Table 1 Summary of technologies assessing bradykinesia in PD offering both home and clinic-based assessment

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from controls (best parameter)	Validation data	Used in other PD studies	Assesses other PD-related features
PKG (Parkinson's Kinetigraph) [1]	Wearable 3-axis iMEMs accelerometer	Continuous (24/7)	34 PD patients and 10 age matched controls	✓	Moderate correlation with UPDRS III ($r = 0.64$, $p < 0.0005$) Bradykinesia measured by algorithm also correlated by bradykinesia measured by dot slide method ($r = 0.63$, $p<0.01$), sensitivity 95%, specificity 88%	Yes [2–6]	LID [1,2] Sleep [3,6] ICBs [5]
AHTD (At Home Testing Device) [7]	Computerized assessment battery	Cross-Sectional	50 early stage PD	N/A	Correlation values N/A for UPDRS Feasibility – overall satisfaction score – 96.5 (out of a total of 100) Compliance – Acceptability ≥90%	Yes [8]	Tremor Speech
Kinesia system [9]	Wearable motion sensor consisting of 3 orthogonal accelerometers and 3 orthogonal gyroscopes	Both continuous (24/7) and Cross-Sectional	42 PD patients	✓	Strong correlation with toe tapping sub-score = ($r = 0.86$) ICC for Kinesia is significantly higher than clinical ratings of FT speed ($p<0.0001$), amplitude ($p<0.0001$) and rhythm ($p<0.05$) [10]	Yes [10–24]	LID [11,12] Gait [9,13] Tremor [14]
Automatic Spiral analysis using touchscreen telemetry device [25]	Touchscreen telemetry device	Cross-Sectional	65 patients with PD and 10 healthy elderly controls	✓ (PC4, $p = 0.001$)	Classification accuracy of 84% and AUC of 0.86 in relation to visual classification by raters	Yes [26–31]	LID

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from controls (best parameter)	Validation data	Used in other PD studies	Assesses other PD-related features
Online BRAIN (BRadykinesia Akinesia INcoordination) tap test [32]	Online FT task through computer keyboard	Cross-Sectional	58 patients with PD and 93 age matched controls	✓ (number of alternate taps in 30 seconds $p = <0.0001$)	3 out 4 parameters correlated with UPDRS III scores (best parameter – number of alternate taps in 30 seconds $r = –0.53$, $p < 0.0001$)	Yes [33–37]	No
CV (Computer vision) motion analysis [38]	Quantitative motion analysis of index fingers along with face detection method	Cross-Sectional	13 PD patients and 6 healthy controls	✓ (average zero crossing rate, $p < 0.0001$)	Guttman correlation with UPDRS-FT subscore = –0.80, $p<0.0001$ Classification accuracy with UPDRS-FT subscore of 88%	Yes [39]	Gait [39]
Microsoft Kinect [40]	Camera-based motion sensor	Cross-Sectional	9 patients with PD and 10 healthy controls	✓	Hand-clasping and pronation-supination measured by the Kinect correlated strongly with the Vicon motion analysis system [Spatial accuracy 0.981 and 0.984 and Temporal accuracy 0.15 and 0.7 respectively]	Yes [41–50]	Rehabilitation through exergaming [41,43,46,51] Gait [42,44,45,47–49]
Smartphone app by Kassavetis et al group [52]	Smartphone application on HTC design smartphone containing tri-axial accelerometer and touch screen technology	Cross-Sectional	14 PD patients	N/A	6 of the 7 parameters correlated significantly (best parameter: finger tapping frequency $r = – 0.75$, $p= 0.001$)	No reports found	Tremor

