA questionnaire or accelerometer research in Parkinson's populations.

Another study comparing PA questionnaire to accelerometer in a Parkinson's population was conducted by Mantri, Wood, Duda and Morley but they used a uniaxial accelerometer as opposed to the triaxial accelerometer of the present study [13]. They observed a similar moderate correlation between self-report Moderate to Vigorous PA minutes reported in the Physical Activity Scale for the Elderly (PASE) and daily step count taken from the accelerometer ($\rho = 0.56$, $p = 0.003$). However, when the calculation of moderate to vigorous PA minutes per day was compared between the PASE and the accelerometer there was no correlation ($\rho = -0.003$, $p = 0.98$). This may reflect issues with converting step counts from uniaxial accelerometer to PA energy expenditure to reflect moderate to vigorous PA. In different populations, multiple calibration studies have generated widely divergent models for these calculations [43]. A laboratory-based study of PA in PwP demonstrated no association between simple step count and oxygen uptake or perceived exertion [44]. The wide variation in correlation coefficients depending on the PA measure used in the Mantri, Wood, Duda and Morley research [13] highlights that important questions remain about the validity of measures of PA in PwP.

There are also concerns of using wrist-worn triaxial accelerometers in Parkinson's populations due to the potential for detection of extraneous movements such as tremor being incorrectly classified as PA [45, 46]. In the present study, attempts were made to mitigate against over-detection with the GENEActiv™ device in PwP by excluding those with a clinically identified tremor on the non-dominant wrist. This

did not significantly change the correlation coefficient so gives more confidence in the results. An alternative strategy for future study would be to consider analysing the raw data of the sample using a 3.75 to 7.5Hz stop filter. This would have the benefit of eliminating frequencies associated with tremor but also non-physiological movements such as vehicle oscillations during transport [47].

Previous literature comparing PA levels of PwP in relation to WHO Guidelines [5], consistently report a low level of PA minutes at moderate or above intensity for PwP [11, 12, 13, 19, 20, 41, 47, 48]. This contrasts with the findings of this study whereby mean weekly minutes of moderate or above PA recorded by accelerometer and IPAQ-S were above guidelines. This may partially be due to the sample in this study being newly diagnosed with a lower median Hoehn and Yahr stage (1.5) than the cohorts in the literature described above (all 2 or above). The cohort in the present study are therefore likely to have been less affected by the motor features of Parkinson's that can impact on PA participation. Longitudinal monitoring, examining this cohort at a comparable Hoehn and Yahr stage would provide a better comparison to the previous studies described above.

In the present study, there was a wide range between the PA measures when examining recording of moderate to vigorous PA: The mean minutes per week of the IPAQ-S were almost double that of the GENEActiv™ (453 verses 265). A criticism of PA questionnaires is that they can over-estimate PA possibly due to social desirability response bias and/or issues with recall [49–52]. Concerns over the issue of recall with self-report questionnaires remain and are demonstrated by the 25 percent of participants who recorded a 'don't know/not sure' answer to at least one of the sections of the IPAQ-S. This is also reflected in the utility questionnaire answers to statement nine where 39 percent of the sample reported difficulty remembering how much PA they had done for the week when completing the PA questionnaire. This effect may have contributed to the wider range of minutes moderate to vigorous PA recorded by the IPAQ-S compared to the GENEActiv™ device (0 – 3010 verses 1 – 794).

Concerns over recall could mean that the IPAQ-S is less suitable for use with those with cognitive impairment, which is a frequent non-motor symptom of Parkinson's. Baseline cognition data in the form of the Montreal Cognitive Assessment (MOCA) would normally be available from the NPP but was not available for the present study due to temporary changes in service provision during COVID-19 restrictions. Assessment of capacity to consent was completed on admission to the study but no formal cognitive outcome measure was completed.

The age at diagnosis of Parkinson's is frequently above the recommended 15-69 age range for administration of the IPAQ-S. The average age of the sample in this study was above this range. Age has potential to influence recall due to with memory difficulties and cognitive problems more prevalent in the elderly. A study comparing the IPAQ-S and accelerometer assessed measurements of PA in Korean adults showed the correlation decreased with age [52]. Limited research has explored the validity of the IPAQ Elderly (IPAQ-E) as an alternative [22, 53].

A lack of generalisability of the GENEActiv™ validation study may have influenced differing results between the PA measures of this study [40]. The validation study did not involve PwP and used a self-identified sedentary sample. Reasoning that PA expenditure for a given absolute intensity effort would be higher for fitter individuals, the validation study used a higher threshold of four METs for moderate to vigorous intensity [44]. Their reasoning may not apply to the Parkinson's population in this study and is higher than the threshold of 3 METs in the IPAQ-S.

A potential limitation from the GENEActiv™ data is that wrist accelerometer measurements can be more complex to measure as they are further from the body's centre of mass [54, 55]. There is also an inability to monitor hand-limited PA such as cycling [45, 52]. There are, however, indications that wrist-worn studies have higher compliance than hip-worn accelerometer studies [56, 57]. Acceptability of, and compliance with wrist-worn devices may also have been a factor in the high levels of wear time in this study.

The utility questionnaire suggested a strong preference for the GENEActiv™ monitoring over the IPAQ-S with only one participant agreeing that they would rather fill in the questionnaire than wear the accelerometer for the week. This conforms to the feedback in the only other study found in the literature to have employed a utility questionnaire in a Parkinson's population [39]. That study compared bilateral wrist-worn accelerometer to symptom diary. Only one participant in the larger sample (n = 34) of that study expressed a preference for keeping a diary over using the accelerometers.

6. Conclusion and Recommendations

This work contributes to the understanding of patient experience and preferences in monitoring of PA remotely. It also contributes to the understanding of using measures of PA in order to plan service provision to support PA in PwP. Findings suggest that it is feasible to introduce a measure of PA to patients newly diagnosed with Parkinson's and to do this via remote correspondence.

Although MET minutes per week were moderately correlated between the measures, wide variation between the measures when determining levels of moderate to vigorous PA highlights key differences between self-report and objectively measured PA. Validation of the GENEActiv™ device against gold-standard measures of PA intensity in a Parkinson's population would give more confidence in its use for providing criterion validity. Reviews into the management of Parkinson's using wearable devices highlight that studies seeking to validate devices in free-living environments remain limited [58, 59]. Questions therefore remain over the accuracy and validity of these measures in Parkinson's populations.

An obstacle to improving PA counselling and designing appropriate PA interventions for PwP is incomplete

knowledge of baseline activity habits [13]. Improved knowledge of these habits with objective PA monitoring could also provide a basis for gaining an understanding of PA behaviours of PwP over time, for example in longitudinal cohort studies. The inclusion of other outcome measures such as the MOCA cognitive screening and Parkinson's Disease Questionnaire (PDQ-39) would allow a better understanding of the interactions between PA and disease outcomes. Inclusion of objective PA measures in disease-modifying trials could also aid in the understanding of the potential confounding effect of PA in these trials.

Acknowledgements

Parkinson's Service, University Hospitals Plymouth, UK, East Taphouse Parkinson's Support Group, Cornwall, UK, This project was supported by a grant from Health Education England (HEE) and the National Institute of Health Research (NIHR) UK Pre-doctoral Clinical Academic Fellowship.

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