Gait and Postural Control in Parkinson's Disease

Wearable Devices and New Technologies

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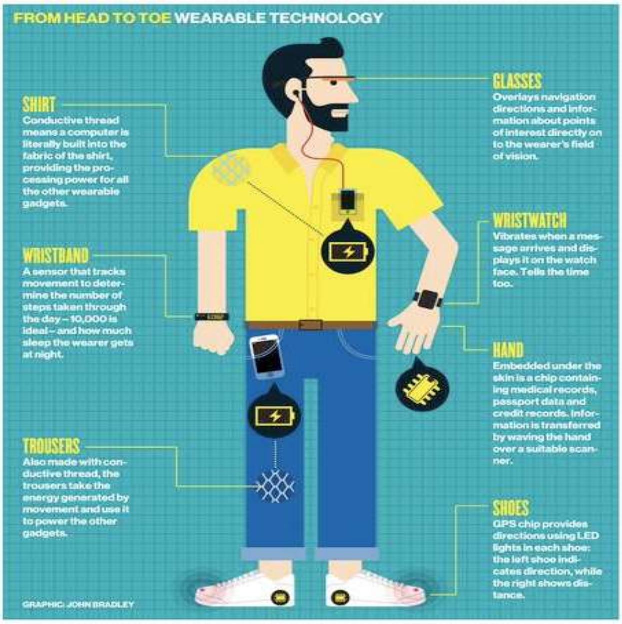
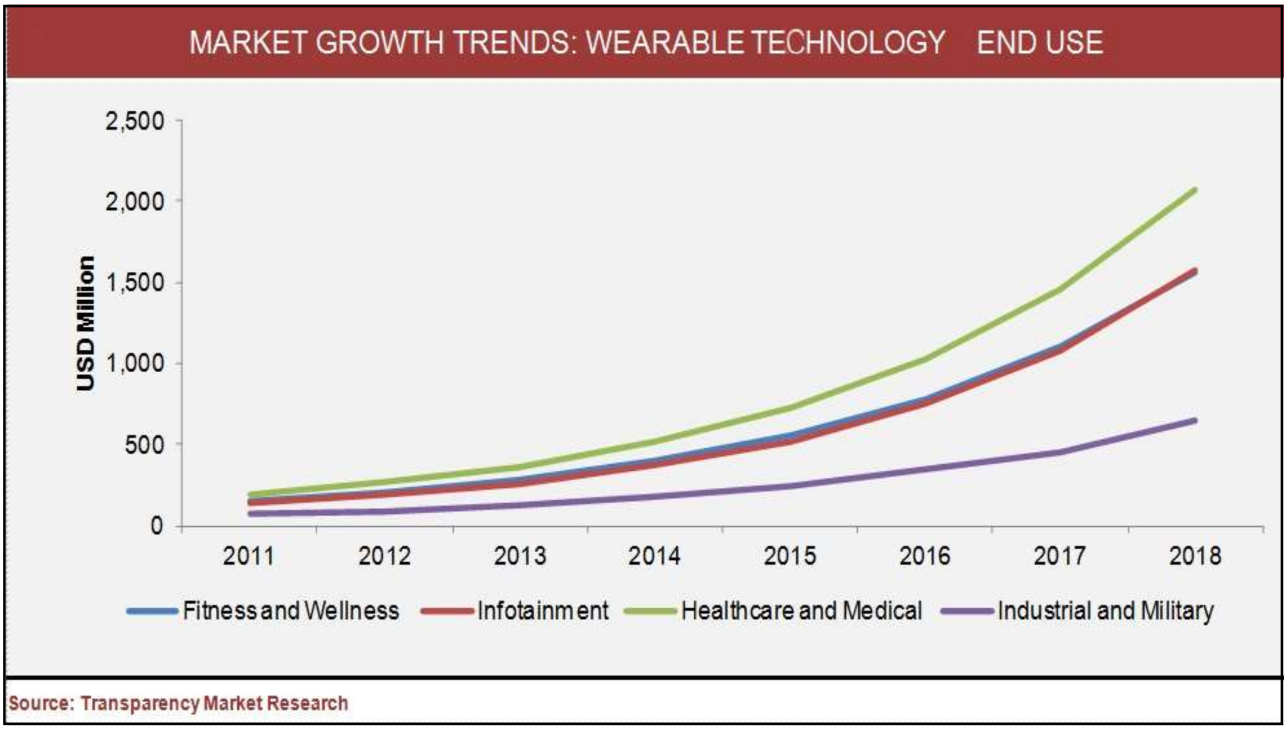
Wearable Devices and New Technologies ?

