Wearable sensing opens new windows to understand and improve human movement

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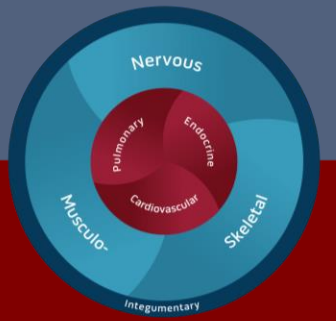

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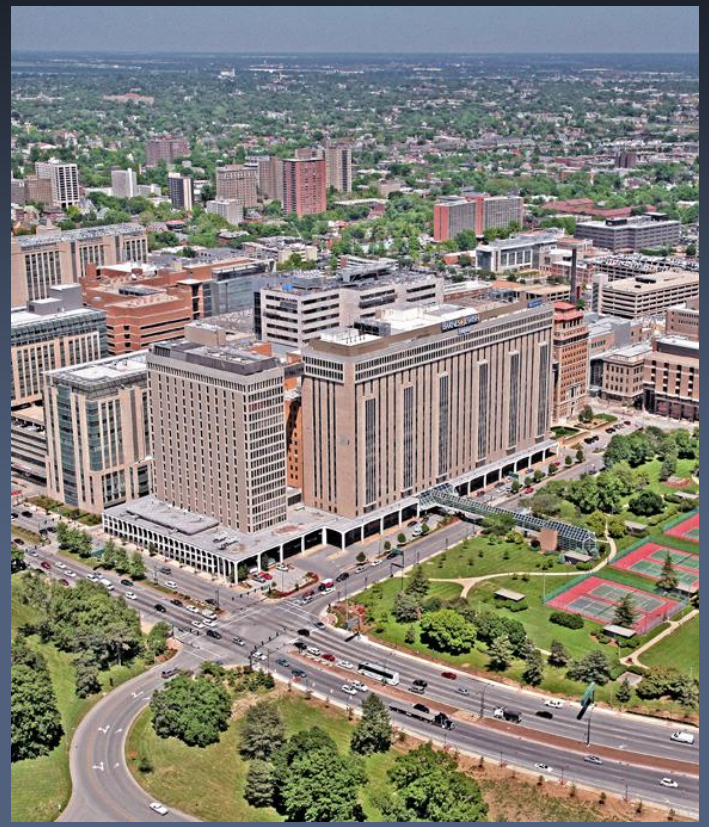


Additional “disclosures”

- My training is in physical therapy and motor systems neuroscience.
- I spend my working life thinking, studying, and teaching about the control of human movement.
- I started using sensors (when accelerometers were mostly uni-axial) in order to solve upper limb stroke problems. Now, every population is a “nail”

Two key points to take away:

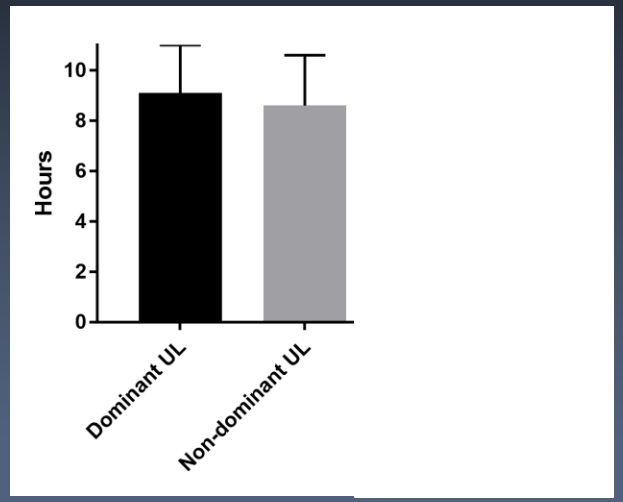
Wrist worn sensors can do so much more than measure daily physical activity.

