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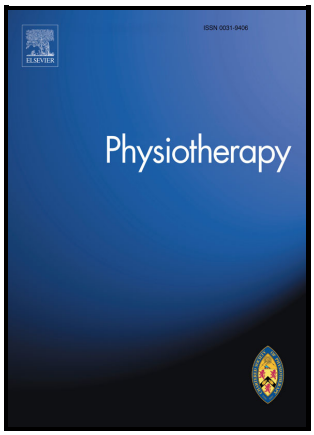

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Assessing impaired bed mobility in patients with Parkinson's disease: a scoping review

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ABSTRACT

Background: Although most patients with Parkinson's disease (PD) experience difficulties in bed mobility, evidence on the suitability of the methods for assessing impaired bed mobility in PD are lacking.

Objectives: To identify objective methods for assessing impaired bed mobility in PD and to discuss their clinimetric properties and feasibility for use in clinical practice.

Data sources: PubMed, Web of Science, and Cochrane Library were searched between 1995

and 2022.

Selection criteria: Studies were included if they described an objective assessment method for assessing impaired bed mobility in PD.

Data extraction and data synthesis: Characteristics of the identified measurement methods such as clinimetric properties and feasibility were extracted by two authors. The methodological quality of studies was evaluated using the Appraisal of studies tool.

Results: Twenty-three studies were included and categorised into three assessment methods: sensor-based assessments (48%), rating scales (39%), and timed-tests (13%). The risk of bias was low for all but one study, which was medium.

Limitations: Despite applying wide selection criteria, a relatively small number of studies were identified in our results.

Conclusion: Rating scales may be the most preferred for assessing impaired bed mobility in PD in clinical practice, until clinimetric validity are adequately demonstrated in the other assessment methods.

Contribution of Paper

• No consensus exists on objective assessment methods for impaired bed mobility in PD.

• This review revealed that bed mobility in PD can be objectively evaluated using rating scales, sensor-based assessments, and timed-tests.

• Rating scales may be the most suitable for assessing impaired bed mobility for PD in clinical practice.

Keywords:

Parkinson's disease; bed mobility; assessment methods; quality of life; scoping review.

1. Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disorder and is clinically characterised by bradykinesia, rigidity, tremor, and postural instability. The prevalence of Parkinson's disease (PD) is rapidly growing worldwide, and the number of people with PD is estimated to double to over 12 million by 2040 (1).

Most patients with PD reported difficulty in bed mobility (2, 3), which is a prerequisite for functional independence before performing sitting, standing, and walking. Moreover, bed mobility difficulties often constitute one of the first symptoms noted (4), negatively impacting not only the patient's quality of life but also caregivers' workloads (5).

Despite the importance and prevalence of these symptoms, objective assessment of bed mobility is challenging for several reasons. First, bed mobility is a complex motor sequence including axial and limb movements with multiple strategies possible (6). Second, the bed mobility component of the Movement Disorder Society-Unified Parkinson's Disease Rating Scale (MDS-UPDRS) (7), the most widely used assessment method for PD, is self-reported. They rely on patients' memory which would be unreliable and limited by recall bias if the patients have memory impairment (8). Additionally, conventional observational analysis can be affected by raters' experiences (9).

Previous reviews have investigated rating scales to assess functional mobility (10), or posture and gait, and balance in PD (11). However, there is no consensus about which objective assessment methods are most suitable for assessing impaired bed mobility for PD in physiotherapy practice. Therefore, the aim of this study is to review objective measurement methods of bed mobility in PD in terms of their clinimetrics and clinical usability.

2. Methods

This scoping review was conducted according to the preferred reporting of items for systematic reviews and meta-analyses extension for scoping reviews (PRISMA-ScR) (12), using the Joanna Briggs Institute framework (13).