Wearable device as an electronic device that is **small**, **easily** and **comfortably** worn for **extended periods** on some part of the body.

Contains digital sensors measuring particular physical parameters such as **acceleration, light flux, sound, pressure, skin temperature, blood pressure** (…).

"Quasi-wearable" are considered devices such as smartphones within this definition (Apps).





Wearables Devices: Identify needs

- **Medical practice** aspires to diagnose patients at the earliest of clinical signs, to monitor disease progression, and to rapidly find optimal treatment strategies.
- **Clinical scientists** and **drug developers** seek to enroll large numbers of participants in trials with minimal cost and effort to maximize the scientific validity of studies.
- **Patients** wish to increase their quality of life while reducing physical clinic visits, and
- **Patient care** seeks to minimize reliance on the clinic and transition into patients' homes.

Ken J. Kubota, 2016

Wearable Devices: Why the need?

Studies…

REVIEW

New Methods for the Assessment of Parkinson's Disease (2005 to 2015): A Systematic Review

Álvaro Sánchez-Ferro, MD, MSc,[1,2*] Morad Elshehabi, MD, MSc,[3,4] Catarina Godinho, PhD,[5,6,7] Dina Salkovic, MD, MSc,[3,4] Markus A. Hobert, MD,[3,4] Josefa Domingos, MSc,[5,7] Janet MT. van Uem, MSc,[3,4] Joaquim J. Ferreira, MD, PhD,[5,7,8] and Walter Maetzler, MD[3,4]

June 2016

TABLE 1. New technologies for the assessment of Parkinson's disease (NAM-PD) published during the past decade (2005-2015) by disease domain

Domain	Number of references describing the NAM-PD (% of all included)
Motor	504 (85.7)
Axial features	212 (36.1)
Bradykinesia	126 (21.4)
Tremor	81 (13.8)
Speech	42 (7.1)
Activity	32 (5.4)
Rigidity	11 (1.9)
Nonmotor[a]	24 (4.1)
Cognition	12 (2.0)
Sleep	9 (1.5)
ANS	2 (0.3)
Neuropsychiatric features	1 (0.2)
Smell	0 (0.0)
Treatment complications	20 (3.4)
Miscellaneous	40 (6.8)
Total, included in the results	588
Not included in the full evaluation process[b]	260
Total number of references evaluated	848

"Sensors - Wearable device" ?

SPDMov

Sensor Characteristics

	ACCELEROMETERS (2)	GYROSCOPE	MAGNETOMETER
Axes	3 axes	3 axes	3 axes
Range	± 16g, ± 200g	± 2000 deg/s	± 8 Gauss
Noise	120 µg/√Hz, 5 mg/√Hz	0.025 deg/s/√Hz	2 mGauss/√Hz
Sample Rate[1]	20 to 200 Hz	20 to 200 Hz	20 to 200 Hz
Bandwidth	50 Hz	50 Hz	32.5 Hz
Resolution	14 bits, 17.5 bits	16 bits	12 bits

[1] Adjustable, up to 24 Opals

Opal - Mobility Lab (APDM)

GAIT ANALYSIS

SPDMov

MEASURES

Lower Limb

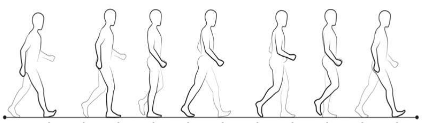
Cadence
Foot Clearance
Gait Cycle Duration
Gait Speed
Double Support
Terminal Double Support
Lateral Step Variability
Circumduction
Dorsiflexion
Plantarflexion
Stance
Step Duration
Stride Length
Swing
Toe Out Angle
Stride Length Variability