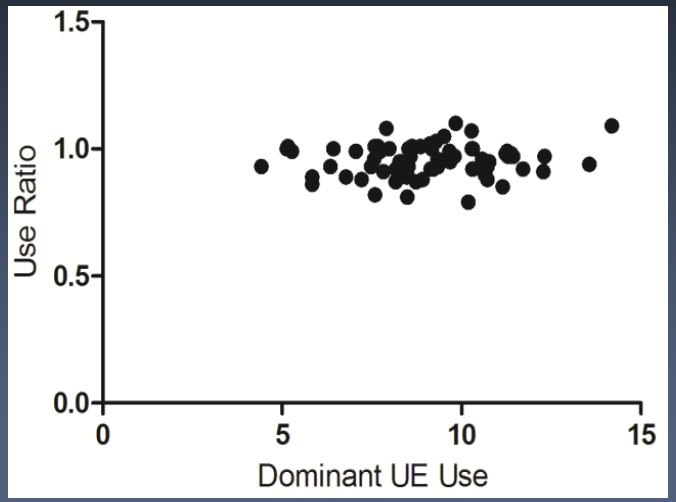
We have a lot of work to do to achieve the enormous promise of wearable sensing for research and clinical care.

Collecting data is the easy part, figuring out how to make sense of the data takes much more time.

E.g. Durations and ratios

N = 74 community dwelling adults
Bailey et al. 2014a, 2014b, 2015





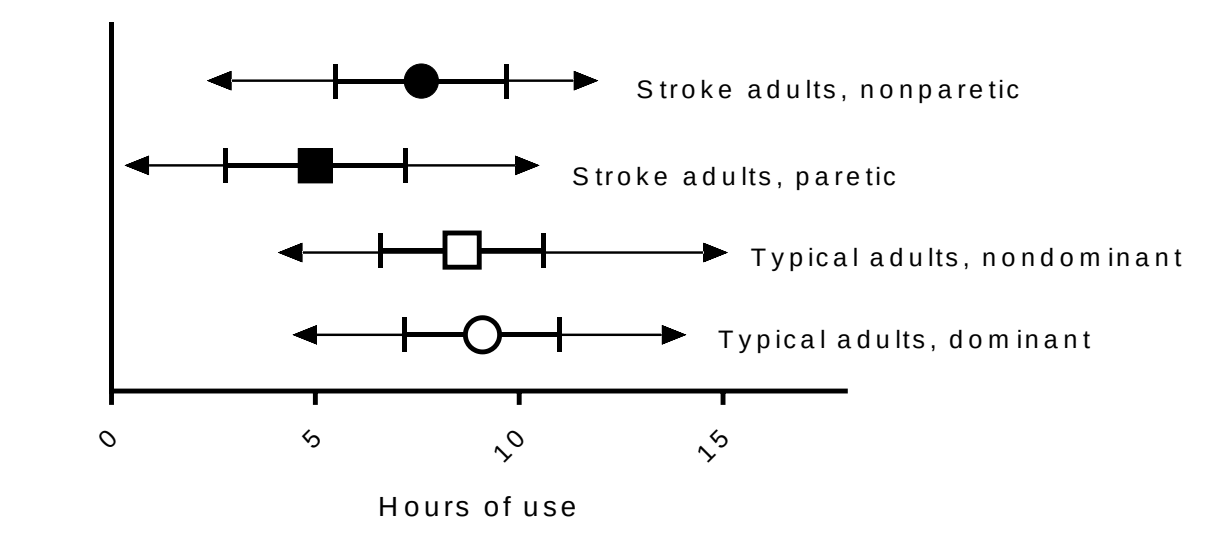
We can quantify a broad range of movement characteristics.