2.1. Search strategy

The literature search was performed in August 2022 on PubMed, Web of Science, and Cochrane Library. A sample search strategy on PubMed is shown in Supplementary Table 1. To identify additional relevant articles, references were also scanned through a manual search. Collected papers and references were managed using EndNote 20 (Clarivate Analytics, Philadelphia, Pennsylvania, USA). Two reviews (ST and AY) independently performed the literature search and screened the abstracts and titles to identify relevant articles for full-text retrieval. Any disagreement between the two reviews was discussed before making the final decision.

2.2. Selection criteria

The explicit inclusion criteria were as follows: i) studies involving patients with PD; ii) studies of objective assessment methods of impaired bed mobility such as rating scales, sensor-based assessments, and timed-tests; iii) articles published in English, including in any format; iv) studies published from January 1995 to May 2022, and v) studies providing information on either reliability, validity, responsiveness, and floor or ceiling effect. The following studies were excluded if they involved: i) atypical parkinsonism, ii) self-report measures, and iv) nonreproducible or non-standardised assessment methods.

2.3. Data extraction

The relevant data were extracted by one reviewer (ST) from chosen studies. Extracted data included: first author, year of publication, sample size, ages, Hoehn and Yahr stage, study design, study setting (home or hospital), and outcome measures and main findings related to bed mobility. If applicable, the number of healthy control

participants, name of instrument tools or device, sensor location, and monitor duration of the measurement method were also recorded. The clinimetric properties (reliability, validity, responsiveness, floor or ceiling effect), and feasibility of the measurement methods (domains/items of assessment methods, assessment time, ease of administration, required equipment, expertise, and available languages) were assessed based on the previous review (11).

2.4. Quality assessment

To analyse the methodological quality of studies, an adapted version of the Appraisal of Cross-sectional studies (AXIS) tool (14, 15) was used by two reviews (ST and YY) who summed all the positive answers for each of the 13 items.

3. Results

3.1.Study selection

Supplementary Figure 1 presents the flow of articles through the review process and publication years of the included studies. A total of 66 titles and abstracts were screened, of which 23 studies fulfilled the inclusion criteria, describing timed-tests (n = 3, 13%) (16-18), sensor-based assessments (n = 11, 48%) (19-29), and rating scales (n = 9, 39%) (30-38) including the “Parkinson Activity Scale (PAS)”, “Modified Parkinson Activity Scale (M-PAS)” (32, 33), and “Lindop Parkinson's Disease Mobility Assessment (LPA)” (34-38). The studies were published between 1999 and 2022, and rating scales and timed-tests were reported on earlier than sensor-based assessments.

3.2. General information

Summary overviews are presented per assessment type in Table 1.

All included studies involved patients with PD. Sample sizes varied among studies: sensor-based sample sizes ranged from1 to 305 patients, rating scales sample sizes ranged from 3 to 49 patients, and timed-tests sample sizes ranged from 15 to 39 patients. Seventeen studies assessed bed mobility impairments in cross-sectional designs (16, 17, 19-23, 25-30, 32, 34, 35, 38), while the others assessed them as outcomes of prospective longitudinal design (18, 24, 31, 33, 36, 37).

[Suggested position Table 1]

3.3.Characteristics of each measurement method

The detailed test descriptions, clinimetric properties, and feasibility of each measurement method are presented below.

3.3.1. Rating scales

The rating scales were specifically created to evaluate the most important activity limitations in PD that can be targeted by physiotherapy (30, 32). In fact, five papers (56% of the rating scales) were physiotherapeutic interventional studies (31, 33, 36-38).

Modified Parkinson Activity Scale (M-PAS)

Description of the assessment method: The M-PAS is a revision of PAS originally developed in 2000 (30), consisting of 18 items covering three functional mobility domains (chair transfer, gait akinesia, and bed mobility). Compared with the PAS, M-PAS have more items on chair transfer, and gait akinesia domain (e.g., Start akinesia

with a motor dual task [item 5], Turning 180° with a motor dual task [item 6], Start akinesia with a cognitive dual task [item 7], and Turning 180° with a cognitive dual task [item 8]), while there were no changes on bed mobility domain.