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from controls (best parameter)	Validation	Used in other PD studies	Assesses other PD-related features
mPower [53]	Smartphone application utilizing inbuilt voice-recorders, accelerometers and touch screen technology	Continuous (four times daily)	10 PD patients and 10 controls	✓ (p<0.001)	Using random forest method, mean error in predicting motor component of UPDRS III was 1.26 UPDRS points (SD 0.16)	Yes [54,55]	Gait and Posture Speech Short-term memory [54]
Low-cost computer peripherals [56]	Force feedback joystick and steering wheel	Cross-Sectional	13 PD patients and 5 controls	✓ (ANOVA p = <0.01)	Capable of differentiating PD patients of varying severity of bradykinesia (p = >0.05 - <0.01)	No reports found	No
Smartphone application by Lee et al group [57]	Smartphone application with timed tapping and rapid alternating movement tests	Cross-Sectional	103 PD patients	N/A	Moderate correlation with upper limb bradykinesia items (best parameter: mean total score for timed tapping test, r = –0.595, p<0.0001) Repeatability – ICC – 0.763, p<0.0001 Over 90% found the application useful based on qualitative assessment for feasibility	N/A	Tremor Cognition
PERFORM system [58,59]	Set of 4 tri-axial accelerometers for each limb, and 1 accelerometer and 1 gyroscope attached at the waist	Continuous (4 hours in the morning and 4 hours in the afternoon)	20 PD patients for short-term recording and 24 PD patients for long-term recording	N/A	74.5% classification accuracy in objectively predicting the MDS-UPRS was obtained for the bradykinesia assessment module, 0.25 mean absolute error	Yes [60–64]	Tremor LID Gait

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from controls (best parameter)	Validation	Used in other PD studies	Assesses other PD-related features
Physilog [65]	Sensors attached to each forearm containing three miniature uni-axial gyroscopes each	Cross-Sectional	1st study 10 PD patients and 10 healthy controls	✓ (Range of rotation of hand in pitch axis, $p = 0.0022$)	1st study strong correlation with UPDRS bradykinesia sub-scores (best parameter: mobility of hand in roll axis, $r = -0.83$, $p < 0.0001$)	Yes [66–73]	Tremor Gait [66–68,73] Motor fluctuations [69]
	ASUR consisting of two two-dimensional gyroscopes	Continuous (24/7)	2nd study 11 PD patients		2nd study strong correlation with UPDRS bradykinesia sub-scores (best parameter for small 5 minute window recording, mobility of hand - $r = -0.74$, $p < 0.01$, whilst for large window size of 40 minutes, activity of hand parameter – $r = –0.80$, $p<0.0003$)		
Computer based assessment tool [74]	Objective assessment tool on a personal computer	Cross-Sectional	10 PD patients and 10 controls	✓ (Time to move between targets $p = 0.038$)	Significant difference was found between PD and control groups based on time taken to move between targets ($p=0.038$). However, no significant difference was observed between the two groups based on accuracy of movements ($p = 0.820$). Marked differences also was noticed between the two groups based on distance analysis in the task	No	Rigidity

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from healthy control	Validation	Used in other PD studies	Assesses other PD-related features
SENSE-PARK system [75]	Set of wearable sensors [Accelerometers and angular rate sensors], Wii balance board, software and smartphone app (PDApp)	Continuous (24/7)	22 PD patients divided into two groups- users and non-users	N/A	All participants (users and non-users) showed willingness to continue the study from visits 1-8 and completed the study. Participants rated the usability of the SENSE-PARK system with a mean score of 2.67(±0.49) on the PPSUQ (Post-Study System Usability Questionnaire)	Yes [76–80]	Gait Tremor Balance Sleep Cognitive function
neuroQWERTY [81]	Computer keyboard	Cross-sectional	Early-PD dataset: 18 early PD patients and 13 healthy spouses as controls De-novo dataset: 24 de-novo PD patients and 30 healthy controls	✓ (nQi $p = 0.001$)	The two subgroups showed a statistically significant difference from the controls (de novo/controls $p = 0.022$, early PD/controls $p = 0.0003$). Correlation of nQi (neuroQWERTY index) with UPDRS part III score $r = 0.50$, $p<0.001$. Using an ensemble regression algorithm, nQi differentiated PD patients from controls with an AUC = 0.81	No	No
3D Depth Sensor [82]	Microsoft 3D camera sensor based on Time of Flight (TOF) technology	Cross-sectional	8 PD patients and 5 healthy controls	✓	80% classification accuracy for hand movements for PD patients using all features and 100% accuracy when using only best predictors 100% classification accuracy for rapid alternating movement test using all features and also when using best predictors 100% classification accuracy for finger tap test	No	No