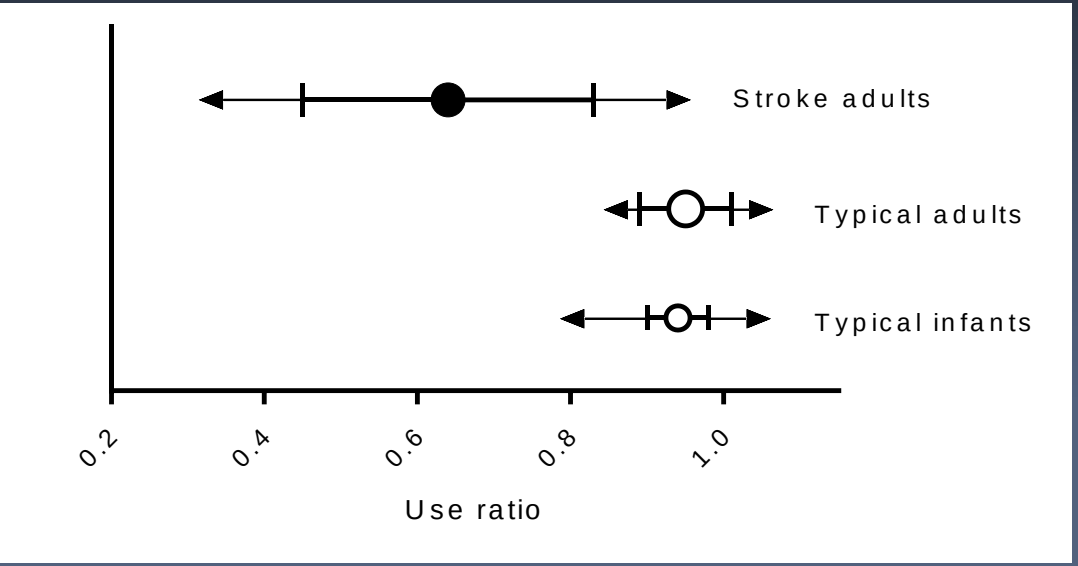
Duration	• *Total movement time* • D & ND time • Simultaneous time	→	For example: Sum of the seconds activity counts ≥ 2
Intensity	• *D & ND magnitude* • D & ND peak magnitude	→	Median acceleration during the seconds the limb was moving
Symmetry	• *Use ratio (durations)* • Magnitude ratio • Variation ratio	→	ND time / D time
Complexity	• D & ND variance • D & ND entropy • *D & ND jerk* • D & ND frequencies	→	Average of the time derivative of the acceleration signal (from 30 Hz)

D: dominant; ND: non-dominant

Lang et al. 2020; Barth et al. 2021; Konrad et al. 2022

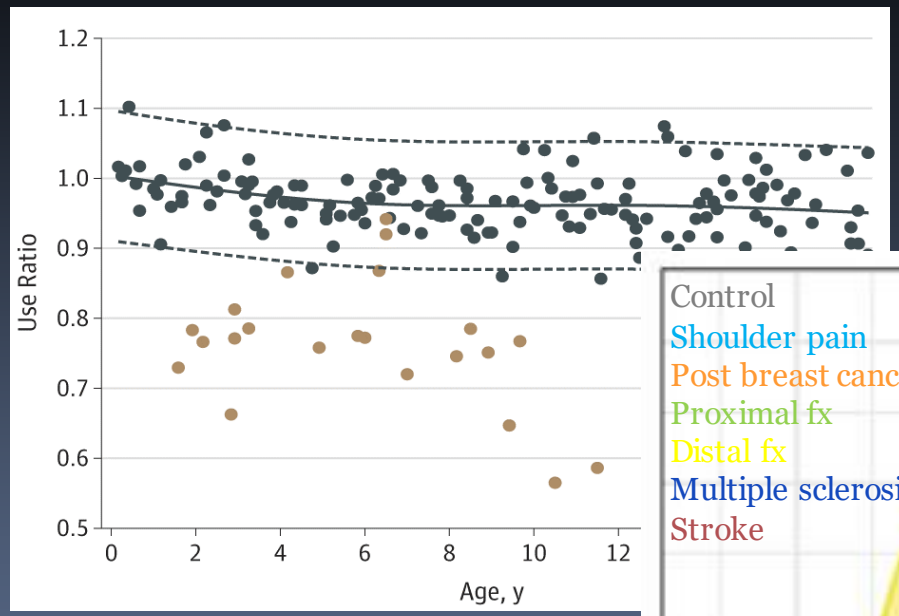
Narrowly distributed sensor variables detect differences from and progress towards “typical” better than widely distributed ones.



