Quantitative Gait Analysis

Falls, Frailty, Polypharmacy and Sarcopenia Seminar
Feb 1st 2019

Tim Foran
Medical Physics and Bioengineering Dept.
St. James's Hospital

"Measure what can be measured, and make measurable what cannot be measured."
Galileo Galilei (1564-1642)

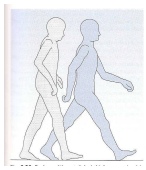
http://brunelleschi.imss.fi.it/itinerari/galleria/TribunaGalileo_344.html, Public Domain, https://commons.wikimedia.org/w/index.php?curid=6581212

"What gets measured gets managed."
Peter Drucker

How do we measure dynamic stability in gait, in a clinically meaningful way?

'despite the extensive effort in the area there is no accepted quantitative way to judge or score the dynamic stability of human locomotion.

The process of determining the stability of particular patients still hinges on the personal observations and past experience of the involved team members'



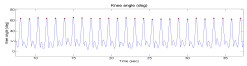
Adapted from Whittle. *Gait analysis.*

Hurmuzlu Y, Basdogan C. *On The Measurement Of Dynamic Stability Of Human Locomotion*. Journal of Biomechanical Engineering-Transactions of the ASME. 1994;116:30-6.

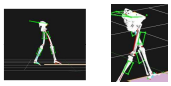
Quantitative gait analysis

Spatio-temporal parameters of gait

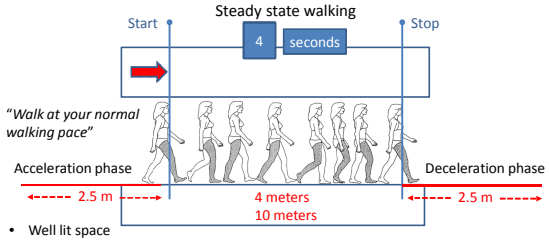
Body worn sensor technology



3-D Laboratory Gait Modelling



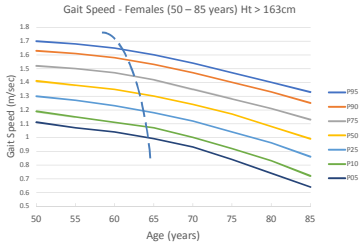
Gait speed
Distance (m) / Time (sec)



- Well lit space
- Uninterrupted walkway
- Comfortable (low heel) walking shoes

Lindemann et al. *Distance to achieve steady state walking in frail elderly persons.* Gait and Posture, 2008, 27(1): 91-96.

Normative values for gait speed (www.tilda.tcd.ie)



Kenny et al. *Normative Values of Cognitive and Physical Function in Older Adults: Findings from The Irish Longitudinal Study on Ageing.* Journal of the American Geriatric Society, 2013, S279 – S290.

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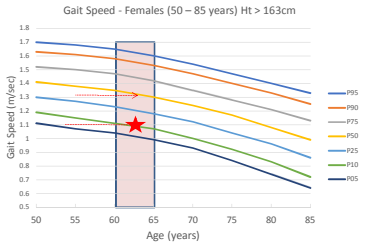

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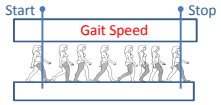
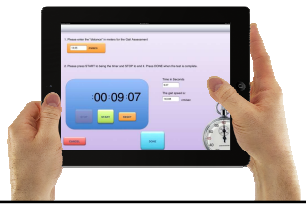
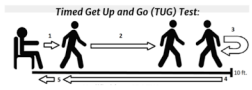
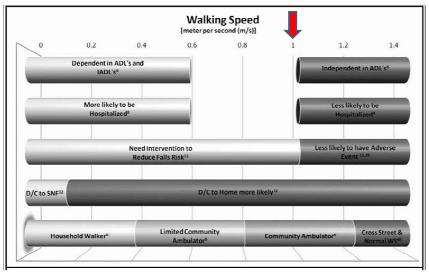
There's an app for that!!





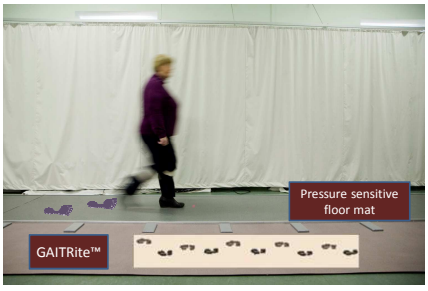


Gait speed and independent living

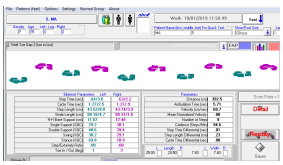


Fritz et al. "Walking speed: the sixth vital sign". Journal of Geriatric Physical Therapy. 32:2:09

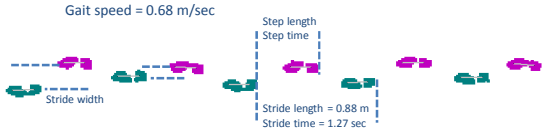
Measuring gait speed using floor mat technology



GAITRite™



Gait speed = 0.68 m/sec



Beauchet et al. *Guidelines for assessment of gait and reference values for spatiotemporal gait parameters in older adults: The Biomathics and Canadian Gait consortiums initiative.* Frontiers in Human Neuroscience, 2017, 11, 353.