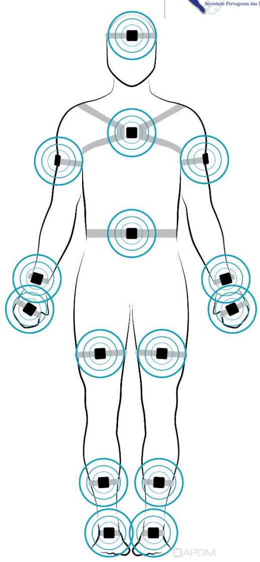
Upper Limb

Arm Swing Velocity
Arm Range of Motion

Anticipatory Postural Adjustment

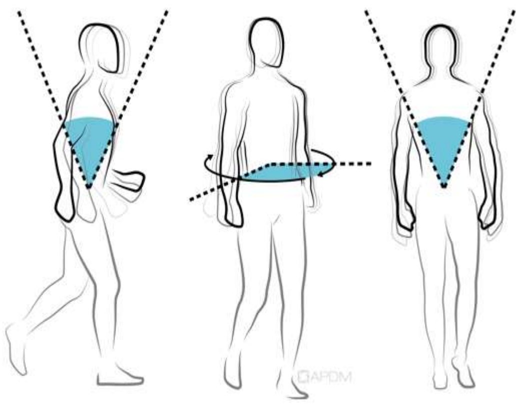
APA Duration
First Step Duration
First Step Range of Motion
Sagittal APA Peak
Coronal APA Peak





Opal - Mobility Lab (APDM)

BALANCE



MEASURES

Trunk

Coronal Range of Motion
Sagittal Range of Motion
Transverse Range of Motion

Lumbar

Coronal Range of Motion
Sagittal Range of Motion
Transverse Range of Motion

Turning

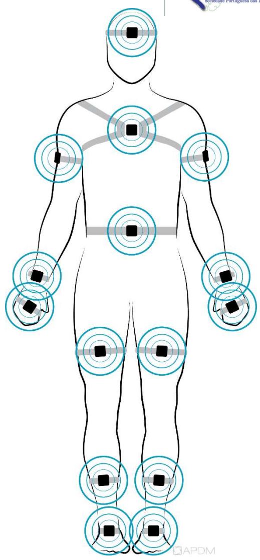
Angle
Duration
Turn Velocity
Steps in Turn

Sit to Stand

Lean Angle
Duration

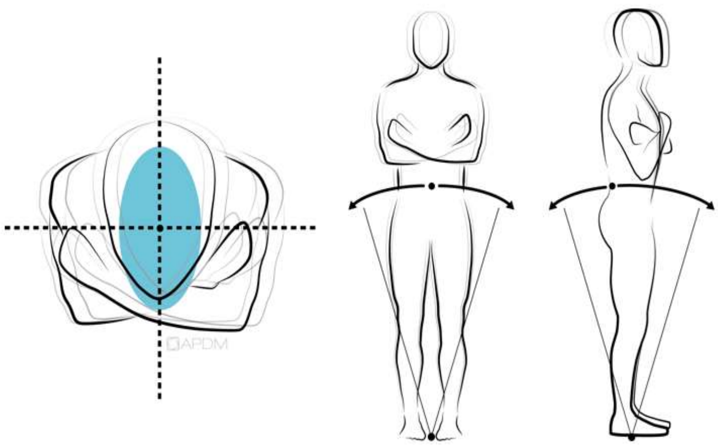
Stand to Sit

Lean Angle
Duration



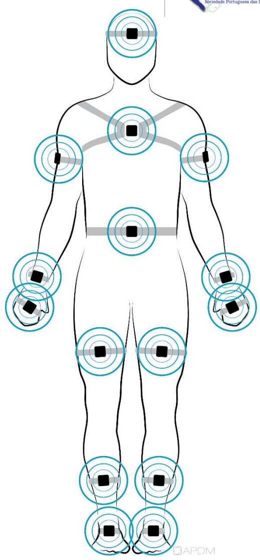
Opal - Mobility Lab (APDM)

POSTURAL SWAY



MEASURES

95% Ellipse Sway Area
RMS Sway
Centroidal Frequency
Frequency Dispersion
Jerk
Mean Velocity
Path Length
Range