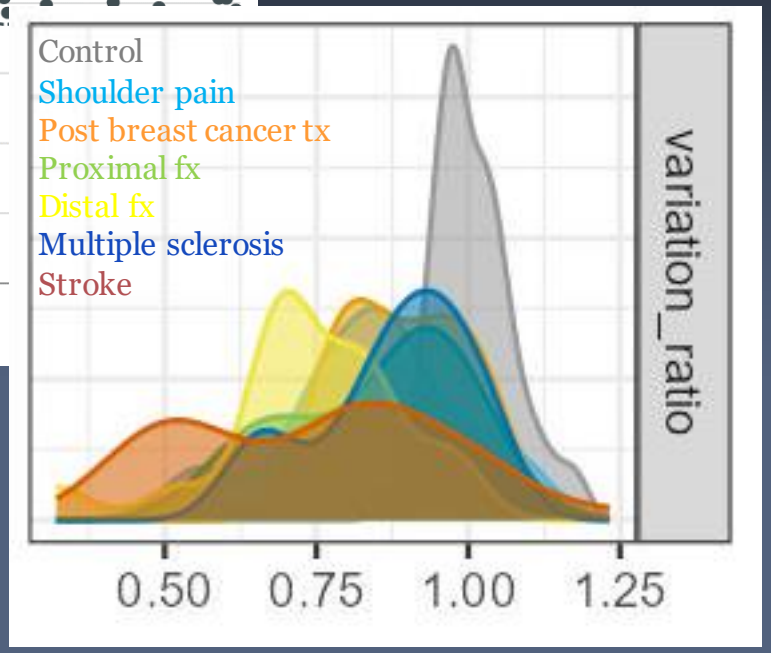


Smith & Lang 2019

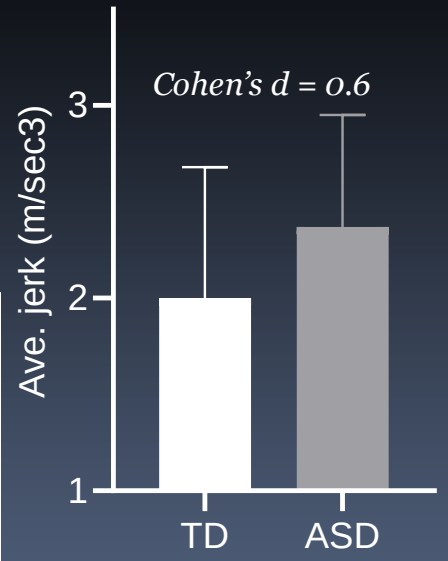
Different variables may be relevant for different populations.