Gait Assessment – Minimum data set

Demographics Age: Sex: Ethnicity:
Clinical characteristics Ht: Wt: Medications: >3 (coded yes/no) Hx of falls: (previous 12 mths coded yes/no) Neurological disease: Dementia (yes/no) Other (yes/no) Depressive symptoms: (yes/no) Anxiety symptoms: (yes/no) Major orthopaedic diagnosis: (yes/no) Vision disorder: (yes/no) Lower limb proprioception disorder: (yes/no) Muscle strength impairment: (yes/no) Use of walking aid: (yes/no)
Clinical gait characteristics
Spatio-temporal gait analysis

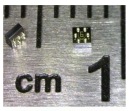
Gait Assessment – Minimum data set

Demographics Age: Sex: Ethnicity:
Clinical characteristics
Clinical gait characteristics Subjective self reported difficulty in walking (coded never, sometimes etc) Clinical gait abnormalities (yes/no) Timed up and go score (sec) Walking speed (4 m) steady state walking (m/sec)
Spatio-temporal gait analysis (GAITRite) Walking speed (mean value) Stride time (mean value and CoV%) Swing time (mean value and CoV%) Stride width (mean value and CoV%)

Beauchet et al. *Guidelines for assessment of gait and reference values for spatiotemporal gait parameters in older adults: The Biomathics and Canadian Gait consortiums initiative.* Frontiers in Human Neuroscience, 2017, 11, 353.

Body Worn Sensor
Inertial Measurement Unit (IMU)

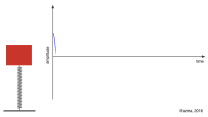
Miniature accelerometers
Miniature gyroscopes



mCube MC3571 1x1mm Accelerometer
Less Than a Cubic Millimeter in Total Size
Smaller than a Grain of Sand

Battery
Sensors
Microprocessor control
Signal data -> Memory chip
Wireless data streaming

- Accelerometer
  - Responds to linear acceleration



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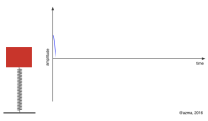
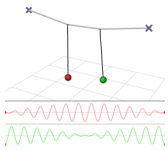
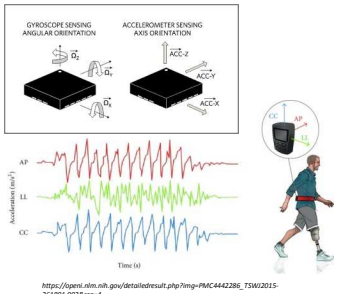


- Gyroscope
  - Responds to rotational movement
  - angular velocity



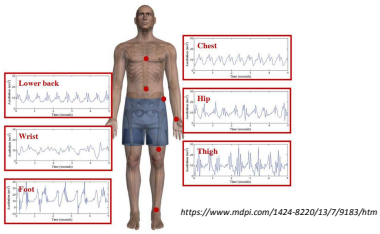
https://commons.wikimedia.org/w/index.php?curid=20485761

Tri-axial sensors



https://openi.nlm.nih.gov/detailedresult.php?img=PMC4442286_TSWJ2015-261801.002&req=4

Sensor placement options



https://www.mdpi.com/1424-8220/13/7/9183/htm

- What gait features are of interest in the clinical cohort
- Environmental considerations (clinic or community)
- Guidance from previous literature

Clinical Applications
Technology Research for Independent Living

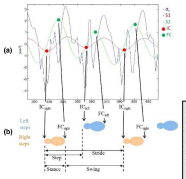
Sensor attachment

Free walking trials over 30 meters

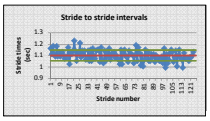
Data streaming via bluetooth

Signal Analysis

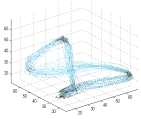
Spatio-temporal parameters



Gait variability



Gait complexity



- Descriptors of gait
- Ageing and neurological cohorts
- Clinic and free living home environment
- Early biomarkers of physical and cognitive decline

Del Din et al. *Free living gait characteristics in ageing and Parkinson's disease: impact of environment and ambulatory bout length.* Journal of NeuroEngineering and Rehabilitation (2016) 13:46

3-D Gait Laboratory

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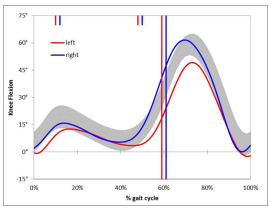
Lower body model of gait
Kinematics



Evolution of knee angle over the gait cycle
(Sagittal Plane)