PD- Parkinson's Disease, iMEMS – Micro-Electro Mechanical System, UPDRS – Unified Parkinson's Disease Rating Scale LID – Levodopa-induced Dyskinesia, PC – Principal Component ICB's –Impulsive-Compulsive Behaviours, N/A – Not available, AUC – Area under the curve, ICC- Intra-class Correlation Coefficient, ASUR – Autonomous Sensing Unit Recorder, ANOVA – Analysis of Variance, FT- Finger Tapping

Table 2 **Summary of technologies assessing bradykinesia in PD offering only clinic/research-facility based assessment**

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from controls (best parameter)	Validation data	Used in other PD studies	Assesses other PD-related features
Smartphone Tapper (SmT) app [83]	Timed tapping task on smartphone application	Cross-Sectional	57 PD patients and 87 controls	✓ (5 parameters having $p<0.0001$)	Significant correlation of median number of taps with total motor MDS-UPDRS Part III score and bradykinesia subscores ($R^2=0.25$-0.32, $p<0.0001$) Significant correlation of mean number of correct tapping (MCoT) with same parameter derived from mechanical tappers	No reports found	No
Tri-axial accelerometer by Jia et al. group [84]	Two ez340 wristwatches having LCD display, 3-axis accelerometer and a pressure sensor	Cross-Sectional	12 patients with PD and 12 non-PD subjects	✓	Correlation data N/A from study	Yes [85]	Medication intake [85]
Nine degrees-of-freedom sensor (9DoF) [86]	9 internal sensors - 3 accelerometers, 3 gyroscopes and 3 magnetic sensors orthogonally aligned to each other	Cross-Sectional	25 PD patients and 10 age matched controls	✓ (toe tapping $p<0.0001$)	Classification errors for finger tapping, dysdiadochokinesis and toe tapping were 15-16.5%, 9.3-9,8% and 18.2-20.2% smaller than average inter-rater scoring error for the MDS-UPDRS	No reports found	No

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from controls (best parameter)	Validation data	Used in other PD studies	Assesses other PD-related features
Alternate tapping performance (ATP) on a handheld computer device [87]	Touch-pad handheld computer	Continuous (4 times per day)	95 patients with PD and 10 healthy elderly controls	✓ (Automated speed score)	Global tapping severity showed strongest correlation with UPDRS III upper limb bradykinesia subscores (r = 0.91) Reliability – Cronbach's α coefficient = 0.75 Sensitivity to change – scores improved on the first test period after LCIG treatment, remaining statistically significant until 24 months (p<0.001) Median compliance- 93%	Yes [28,88]	No
QDG (Quantitative Digitography) [89]	MIDI Piano keyboard	Cross-Sectional	16 PD patients and 11 age matched healthy controls	✓	4 parameters correlated moderately with UPDRS part III bradykinesia subscores (best correlation - coefficient of variation for key strike duration r = 0.67, p<0.001) [90]	Yes [90–93]	Rigidity Arrhythmokinesis [91]
IMU by Djurić-Jovîčić et.al group [94] **Differentiated PSP-R from PD and MSA-P*	Wireless distributed functional electrical stimulation system [95]	Cross-Sectional	13 PD patients, 15 PSP-R patients, 14 MSA-P patients and 14 healthy controls	✓ (12 parameters differentiated, 6 parameters had p= <0.0001)	No correlation between kinematic parameters and total UPDRS and part III scores was seen	Yes [96–101]	Gait [96–99]

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from controls (best parameter)	Validation data	Used in other PD studies	Assesses other PD-related features
CATSYS (Co-ordination ability testing system) [102]	Portable Microsoft-windows based system that consists of a data logger and 4 different types of sensors: a tremor pen, touch recording plate, reaction time handle, and a force plate	Cross-Sectional	44 PD patients and 28 healthy controls	✓ (reaction time $p < 0.009$)	Pronation supination correlated with UPDRS part III body bradykinesia sub-score ($r = -0.41$, $p < 0.014$), finger tapping did not correlate	Yes [103–106]	Tremor [103–106]
Finger tapping movement measurement system [107]	System consists of 2 tri-axial accelerometers, touch sensor, AD converter, and a personal computer	Cross-Sectional	16 PD patients and 27 healthy subjects	✓	Maximum finger tapping contact force showed an inverse relationship with UPDRS FT scores 3 out of 4 parameters showed correlation with UPDRS finger tapping score, highest correlation was seen with MoV (Maximum opening velocity) parameter ($r = -0.59$) [108]	Yes [108]	No