Bed mobility domain includes eight items: lying down with or without a cover (item 9 and 12), rolling over with or without a cover (item 10a/10b and 13a/13b), and getting out of bed with or without a cover (item 11 and 14). The quality of movement is scored on a 5-point ordinal scale ranging from 0 (worst) to 4 (best). The M-PAS considers the quality of movement and the number of difficulties – for instance of the item 11 (Getting out of bed without a cover) distinguishing between *"normal, without apparent difficulties"* (4 points), *"one difficulty, difficulty with turning trunk/pelvis"* (3 points), *"two difficulties, difficulty with moving legs"* (2 points), *"three difficulties, difficulty with reaching adequate end position: asymmetric, uncomfortable"* (1 point), and *"dependent on physical assistance"* (0 point) (32, 39).

Clinimetric properties: No ceiling effects were found (32), while floor effects were not investigated. *Reliability.* Excellent inter-rater reliability (intraclass correlation coefficient [ICC] = 0.97; ranged 0.95–0.98) and high internal consistency for bed mobility domain with/without covers (Cronbach's $\alpha = 0.79/0.89$), and excellent test-retest reliability in ON (ICC=0.81) and OFF (ICC=0.93) (30). *Validity.* Good concurrent validity with UPDRS motor scores (Rs = 0.64), and with the VAS-Global Functioning (Rs = 0.79) (32). *Responsiveness.* This has not formally been examined. Keus et al. calculated that the smallest detectable difference the M-PAS total score was 7.2 points (32). The items of bed mobility domain in M-PAS have been used to detect physiotherapeutic interventional changes (31, 33).

Feasibility: Assessment time for the entire scale is about 30 minutes (10 minutes for bed domain) (39). The M-PAS is relatively easy to use and requires sheets and a blanket

or duvet in the bed mobility domain. It is reported that M-PAS can be used by both expert and non-expert physiotherapists in PD with no significant differences in the mean scores of M-PAS (p = 0.28) (32). It may be beneficial in mild to moderate stages PD patients due to a lack of a ceiling effect. M-PAS has been validated in English (32), Portuguese, and Japanese.

Lindop Parkinson's Disease Mobility Assessment (LPA)

Description of the assessment method: LPA consists of 10 items covering two functional mobility domains (gait mobility and bed mobility). Bed mobility domain includes four items: sit-to-lie, turning to the left in bed, turning to the right in bed, and lie-to-sit in bed. The independent level and required time for performance are scored on a 4-point ordinal scale grading raged from 0 (worst) to 3 (best). The LPA considers not only the quality of movement, but also its speed – for instance of the item 1 (Sit-to-lie) distinguishing between *"unaided with ease within 5 seconds"* (3 points), *"unaided with effort 6 seconds or more"* (2 points), *"help of one"* (1point), and *"help of two/unable"* (0point) (34).

Clinimetric properties: Regarding the ceiling effect, Janssens et al. reported that all patients already had a maximum or near-maximum score on the LPA bed mobility domain before training, which precluded the detection of any treatment effect (37). There is no evidence of floor effect. *Reliability.* A high level of inter-rater reliability was found for the bed mobility domain (agreement ranged from 82% to 100% in Bland-Altman analysis) (34), and intra-rater reliability (ICC=0.99) (35), but test-retest reliability was not examined. *Validity.* Concurrent validity of the LPA total score with UPDRS motor was shown for both raters (Rs = −0.67 and −0.63, p< 0.001) (34). The LPA bed mobility domain also showed discriminative validity between patients with PD

and healthy controls (median 6.78 points for the PD group, and median 4.11 points for the control group, p≤0.001)(35). *Responsiveness.* This has been demonstrated in patients with PD in group physical therapy intervention (standardised response mean = 0.7)(36). The items of bed mobility domain in LPA have been used to detect interventional changes (36-38) of which two studies showed a significant improvement in scores for bed mobility in LPA (p<0.001) (36, 38).

Feasibility: Assessment time of the LPA is about 10 min (34) (likely half of this time is taken for the bed mobility domain). The LPA is easy to use and requires no equipment apart from a stopwatch. LPA is available in English and Japanese.