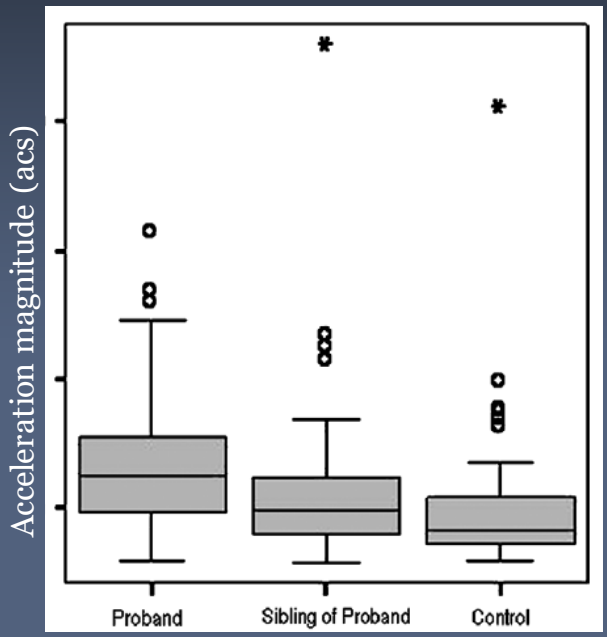
Hoyt et al. 2019



Ongoing study, n = 204



Konrad et al. 2022



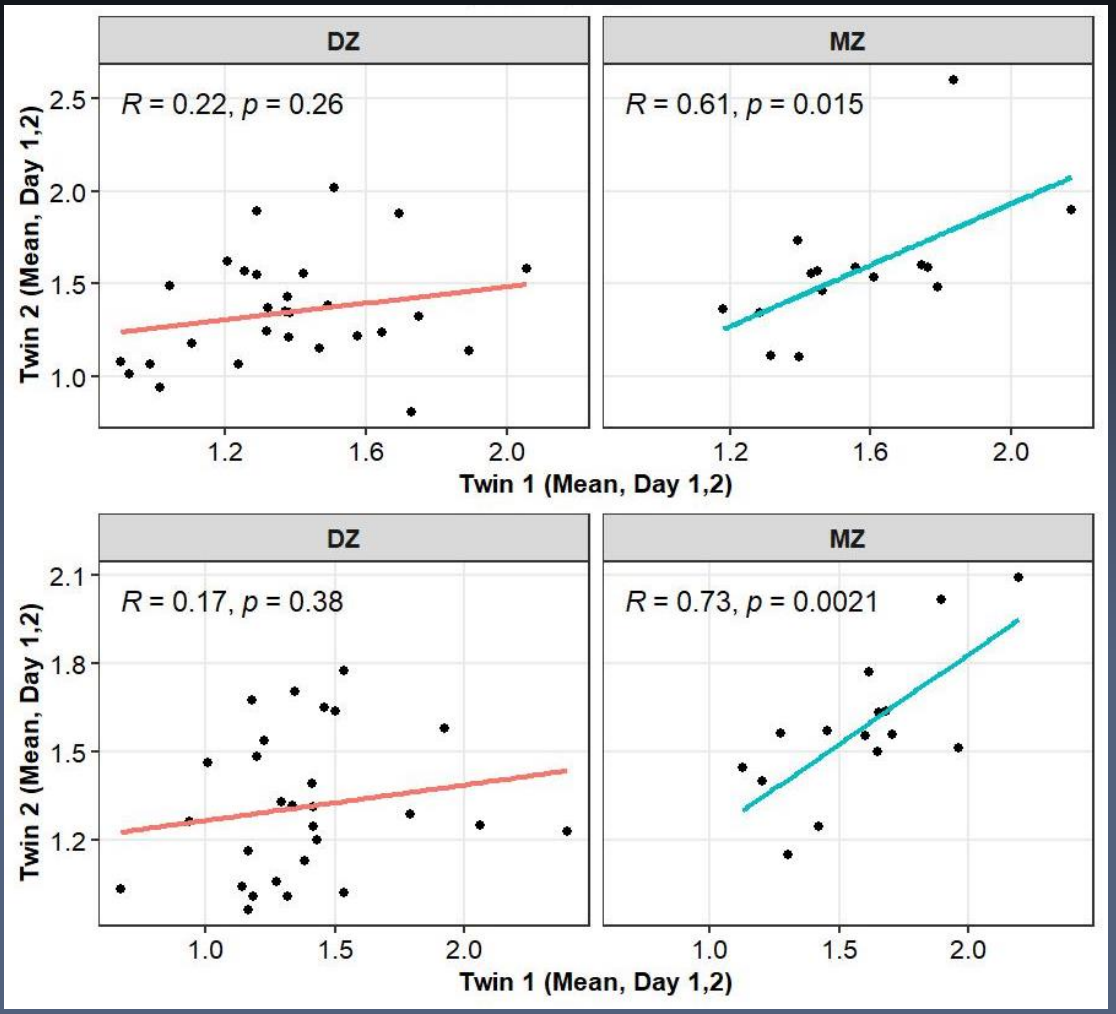
Wood et al. 2009

Wrist-worn accelerometers can quantify heritable motor behavior in infants.

Left H2 = 0.75
ICC = 0.89

Jerk is similar on both limbs, highly stable, and *highly heritable*.
(expressed in m/s^3, or g/s)

Right Adj H2 = 0.73
ICC = 0.86



Marrus et al. submitted

Two key points to take away:

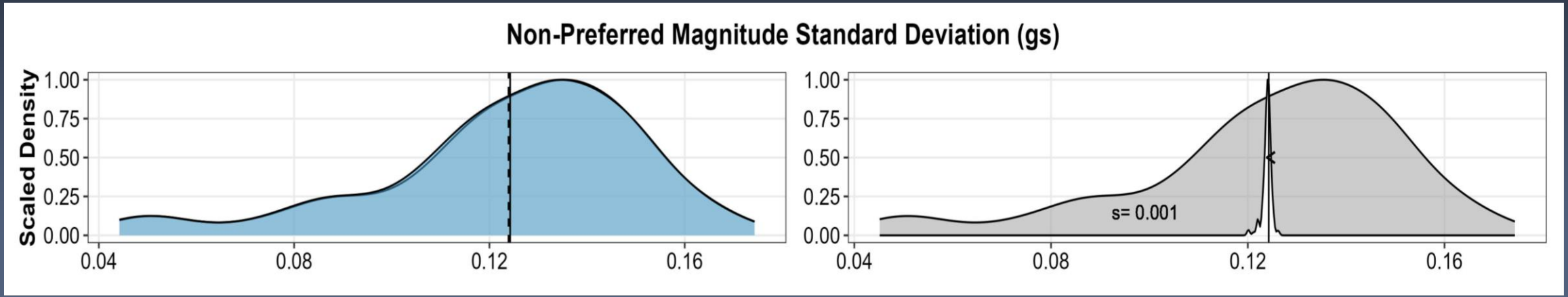
Wrist worn sensors can do so much more than measure daily physical activity.