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from controls (best parameter)	Validation data	Used in other PD studies	Assesses other PD-related features
Magnetic detection system [109]	Magnetic induction coil, sensing coil and circuit unit	Cross-sectional	20 PD patients, 6 age matched controls, and 12 normal volunteers	✓ (Average maximum closing velocity, p = <0.01) [110] AUC (0.8835) [111]	Classification accuracy in predicting UPDRS scores- 93.1%±3.69% using 12 LLGMNs [112] Repeatability – 5 parameters with ICC ≥ 0.5 [113]	Yes [110–115]	No
Surface electromyography (SEMG) [116]	Bipolar Surface EMG	Cross-Sectional	19 patients with PD, 20 age matched controls and 20 young control subjects	✓ (p = <0.01-<0.05)	Correlated significantly with UPDRS scores, especially FT (finger tapping) score (p = <0.01-<0.05)	Yes [117–143]	Gait [120–123] RBD [124] Tremor [106,113-117] Dyskinesia [125] Rigidity [132–135] Camptocormia [136] Deglutition [137,138]
Digitomotography using Q-motor [144]	Force transducer with a circular plane contact surface	Cross-Sectional	16 early PD, 17 mid-stage PD, 18 healthy controls	✓ (Tap force, ANOVA p = 0.009)	3 out of 6 parameters correlated weakly with UPDRS III finger tapping (best parameter: inter-peak interval r = 0.16, p < 0.05)	Yes [145]	LID [145]
3D motion analysis system by Codamotion [146] **Can differentiate PSP and PD as well*	Motion analysis system	Cross-Sectional	15 PD patients, 9 PSP patients, and 16 healthy controls	✓ (Amplitude of finger tap and coefficient of variation of cycle duration ANOVA – p= <0.001)	Moderate correlation with significance for 3 variables, best parameter mean amplitude (r = –0.79, p<0.001	Yes [147,148]	Gait [148]

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from controls (best parameter)	Validation	Used in other studies	Assesses other PD-related symptoms
Gyrosensor by Kim et al. group [149]	Gyrosensor	Cross-Sectional	40 PD patients and 14 age matched controls	✓ (all 4 parameters $p<0.001$)	Strong correlation with FT sub-score for all four parameters, best parameter: peak power in the power spectrum of angular velocity ($r = -0.80$, $p < 0.001$)	Yes [150–153]	Gyrosensor used by research group was not used to assess other PD symptoms
Bradykinesia assessment system [154]	IMU- Three axis gyroscope and three axis accelerometer and a command module (micro-controller and a serial USB interface) acquires sensor data and sends them to a computer	Cross-sectional	9 PD patients and 7 healthy controls	✓	2 parameters had strong correlation and 2 had poor correlation with UPDRS bradykinesia score, best parameter: modified mean range ($r = -0.83$, $p<0.001$)	Yes [155–158]	Motor fluctuations [156] Tremor [155,158] Rigidity [157,158]
Bradyapp [159]	Kinematic tasks on application in iPhone device with inbuilt – gyroscope accelerometer, capacitive touch screen, microphone and front facing camera	Cross-sectional	18 PD patients	N/A	Accurate classification between less and more severe motor impairment was not achieved using Bradykinesia Subscore (BSS). However, other features were found to be highly discriminatory (AUC>0.85)	No	No
3D Ultrasonic measurement system [160]	Kinematic motion analysis system (CMS 20S) consisting of measuring sensor , basic unit with power pack together with table-mounted/floor stand [161]	Cross- Sectional	16 right handed PD patients and 12 right handed healthy controls	✓ (peak frequency of the power density spectrum, $p=0.016$)	Correlation between improvement of the UPDRS III after dopaminergic stimulation and changes of peak frequencies and peak power discontinuities was not significant ($p=0.658$)	Yes [162]	No
3D motion capture camera system [163]	2 cameras, 2 Infra-Red (IR) emitters connected to a computer laptop via USB interface	Cross-sectional	22 PD patients and 22 normal controls	✓ (Combination of average opening velocity and decrease in maximal opening distance AUC = 0.94)	Correlation of computer bradykinesia parameter and UPDRS-FT task ($r = 0.75$, $p<0.001$). System functionality verified with the commercial capture system OptiTrack	No reports found	No