3.3.2. Sensor-based assessments

Description of the assessment method: All studies for sensor-based assessments used triaxial wearable sensors and common kinematic parameters such as number, duration, velocity, degree of axial turn (19-29), number of getting out of bed episodes (20, 22-24, 26), and number of limb movements (22, 23, 26) to quantify nocturnal hypokinesia. In terms of sensor locations, the single sensor mostly on the sternum (20-25, 29), followed by the waist (19, 26, 27), or lower back (28) to assess axial function (e.g., turning in bed and getting out of bed), while multisite sensors on the wrists and ankles evaluated the number of limb movements (22, 26). Measurement duration of recording ranged from 2 hours (29), one night (20, 22, 23, 26, 27), or 36 hours (19), to over two nights (21, 24, 25, 28). Notably, most studies (73% of the sensor-based assessments) were performed in the home setting (19-25, 28, 29), while a few studies were conducted in the hospital (26, 27).

Clinimetric properties: Although the most frequently reported among three assessment methods, only a few studies examined its clinimetric properties. *Reliability.* Only one

study examined test-retest reliability that was adequate in the number of turning in bed within 24 hours (ICC=0.74) (27). *Validity.* There was no official validation study of assessing bed mobility in PD, but several studies showed decreased bed mobility which was correlated with clinical severity (e.g., UPDRS axial sub-scores, H&Y stages) (22, 23, 25-29). The outcomes of sensor-based assessments have been able to discriminate the performance for turning in bed, getting out of bed, and numbers for limb movements in PD and healthy control (20, 22, 23, 25, 28, 29). *Responsiveness.* Two studies of sensor-based assessments evaluated the effect of medication that showed a significant improvement in degree of turning in bed ($p<0.05$) (21, 24).

Feasibility: It may provide insights into daily-life behaviour and have high ecological validity. However, this test is not very easy to administer since it requires wearable sensor(s), computers, and analysis software which cost around USD 800 (20). Also, the time and expertise can be required for signal data processing to extract parameters of interest. Furthermore, no reports were found regarding relationships between sensor-based assessments and the rating scales.

3.3.3. Timed-tests

Description of the assessment method: Timed-tests assess the time taken to get out of bed using video recordings of movement patterns from supine to the upright standing position (16, 18) or from supine to sitting in bed (17). All studies of timed-tests were conducted in the hospital (16, 17).

Clinimetric properties: One study established test-retest reliability of the time that was excellent (ICC=0.84) (18), and discriminant validity showing slowed getting out of bed time in PD compared to healthy adults (16, 17), whereas data on responsiveness are lacking.

Feasibility: Timed-tests are quick and easy to administer. Outcomes may be varied between experienced and inexperienced raters in real-time assessment.

3.4. Quality assessment

The results of the quality assessment are presented in Supplementary Table 2. The mean overall quality score of studies was 11.9 out of 13 points. Only one study (19) with 9 points had a medium risk of bias, while the remaining 21 studies had low risk of bias with scores ranging from 11–13 points. The quality of the study by Janssens et al. (37) could not be assessed as detailed data could not be retrieved.

4. Discussion

Although several reviews focused on objective assessment methods in PD (10, 11, 40-42), they did not discuss detailed evaluation of bed mobility from a physiotherapy perspective. With this review, our goal was to identify the physiotherapy tools to assess impaired bed mobility in PD, and provide the best evidence on utility for use in clinical practice.

4.1. Characteristics of each assessment method for use in clinical practice

4.1.1. Rating scales

The important question in this scoping review was which assessment methods are the most suitable for assessing impaired bed mobility in PD in clinical practice?