- Sensor can quantify a broad range of movement characteristics.
- Different populations may need different variables.
- We are just beginning to explore what movement sensors can do.

We have a lot of work to do to achieve the enormous promise of wearable sensing for research and clinical care.

Sensor data processing pipelines need to be as simple and efficient as possible.

E.g. There is a negligible effect of sleep on accelerometer variables



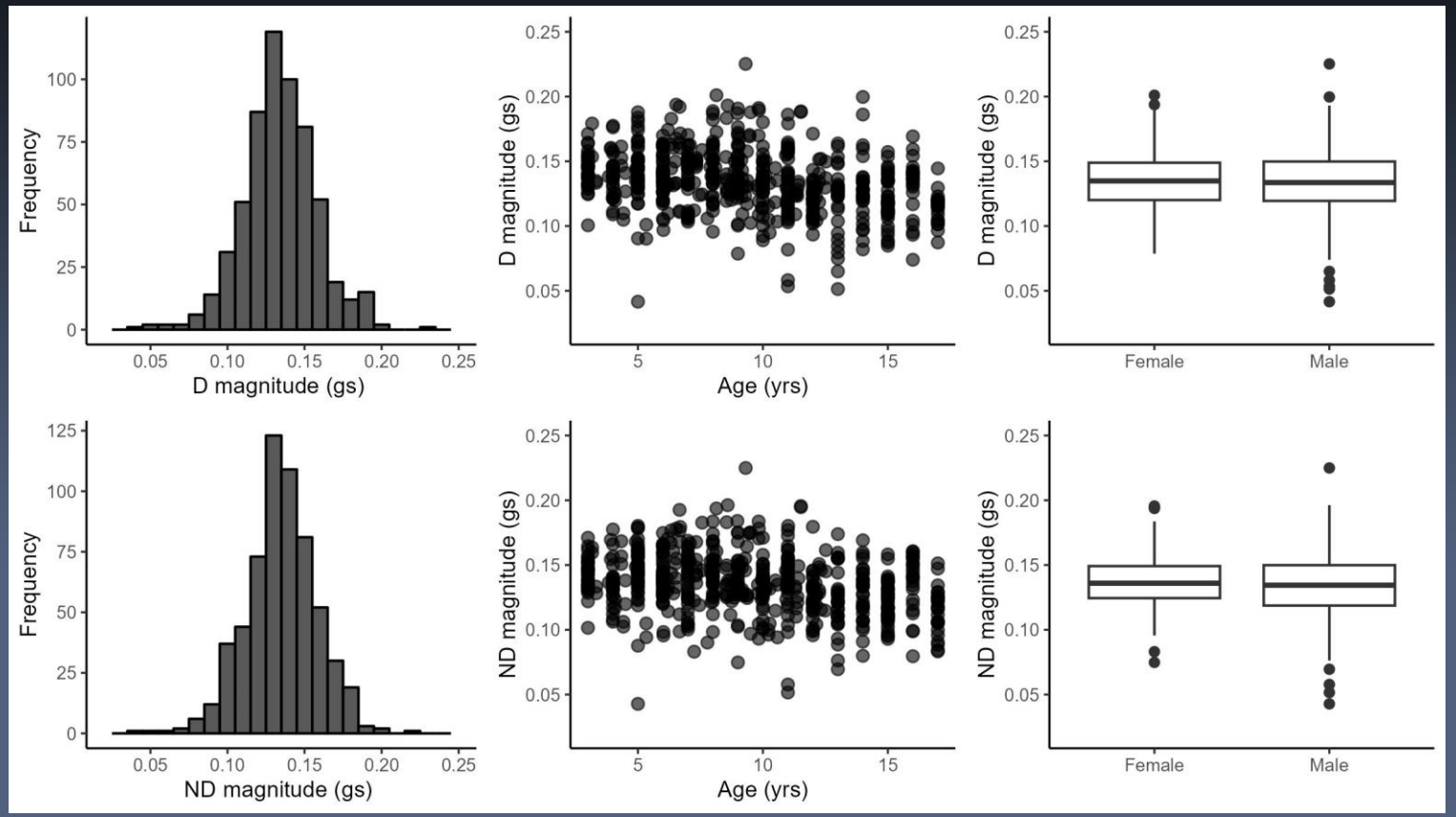
Overlapping distributions with sleep included vs. excluded

Sleep included distribution, with distribution of differences superimposed

Miller et al. submitted

Referent data from upper limb sensors will help researchers design, analyze, and interpret data from clinical populations.