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from healthy controls	Validation data	Used in other PD studies	Assesses other PD-related features
Smart glove [164]	Wireless wearable sensor system consisting of 2 touch sensors ,2 3D accelerometers and a force sensor	Cross-Sectional	6 patients with PD and 3 healthy subjects	✓	Patients with bradykinesia had a higher standard deviation and/or average of movement time than healthy subjects	No reports found	Tremor Rigidity
Tri-axial accelerometer based device by Stamatakis et al [165]	4 tri-axial accelerometers	Cross-sectional	36 PD patients and 10 healthy volunteers	✓ (AUC – 0.945)	Predictive performance of model (Goodman-Kruskal Gamma Index-0.961) similar to MDS-UPDRS FT (Finger tapping) scores given my 3 specialists in movement disorders (0.870-0.970)	Yes [166,167]	Gait [167]
ParkDetect [168]	Smartphone application	Cross-sectional	17 PD subjects and 18 healthy subjects	✓	In the spiral analysis part of the application, there was a significant difference between PD and controls. The tapping task was not considered long enough to gather data regarding bradykinesia and number of taps to complete the test should have been higher	No reports found	Tremor Gait and Posture
SMART motion system [169]	3 Infra-Red (IR) cameras that follow 3D displacement of reflective markers taped to the patient's hand	Cross-sectional	25 right handed PD patients (14 E-PD and 11 A-PD) and 20 age and gender matched right handed healthy controls	✓ ($p<0.05$)	Significant differences were observed between HC and E-PD with regards to kinematic variables amplitude, speed and amplitude slope ($p<0.05$), between HC and A-PD with the same kinematic variables ($p<0.05$) and between E-PD and A-PD groups ($p<0.05$) No correlations were found between kinematic variables and MDS-UPDRS Part III bradykinesia sub-scores ($p>0.05$)	Yes [170,171]	Tremor [170]

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from controls (best parameter)	Validation data	Used in other PD studies	Assesses other PD-related features
SensHand V1 wearable device [172]	Miniaturised IMU composed of full 9 axis inertial sensors (accelerometers and gyroscopes)	Cross-sectional	15 patients with PD and 6 healthy controls	✓	Correlation with MDS-UPDRS Part III ($r = 0.87$), MDS-UPDRS I-IV ($r = 0.95$), Hoehn and Yahr Scale ($r = 0.92$), Schwab and England ($r = 0.86$)	Yes [173]	Tremor [173]
Accelerometer by Costa et al [174]	Uni-axial accelerometer	Cross-sectional	33 patients with PD, 18 patients with ET and 21 healthy volunteers	✓ (5 parameters $p< 0.001$)	Weak correlations exist with UPDRS subscores, best parameter: beat decay of the Auto Manual Information (BD-AMI) of FT $r = 0.451$, $p <0.001$. ROC for discriminating between patients and controls was best for BD-AMI of forearm movement 77.4%	No reports found	No
Electromagnetic tracking device [175]	Tracks motion with six degrees of freedom	Cross-sectional	24 patients with PD and 16 age matched healthy controls	✓	Significant correlations between amplitude and UPDRS-III ($r = 0.467$, $p = 0.02$), but not between speed and motor section of UPDRS ($r = 0.272$, $p = 0.20$) in the 'off state'. Raw correlations were not significant for the H&Y and S&E scales in the off state as well.	Yes [176–178]	Tremor [176–178]
Synertial motion capture system [179]	Motion capture suit and IMU (3D gyroscopes, 3D accelerometers and 3D magnetometers)	Cross-sectional	13 PD participants and 10 healthy controls	✓ (bradykinesia index $p = 0.018$)	Separated PD population with and without bradykinesia ($p <0.001$) Significant correlation of bradykinesia index with pronation supination subscore of UPDRS ($r = -0.626$, $p = 0.001$)	Yes [180]	No