Most importantly, among the identified assessment methods, only the rating scales showed adequate reliability, validity, and high feasibility, being specifically designed to detect the effect of physiotherapeutic interventions (33, 36-38). Thus, the rating scales seem to be the most preferable method for assessing impaired bed mobility in PD in clinical practice, until clinimetric evaluation are adequately demonstrated in the other

methods. Moreover, compared with the LPA, the M-PAS may have some advantages including more detailed qualitative scoring options, lack of a ceiling effect, more available languages, and usability by inexperienced raters. Indeed, the European Physiotherapy Guideline for PD recommended the M-PAS for assessing bed mobility based on its adequate clinimetric properties (39), which is consistent with our findings. In contrast, drawbacks of M-PAS are it is time-consuming to apply in everyday clinical practice and requires extra equipment such as a blanket. Therefore, the LPA which requires a shorter assessment time for less detailed qualitative scoring options, may lead to lower burdens for both patients and raters in situations with strict time limitations.

4.1.2. Sensor-based assessments

Although lacking established clinimetric properties, sensor-based assessments seem worthy especially because of long-term monitoring in patient's home, which is a crucial aspect for monitoring motor problems of PD, as also shown for gait analysis in PD (43, 44). Additionally, sensors are able to quantify turning difficulty resulting from axial dysfunction that is an important contributor to difficulties with turning in bed for PD (16). Despite these benefits, sensor-based assessments have not yet been used to evaluate the effect of physiotherapeutic interventions. As highlighted by Lang et al. (45), the barriers for implementing sensors in the physical rehabilitation practice include the cost of these systems and the time, and expertise required for signal processing. Given the tremendous potential of objective sensor-based outcomes, developments to lower these barriers will enable quicker adoption of sensor-based methods in clinical practice.

4.1.3. Timed-tests

Timed-tests are relatively under-utilized despite being simple to administer and having

excellent test-retest reliability in PD (18). This may be due to a lack of clinimetric evaluation and the challenge of interpreting different movement strategies as better or worse. Conversely, a study in healthy elderly by Alexander et al. examined the reliability and validity of timed-tests for bed mobility (46), and they described its utility in detecting subtle declines in mobility impairments (47). Despite not providing information on the nature of the mobility limitations, differences in movement times would be more sensitive to mobility impairments, representing capacity rather than performance (39), and being less affected by preferred strategies (17). However, the minimal clinically important change has not been established for the movement time, which hampers interpretation of intervention effectiveness. Further longitudinal work in people with PD is needed to clarify this issue.

4.2. Complementarity among the identified methods and Future recommendations

Another pertinent point to be considered was the complementarity among the identified assessment methods. In terms of the parameters of assessment methods, the outcome from sensor-based assessments and rating scales can quantify axial dysfunctions and limb movements underlying impaired bed mobility in PD that may be helpful for setting goals and detecting changes in physiotherapy. In contrast, the outcome from timed-tests involves whole body movements that cannot of itself indicate motor impairments in PD. To overcome this limitation, we believe that timed-tests should be combined with other validated assessment methods for application in clinical practice, similar to the LPA incorporating a time measure. On the other hand, video capture of timed-tests could undergo pose estimation to capture specific segmental control of the trunk and limbs, allowing for more sensitive measures of bed mobility dysfunction.

In terms of the feasibility issues, the rating scales and timed-tests are relatively simple and easy to administer with little setup or equipment. Thus, they are more practical to

use in clinical practice. On the other hand, sensor-based assessments can be performed in unsupervised environment over a number of days to provide a more holistic view of patients' bed mobility, while rating scales and timed-tests only provide a single-moment snapshot of the patient.

Therefore, taken together, future studies for evaluating impaired bed mobility in PD should consider combining both, the PD-specific rating scales with strong clinimetric properties, as well as unsupervised sensor-based assessment for greater ecological validity. Besides providing a more comprehensive view of bed mobility, these studies will provide insights into the functional correlates of the various outcomes from sensor-based assessment, and aid interpretation of these outcomes.

4.3. Limitation

Although this scoping review applied wider selection criteria, a relatively small number of studies were identified in our results. This paucity of clinimetric evidence is not PD-specific, and has been highlighted in reviews of assessment methods in physiotherapy for stroke (48), respiratory disorders (49), and children (50).