Opal - Mobility Lab (APDM)

FULL-BODY KINEMATICS

Neck

Flexion-Extension
Lateral Bending
Rotation

Clavicle

Elevation-Depression
Protraction-Retraction
Anterior-Posterior Rotation

Trunk

Flexion-Extension
Lateral Bending
Rotation

Shoulder

Flexion-Extension
Abduction-Adduction
Internal-External Rotation

Elbow

Flexion-Extension
Supination-Pronation

Wrist

Flexion-Extension
Ulnar-Radial

Lumbar

Flexion-Extension
Lateral Bending
Internal-External Rotation

Hip

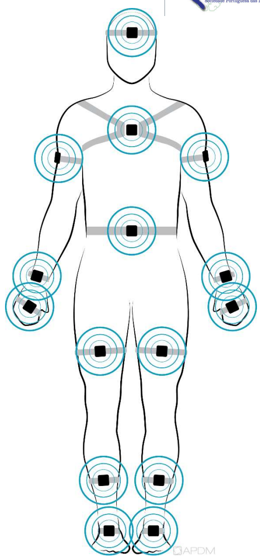
Flexion-Extension
Abduction-Adduction
Internal-External Rotation

Knee

Flexion-Extension
Varus-Valgus
Internal-External Rotation

Ankle

Dorsiflexion-Plantarflexion
Inversion-Eversion
Rotation



Opal - Mobility Lab (APDM)

Movement Disorders Society Task Force on Technology

REVIEW

Technology in Parkinson's Disease: Challenges and Opportunities

Alberto J. Espay, MD, MSc,[1*] Paolo Bonato, PhD,[2] Fatta B. Nahab, MD,[3] Walter Maetzler, MD,[4,5]
John M. Dean, MA, CCC-SLP,[6] Jochen Klucken, MD,[7] Bjoern M. Eskofier, PhD,[8] Aristide Merola, MD, PhD,[9]
Fay Horak, PhD,[10,11] Anthony E. Lang, MD, FRCPC,[12] Ralf Reilmann, MD, PhD,[13,14,15] Joe Giuffrida, PhD,[16]
Alice Nieuwboer, PhD,[17] Malcolm Horne, MBBS, MD,[18] Max A. Little, PhD,[19,20] Irene Litvan, MD,[3] Tanya Simuni, MD,[21]
E. Ray Dorsey, MD, MBA,[22] Michelle A. Burack, MD,[22] Ken Kubota, BS, SEP,[23] Anita Kamondi, MD, PhD,[24]
Catarina Godinho, PhD,[25] Jean-Francois Daneault, PhD,[2] Georgia Mitsi, PhD, MBA, MSc,[26] Lothar Krinke, PhD,[27]
Jeffery M. Hausdorff, PhD,[28] Bastiaan R. Bloem, MD, PhD,[29] and Spyros Papapetropoulos, MD, PhD,[30]
on behalf of the Movement Disorders Society Task Force on Technology

Volume 31, Issue 9Pages 1257-1429, e1-e13, September 2016 Mini-Series:
Advances in Sensor and Wearable Technologies for Parkinson's Disease

What we expect form wearables?

We expect solutions to provide:

(1) **Valid** and **accurate** results, that contribute to an ecologically **effective therapeutic decision** (by influencing the HrQoL of the patient),
(2) Adequate information about a **treatment response** or **disease course,**
(3) **Easy** and **repetitive** use for medical staff and/or PD patients.

Validity…

Godinho *et al. Journal of NeuroEngineering and Rehabilitation* (2016) 13:24
DOI 10.1186/s12984-016-0136-7

Journal of NeuroEngineering and Rehabilitation

REVIEW Open Access

CrossMark

A systematic review of the characteristics and validity of monitoring technologies to assess Parkinson's disease

Catarina Godinho[1,3,4], Josefa Domingos[1,4], Guilherme Cunha[2], Ana T. Santos[1], Ricardo M. Fernandes[1,2], Daisy Abreu[1], Nilza Gonçalves[1], Helen Matthews[5], Tom Isaacs[5], Joy Duffen[5], Ahmed Al-Jawad[6], Frank Larsen[7], Artur Serrano[7], Peter Weber[8], Andrea Thoms[8], Stefan Sollinger[9], Holm Graessner[10], Walter Maetzler[11] and Joaquim J. Ferreira[1,2,4*]