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from healthy controls	Validation data	Used in other PD studies	Assesses other PD-related features
MotionMonitor magnetic tracking system [181]	6 degrees of freedom electromagnetic measurement system	Cross-sectional	10 PD patients with mild-moderate LID, 10 non-dyskinetic PD patients and 10 age and gender matched healthy controls	✓ ($p<0.05$)	Significant difference was observed between controls and PD patient group (those with LID and non-dyskinetic) with regards to rapid alternating movement (RAM) characteristics of range and velocity ($p<0.05$). Significant difference was already observed between PD patients with LID and non-dyskinetic subjects (controls and PD) with regards to irregularity RAM characteristic ($p<0.05$)	Yes [182–184]	LID [181,184]
Forearm pronation and supination motor tasks (FPSMT) utilising a smartphone [185]	Tri axial accelerometer sensors built into an android smartphone	Cross-sectional	6 PD patients, 9 healthy and age matched controls and 18 healthy young controls	N/A	100% sensitivity and 88.8% specificity of the bradykinesia assessment algorithm assessed by comparing results to UPDRS bradykinesia subscores	No	Resting tremor Rigidity Postural disturbance
Body sensor network (BSN) [186]	Two shimmer nodes – one per thigh consisting of a tri-axial accelerometer, gyroscope and magnetometer	Cross-sectional	24 PD patients	N/A	Various classification systems for automatic UPDRS evaluation have been carried out – NCC (Nearest Centroid Classifier) and *k*NN (*k* Nearest Neighbours). Precision, Sensitivity and Specificity for the leg agility task is 34.55%, 25.17%, and 84.52% respectively [187] Correlation between mean UPDRS scores and right leg agility task ($r = 0.82$, $p\leq0.05$) and left leg agility task ($r = 0.87$, $p\leq0.05$) [187]	Yes [187–189]	Gait [187,189]

Technology	Specifications	Type of assessment	Sample size	Differentiates PD from healthy controls	Validation data	Used in other PD studies	Assesses other PD-related features
Motus motion analysis system [93]	Motion analysis system with angular velocity sensors. Sensors consist of vibrating quartz crystals that act like solid-state gyroscopes [190]	Cross-sectional	20 patients with early stage, untreated PD and 19 controls	Less affected side of PD and non-dominant side of controls ($p>0.05$) More affected side of PD and non-dominant side of controls ($p<0.001$)	Root mean square of the forearm angular velocity data (V_{rms}) was significantly worse on the more affected side of PD when compared to the less affected side ($p<0.005$) Significant correlations were obtained between more affected side V_{rms} scores and UPDRS part III ($r = -0.51$, $p<0.001$), and between less affected side scores and UPDRS part III ($r = -0.69$, $p<0.001$) [92]	Yes [92,190–196]	Dyskinesia [191] Tremor [192]
Window-based genetic programming classifiers [197]	Polhemus Patriot electromagnetic motion tracking device and IRCGP	Cross-sectional	49 PD patients and 41 age matched controls	✓ (AUC = 0.92)	Evolved classifier achieved an AUC of 0.92, Mean closing deceleration AUC (patients/controls) 0.84, Mean amplitude AUC 0.78, Mean speed AUC 0.74	Yes [198,199]	No

UPDRS – Unified Parkinson's Disease Rating Scale, PD – Parkinson's Disease, RBD – Rapid Eye Movement Sleep Behaviour Disorder, LID- Levodopa-Induced Dyskinesia, IMU – Inertial Measurement Unit, MIDI – Musical Instrument Digital Interface, LLGMNs – Log Linearized Gaussian Mixture Networks, ICC – Intra-class Correlation Coefficient, AUC – Area under the curve, EMG- Electromyography, ANOVA- Analysis of Variance, ROC- Receiver Operating Characteristic, N/A – Not available, FT- Finger Tapping, HC – Healthy Controls , E-PD – Early Parkinson's Disease , A-PD – Advanced Parkinson's Disease , H&Y scale– Hoehn and Yahr scale, S&E scale – Schwab and England scale, IRCGP – Implicit context representation of Cartesian genetic programming