Further work is needed to include new resources, in particular to examine validity and responsiveness on sensor-based assessments and timed-tests for bed mobility in PD.

5. Conclusion

This scoping review identified three types of objective assessment methods of impaired bed mobility, which were mostly sensor-based assessments, followed by rating scales, and timed-tests. Rating scales (M-PAS and LPA) are PD-specific and specifically designed for physiotherapy with adequate clinimetric properties. Although sensor-based

assessment and timed-tests have some benefits for assessing impaired bed mobility in PD (e.g., discriminative ability between PD and healthy controls, high test-retest reliability), they need more extensive clinimetric evaluation. Therefore, the rating scales seem to be the most preferable method for assessing impaired bed mobility in PD in clinical practice, until clinimetric evaluation are adequately demonstrated in the other methods.

Ethical approval

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Declaration of interest

None of the authors has any conflicts of interest to declare.

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Tables

Table 1: Summary of findings for the included studies.

Author, year (Reference)	Sample size (Control) [a] / Ages H&Y (range)	Design	Assessment methods (required equipment/ device name)	Study setting	Sensor location (Monitor duration)	Outcomes measures	Main findings
Rating scales							
Nieuwboer 2000 (30)	PD = 29 mean 64.1 yr H&Y II–III	Cross-sectional	PAS [b] (bed cover)	home		Domains of bed mobility in PAS	PAS was established and ensured its reliability and "on–off" variability.
Nieuwboer 2000 (31)	PD = 33 mean 66.2 yr H&Y II–IV	Prospective longitudinal	PAS [b] (bed cover)	home and hospital		Domains of bed mobility in PAS	A mild improvement in PAS scores was observed during the baseline period at home: bed mobility with cover ($p = 0.03$). None of the baseline increments was significant in the hospital setting.
Keus 2009 (32)	PD = 15 median 68.4 yr H&Y II–IV	Cross-sectional	M-PAS (bed cover)	home		Domains of bed mobility in M-PAS	M-PAS was found to be valid, with good inter-rater reliability, no ceiling effect, and no differences between specialist and non-specialist in PD.
Shujaat 2014 (33)	PD = 48 mean 56 yr H&Y I–III	Prospective longitudinal	M-PAS (bed cover)	hospital		Domain of bed mobility in M-PAS	Bed mobility on the M-PAS scale and rotation showed significant improvements after kayaking exercises and general mobility exercise.
Pearson 2009 (34)	PD = 49 mean 75.8 yr H&Y I–IV	Cross-sectional	LPA (stopwatch)	hospital		Domains of bed mobility in LPA	LPA showed to be valid with good inter-rater reliability.
Verheyden 2014 (35)	PD = 38 (19 controls) mean 69 yr H&Y I–IV	Cross-sectional	LPA (stopwatch)	hospital		Domains of bed mobility in LPA	Bed mobility on the LPA showed good reliability and validity, and discriminative ability between PD and healthy controls.
Spagnuolo 2018 (36)	PD = 30 mean 65.5 yr H&Y I–IV	Prospective longitudinal	LPA (stopwatch)	hospital		Domains of bed mobility in LPA	LPA showed responsiveness to the group physical therapy intervention.
Janssens 2014 (37)	PD = 3 each aged 52, 54, and 70 yr H&Y I–III	Prospective longitudinal (case report)	LPA (stopwatch)	home		Domains of bed mobility in LPA	The case series suggests that bed mobility on the LPA, and the other two scores were improved after LSVT BIG.
Sankarapandiani 2019 (38)	PD = 15 50-60 yr: n = 7 60-70 yr: n = 6 70-75 yr: n = 2 H&Y I–V	Cross-sectional	LPA (stopwatch)	hospital		Domains of bed mobility in LPA and UDPRS motor	Bed mobility on LPA and UPDRS showed significant improvements after intensive bed mobility training.
Sensor-based assessments							