Validity…

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Devices were classified in order of recommendation based on the following criteria: (1) having been used in the assessment of PD symptoms and signs; (2) having been used by people other than the developers (Yes/No); and (3) having had successful reported clinimetric testing (Yes/No). The devices were classified as "recommended" if they met three criteria, "suggested" if they met only two of the criteria or "listed" if they met one criterion only [3].

Validity…

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Results: Seventy-three devices were identified, 22 were wearable, 38 were non-wearable, and 13 were hybrid devices. In accordance with our classification method, 9 devices were 'recommended', 34 devices were 'suggested', and 30 devices were classified as 'listed'. Within the wearable devices group, the Mobility Lab sensors from Ambulatory Parkinson's Disease Monitoring (APDM), Physilog®, StepWatch 3, TriTrac RT3 Triaxial accelerometer, McRoberts DynaPort, and Axivity (AX3) were classified as 'recommended'. Within the non-wearable devices group, the Nintendo Wii Balance Board and GAITRite® gait analysis system were classified as 'recommended'. Within the hybrid devices group only the Kinesia® system was classified as 'recommended'.

Sensor-based gait analysis …

Despite the large number of studies that have investigated the use of wearable sensors to detect **gait disturbances** such as **freezing of gait** and **falls**, there is little consensus regarding **appropriate methodologies** for how to optimally apply such devices.

Gait analysis has reached the state of **validated parameters** that can serve as surrogate markers for **therapeutic effects** or as measures of **disease progression**; however, a validated improvement of the **direct effect on therapeutic decisions** remains to be shown.

Lima A. et al, 2017

In Home-based care…

REVIEW

Free-Living Monitoring of Parkinson's Disease: Lessons From the Field

Silvia Del Din PhD,[1] Alan Godfrey PhD,[1] Claudia Mazzà PhD,[2,3] Sue Lord PhD,[1] and Lynn Rochester PhD[1*]

[1]*Institute of Neuroscience, Newcastle University Institute for Ageing, Clinical Ageing Research Unit, Campus for Ageing and Vitality, Newcastle University, Newcastle upon Tyne, UK*
[2]*Department of Mechanical Engineering, The University of Sheffield, Sheffield, UK*
[3]*INSIGNEO Institute for In Silico Medicine, The University of Sheffield, Sheffield, UK*

Del Din S, et al., (2016)

In Home-based care…

Ambulatory activity provides a picture of the **true burden of disease** and **therapeutic efficacy**.

Macro outcomes can be derived from physical activity such as intensity of movement (energy expenditure), temporal periods (bouts) of ambulatory activity (bouts of walking), and sedentary behaviors that are quantified.

Free-living gait characteristics **(micro outcomes)** showed **better discriminative validity** than those collected in the laboratory.

Lord S, et al., (2013); van Nimwegen M, (2010)

Limitations…

- **Lack of compatibility** among wearable systems

- Data collected in the home and community settings using sensors **do not always** provide **sufficient information** to achieve a **reliable clinical assessment** of motor symptoms:

"…Slowness of movement (bradykinesia) or the result of fatigue or other factors (eg, fear of falling)…"

- The resolution of sensors is restricted to the **anatomical area** on which they are applied, which may yield **low quantitative agreement** with the wider range of motor disability, quality of life, and other measurable patient relevant endpoints.

Ellis T, et al (2011); Berganzo K, et al (2014)

Limitations…

- **Lack of motivation** to use wearables/self monitoring systems should not be underestimated, particularly in the absence of meaningful feedback provided to their users.
- Patient and caregiver **engagement** with wearable and mobile technology is modest.
- Because these technologies have only really matured in the last 10 years, they are unlikely to have formed **part of the traditional training** of clinicians and clinical researchers.