Final search query

IEEE Xplore database – Advanced search option

1) PD (OR) Parkinson (OR) Parkinson's (OR) Parkinsonian – Metadata only; refined by 2006-2017
2) bradykinesia (OR) hypokinesia (OR) akinesia (OR) slowing (OR) finger tapping (OR) pronation (OR) supination (OR) leg agility (OR) toe tapping – Metadata only; refined by 2006-2017
3) technology (OR) wearable (OR) smartphone (OR) gyroscope (OR) accelerometer (OR) sensor (OR) mobile (OR) tool (OR) device – Metadata only; refined by 2006-2017
4) Combing search sets 1, 2, 3 using AND function to yield final search query - **((((((Parkinson) OR Parkinson's) OR PD) OR Parkinsonian) refined by: Year:2006-2017)) AND ((((((((((technology) OR wearable) OR smartphone) OR gyroscope) OR accelerometer) OR sensor) OR mobile) OR tool) OR device) OR computer) refined by:Year:2006-2017)) AND ((((((((bradykinesia) OR akinesia) OR hypokinesia) OR slowing) OR finger tapping) OR pronation) OR supination) OR leg agility) OR toe tapping) refined by:Year:2006-2017)**

Web of Science database – Advanced search option

1) TS = (PD OR Parkinson* OR Parkinson's* OR Parkinsonian*)
   Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC
   Timespan=2006-2016
2) TS = (bradykinesia* OR hypokinesia* OR akinesia* OR slowing* OR finger tapping* OR pronation* OR supination* OR leg agility* or toe tapping*)
   Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC
   Timespan=2006-2016
3) TS = (sensor* OR sensors* OR wearable* OR device* OR devices* OR tool* OR tools* OR smartphone* OR mobile* OR application* OR applications* OR gyrosensor* OR accelerometer* OR technology* OR technologies* OR computer* OR keyboard*)
   Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC
   Timespan=2006-2016
4) Search sets 1, 2 and 3 combined using AND function under search history

Scopus database – Advanced search option

1) TITLE-ABS-KEY (PD OR Parkinson's OR Parkinson OR Parkinsonian) AND PUBYEAR > 2005

2) TITLE-ABS-KEY (bradykinesia OR hypokinesia OR slowing OR akinesia OR "finger tapping" OR supination OR pronation OR "leg agility" OR "toe tapping") AND PUBYEAR > 2005

3) TITLE-ABS-KEY (sensor OR sensors OR wearable OR device OR devices OR technology OR technologies OR gyrosensor OR accelerometer OR smartphone OR mobile OR application OR tool OR tools OR applications OR computer OR keyboard) AND PUBYEAR > 2005

4) Combine search sets 1 AND 2 AND 3 – Final search query - **(TITLE-ABS-KEY (PD OR Parkinson's OR Parkinson OR Parkinsonian) AND PUBYEAR > 2005) AND (TITLE-ABS-KEY (bradykinesia OR hypokinesia OR slowing OR akinesia OR "finger tapping" OR supination OR pronation OR "leg agility" OR "toe tapping") AND PUBYEAR > 2005) AND (TITLE-ABS-KEY (sensor OR sensors OR wearable OR device OR devices OR technology OR technologies OR gyrosensor OR accelerometer OR smartphone OR mobile OR application OR tool OR tools OR applications OR computer OR keyboard) AND PUBYEAR > 2005)**

Engineering Village (Compendex and Inspec)

1) (((((PD) WN All fields) OR ((Parkinson) WN All fields)) OR ((Parkinson's) WN All fields)) OR ((Parkinsonian) WN All fields))

2) ((((((((bradykinesia) WN All fields) OR ((akinesia) WN All fields)) OR ((hypokinesia) WN All fields)) OR ((slowing) WN All fields)) OR ((finger tapping) WN All fields)) OR ((pronation) WN All fields)) OR ((supination) WN All fields)) OR ((leg agility) OR ((toe tapping)) WN All fields))