Yoneyama 2013 (19)	PD = 1 (2 controls) aged 60 yr H&Y II	Cross-sectional	Accelerometer (MIMAMORI-gait system, Japan)	home	single sensor on the waist (36 hours)	Angle of turning over	The turnover angle was markedly smaller than the controls and indicated impaired bed mobility in PD patients.
Bhidayasiri 2016 (20)	PD = 6 (6 healthy controls) mean 65.5 yr mean H&Y 2.25	Cross-sectional	Accelerometer and Gyroscope (NIGHT-Recorder, Thailand's National Electronics and Computer Technology Center, Thailand)	home	on the sternum (one night)	Numbers, angle, duration, speed, acceleration of rolling over in bed; numbers of rising from bed	Significantly fewer rolling over, smaller in the position change, slower speed in rolled over, and acceleration in PD group than their spouses. The PD patients showed more numbers of rising from bed than their spouses.
Bhidayasiri 2016 (21)	PD = 10 mean 65.4 yr H&Y 3.25	Cross-sectional	Accelerometer and Gyroscope (NIGHT-Recorder, Thailand's National Electronics and Computer Technology Center, Thailand)	home	on the sternum (over two nights)	number, velocity, acceleration, degree, and duration of rolling over, and number of episodes of getting out of bed	Following nocturnal apomorphine infusion, PD patients showed significant improvements in the number of turning in bed, turning velocity, and the degree of turning
Sringean 2016 (22)	PD = 19 (19 healthy controls) mean 64.6 yr H&Y I–IV	Cross-sectional	Accelerometer and Gyroscope (NIGHT-Recorder, Thailand's National Electronics and Computer Technology Center, Thailand)	home	on the sternum, wrists, and ankles (one night)	Numbers, degree, velocity, acceleration, duration of rolling over; numbers of getting out of bed; limb movements	Fewer instances of rolling over, turning with a smaller degree, lower velocity, and acceleration were observed in the PD group. These PD patients more frequently got out of bed compared to their spouses. There were moderate and significant correlations were observed between the mean duration of rolling over and the UPDRS axial score, and Nocturnal Akinesia Dystonia and Cramp Score.
Sringean 2016 (23)	PD = 18 (18 healthy controls) mean 64.9 yr mean H&Y 2.53	Cross-sectional	Accelerometer and Gyroscope (NIGHT-Recorder, Thailand's National Electronics and Computer Technology Center, Thailand)	home	on the sternum, wrists, and ankles (one night)	Numbers, degree, velocity, acceleration, duration of rolling over; numbers of getting out of bed; limb movements	Significantly fewer rolling over, smaller in the position change, slower speed and acceleration in rolled over in PD group than their spouses. The PD patients showed more numbers of getting out of bed than their spouses. Duration of supine position significantly correlated with the UPDRS axial score, and the degrees of turns in bed.