Ken J. Kubota, 2016

Next Steps…

Applied to all areas of measurement:

(1) Clear **definitions** of the **clinical feature** of interest,

(2) **Validation** of real-world data and technical challenges (algorithms),

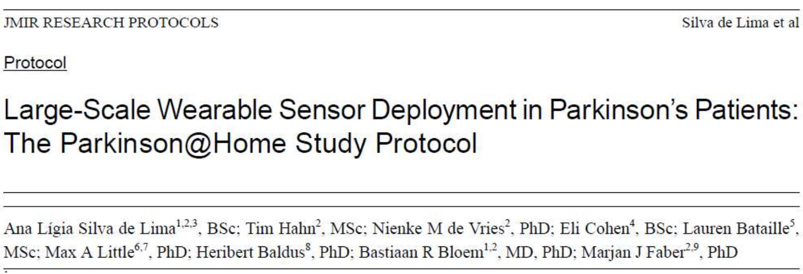
(3) Consensus on outcomes.

Next Steps…

Technologies will need to be:

(1) Developed as **open platforms** and **integrated** with electronic medical record systems.
(2) Suitable for the acquisition of data that captures **motor** and **nonmotor** phenomena.
(3) **Integrated in treatment** delivery systems - Closed-Loop (Feedback) Systems.
(4) Secure about **privacy** issues.

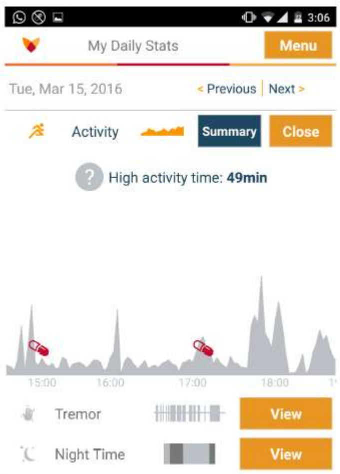
Next Steps…


JMIR RESEARCH PROTOCOLS Silva de Lima et al

Protocol

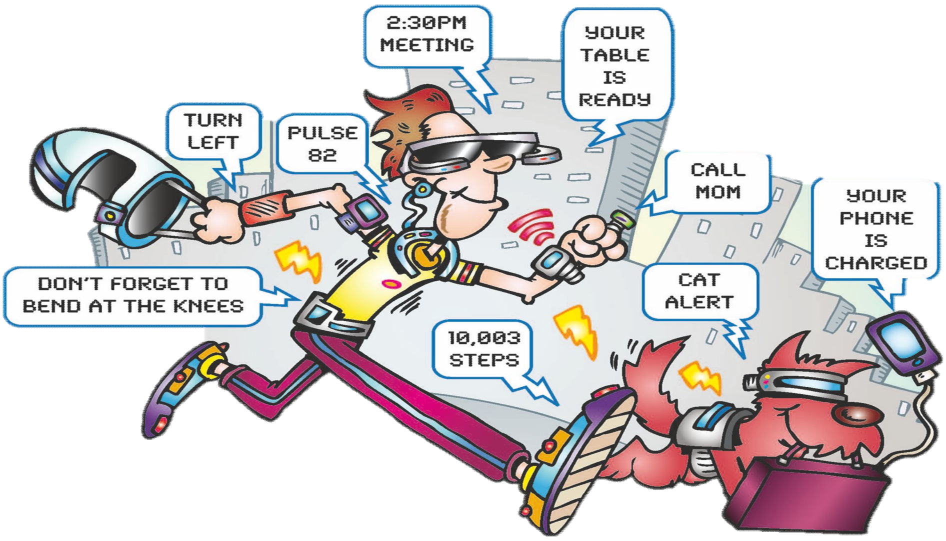
Large-Scale Wearable Sensor Deployment in Parkinson's Patients: The Parkinson@Home Study Protocol

Ana Lígia Silva de Lima[1,2,3], BSc; Tim Hahn[2], MSc; Nienke M de Vries[2], PhD; Eli Cohen[4], BSc; Lauren Bataille[5], MSc; Max A Little[6,7], PhD; Heribert Baldus[8], PhD; Bastiaan R Bloem[1,2], MD, PhD; Marjan J Faber[2,9], PhD



Fox Insight Mobile App activity graph.

2016



Keep pushing forward …