3) ((((((((((((wearable) WN All fields) OR ((technology) WN All fields)) OR ((accelerometer) WN All fields)) OR ((tool) WN All fields)) OR ((sensor) WN All fields)) OR ((device) WN All fields)) OR ((gyroscope) WN All fields)) OR ((smartphone) WN All fields)) OR ((application) WN All fields)) OR ((technologies) WN All fields)) OR ((mobile) WN All fields)) OR ((computer) WN All fields))

4) ((((($PD) WN ALL) OR (($Parkinson) WN ALL)) OR (($Parkinson's) WN ALL)) AND (2006-2017 WN YR)) AND ((((($bradykinesia) WN ALL) OR (($akinesia) WN ALL)) OR (($hypokinesia) WN ALL)) AND (2006-2017 WN YR)) AND ((((($wearable) WN ALL) OR (($technology) WN ALL)) OR (($accelerometer) WN ALL)) AND (2006-2017 WN YR))

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PRISMA-P checklist

Section and topic	Item No	Checklist item	Page number
Administrative information			
Title	1a	Identify the report as a protocol of a systematic review	1
Update	1b	If the protocol is for an update of a previous systematic review, identify as such	Not an update
Registration	2	If registered, provide the name of the registry (such as PROSPERO) and registration number	Not registered since data extraction occurred prior to registration of study
Authors: Contact	3a	Provide name, affiliation, email-address of all protocol authors; provide physical mailing address of corresponding author	1
Contributions	3b	Describe contributions of protocol authors and identify the guarantor of the review	23
Amendments	4	If the protocol represents an amendment of a previously completed or published protocol, identify as such and list changes; otherwise state plan for documenting important protocol amendments	Not an amendment
Support Sources Sponsor Role of sponsor or funder	 5a 5b 5c	 Identify sources of financial or other support for review Provide name for review funder and/ or sponsor Describe role of sponsor(s), funder(s), and/or institution(s), if any, in developing the protocol	 N/A N/A N/A

Section and topic	Item No	Checklist item	Page number
Introduction			
Rationale	6	Describe the rationale for the review in the context of what is already known	4
Objective	7	Provide an explicit statement of the question(s) the review will address with reference to participants, interventions, comparators, and outcomes (PICO)	5
Methods			
Eligibility criteria	8	Specify the study characteristics (such as PICO, study design, setting, time frame) and report characteristics (such as years considered, language, publication status) to be used as criteria for the eligibility of the review	7,8
Information sources	9	Describe all intended information sources (such as electronic databases, contact with study authors, trial registers, or other grey literature sources) with planned dates of coverage	6
Search strategy	10	Present draft of search strategy to be used for at least one electronic database, including planned limits, such that it could be repeated	7, S1 file page 15-17
Study records: Data management	11a	Describe the mechanism(s) that will be used to manage records and data throughout the review	8,9
Selection process	11b	State the process that will be used for selecting studies (such as two independent reviewers) through each phase of the review (that is screening, eligibility, and inclusion in meta-analysis	6,11
Data collection process	11c	Describe planned method of extracting data from reports (such as piloting forms, done independently, in duplicate), any processes for obtaining and confirming data from investigators)	8,9

Section and topic	Item No	Checklist item	Page number
Data items	12	List and define all variables for which data will be sought (such as PICO items, funding sources), any pre-planned assumptions and simplifications	8,9
Outcomes and prioritization	13	List and define all outcomes for which data will be sought, including prioritization of main and additional outcomes, with rationale	8,9
Risk of bias in individual studies	14	Describe anticipated methods for assessing risk of bias of individual studies, including whether this will be done at the outcome or study level, or both; state how this information will be used for data synthesis	9
Data synthesis	15a	Describe criteria under which data will be quantitatively synthesised	-
	15b	If data are appropriate for quantitative synthesis, described planned summary measures, methods of handling data and methods of combining data from studies, including any planned exploration of consistency	-
	15c	Describe any proposed additional analyses (such as sensitivity or subgroup analyses, meta-regression)	Not applicable
	15d	If quantitative synthesis not planned, describe the type of summary planned	-
Metabias(es)	16	Specify any planned assessment of meta-bias(es) such as publication bias across studies, selective reporting within studies	-
Confidence in cumulative evidence	17	Describe how the strength in the body of evidence will be assessed	-