Bhidayasiri 2017 (24)	PD = 34 mean 60.6 yr H&Y I–IV	Prospective longitudinal	Accelerometer and Gyroscope (NIGHT-Recorder, Thailand's National Electronics and Computer Technology Center, Thailand)	home	on the sternum (two nights)	Numbers, degree, velocity, acceleration of axial turn; numbers of getting out of bed	The rotigotine group showed more numbers and higher degree of turning in bed than the placebo group. There were no significant differences in the mean change in the number of getting out of bed between the rotigotine group and the placebo group.
Bhidayasiri 2017 (25)	PD = 17 (17 healthy controls) mean 64.9 yr mean H&Y 2.59	Cross-sectional	Accelerometer and Gyroscope (NIGHT-Recorder, Thailand's National Electronics and Computer Technology Center, Thailand)	home	on the sternum (two nights)	Numbers, angular displacement, velocity, angular acceleration of turning in bed	PD patients showed fewer number of turns in bed, smaller degree of turning in bed, slower speed, and acceleration than their spouses. There were significant and moderate correlations were observed between the torque of turning in bed and total UPDRS score, akinesia sub-score, disease duration as well as total Nocturnal Akinesia Dystonia.
Xue 2018 (26)	PD = 29 PD with/without impaired bed mobility 68yr/66yr	Cross-sectional	Accelerometer and Gyroscope (Suzhou Institute of Biomedical Engineering and Technology, China)	hospital	on the waist and both wrists and ankles (one night)	Numbers, duration, degrees, velocity, and acceleration of turning over; number of limb movements, and getting out of bed	PD patients with impaired bed mobility tended to have fewer turning-over episodes and smaller degree turns than PD patients without impaired bed mobility. Scores in the Parkinson's Disease Questionnaire related to movement time and turning speed. Scores in the Berg Balance Scale related to time to peak counteraction.
Uchino 2017(27)	PD = 64 Mean 73.3 yr Mean H&Y 3.0	Cross-sectional	Accelerometer (MIMAMORI-gait system, Japan)	hospital	on the abdomen (one night)	Number of turning	Number of turning significantly correlated with disease duration, L-dopa-equivalent dose, media H&Y stages, total score of UPDRS, and positively correlated with scores in Barthel index. Good test-retest reliability for the number of turning was found within 24 hours with ICC=0.737.
Mirelman 2020 (28)	PD = 305 (205 healthy controls) Mean 66.1 yr H&Y I–III	Cross-sectional	Accelerometer and Gyroscope (Axivity AX3, Axivity Ltd, Newcastle, UK or DynaPort MiniMod Module, McRoberts BV, The Hague, Netherlands)	home	on the lower back L4-5 area (two nights)	Number, duration, degree, and velocity of turning in bed	PD patients exhibited longer turn duration with reduced degrees of turning than controls. There were no significant differences in the number of turning at night between PD patients and controls. Nocturnal movements were all significantly correlated with motor severity, rigidity, bradykinesia, and levodopa equivalent daily dose.

Sringean 2020 (29)	PD = 16 (16 healthy controls) mean 61.3 yr mean H&Y 2.53	Cross-sectional	Accelerometer and Gyroscope (NIGHT-Recorder, Thailand's National Electronics and Computer Technology Center, Thailand)	hospital	on the sternum (two hours)	Duration, velocity, and acceleration of turning in bed.	PD patients showed a significant longer duration, slower velocity, and acceleration in turning compared to controls. There were significant and moderate correlations between turning duration and UPDRS motor and axial sub-scores as well as the Nocturnal Hypokinesia Questionnaire.
Timed-tests							
Purser 1999 (18)	PD = 15 (24 healthy controls)[c)] mean 75yr H&Y II–III	Prospective longitudinal	Digital stopwatch	hospital		Movement time	Excellent test-retest reliability (ICC of 0.83 for stand-to-supine, ICC of 0.84 for supine-to-stand) in PD group. Also, within-subject error variance for test-retest reliability was 0.37 for stand-to-supine, and 0.51 for supine-to-stand.
Mount 2009 (16)	PD = 39 (42 healthy controls)[d)] Mean 72.4 yr H&Y I–IV	Cross-sectional	Video	hospital		Movement pattern, movement time	PD patients exhibited significantly slower movement time than healthy control. The most common movement patterns were "come to sit" for the axial region, "multipush" for the near arm, "double-push" for the far arm, and "synchronous" for the legs.
Taniguchi 2022 (17)	PD = 16 (10 healthy controls) mean 73.4 yr H&Y II–V	Cross-sectional	Video	hospital		Movement time, movement pattern, muscle torque in lower extremities, and motor symptom	PD patients showed significantly slower movement time than healthy control. Slower movement time in PD was correlated with reduced hip adductor strength as well as with higher scores in arm rigidity on the more affected side.

Studies are grouped per assessment type as highlighted in bold font. PD: Parkinson's disease; UK: United Kingdom; USA: United States of America; NL: The Netherlands; yr: years old; H&Y: Hoehn & Yahr scale; PAS: Parkinson Activity Scale; M-PAS: Modified Parkinson Activity Scale; LPA: Lindop Parkinson's Assessment Scale;

[a)]: if applicable, [b)]: previous version of M-PAS, [c)]: community-dwelling elders (18), [d)]: the author referred to their previous study of healthy older adults.