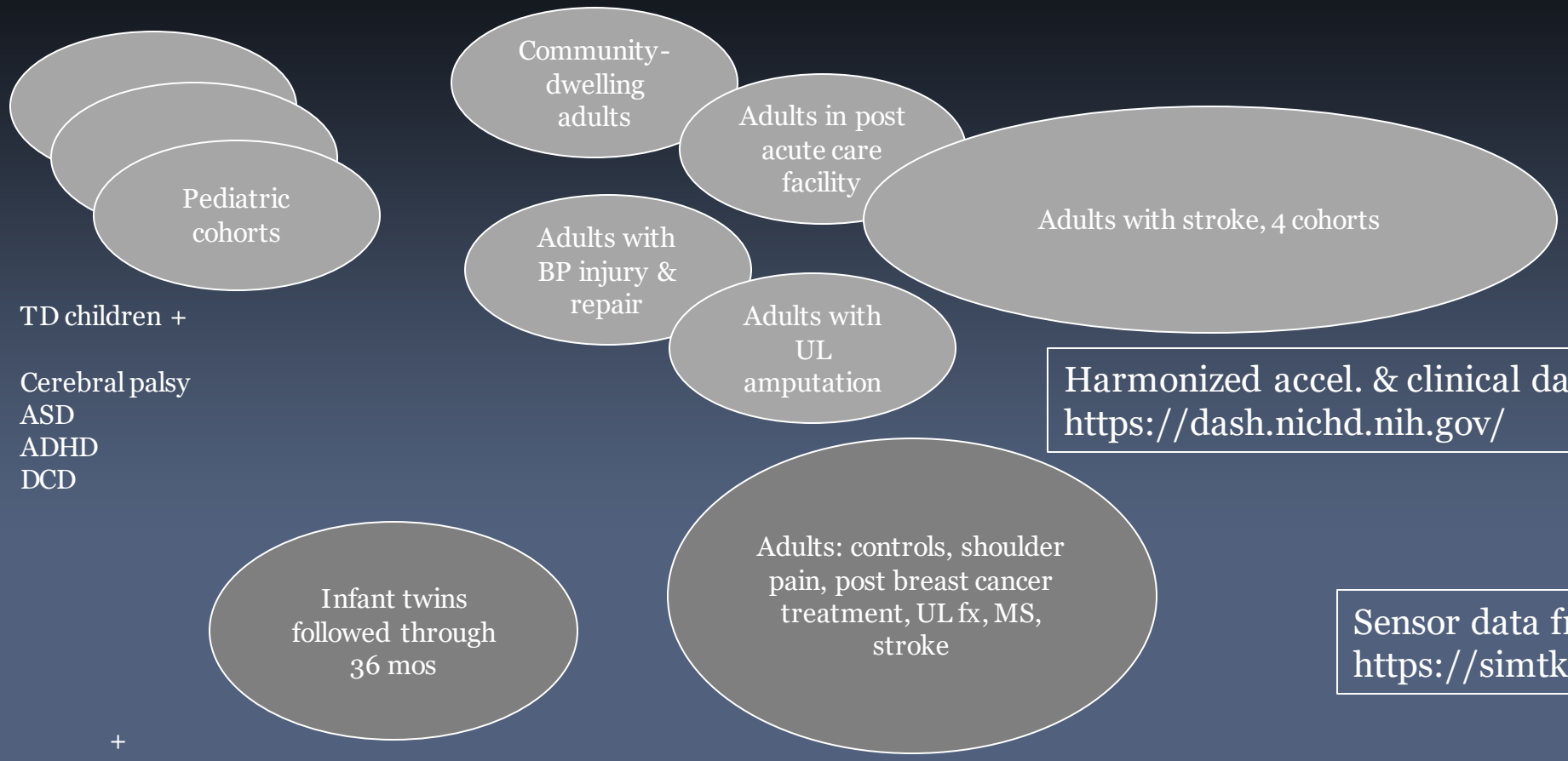
E.g. 1 of 25 variables from 222 children, ages 3-17 yrs, over 622 recording days



Play with the data yourself: https://langlab.shinyapps.io/harmonized_data/

Lang et al. in press

Data need to be harmonized and accessible.

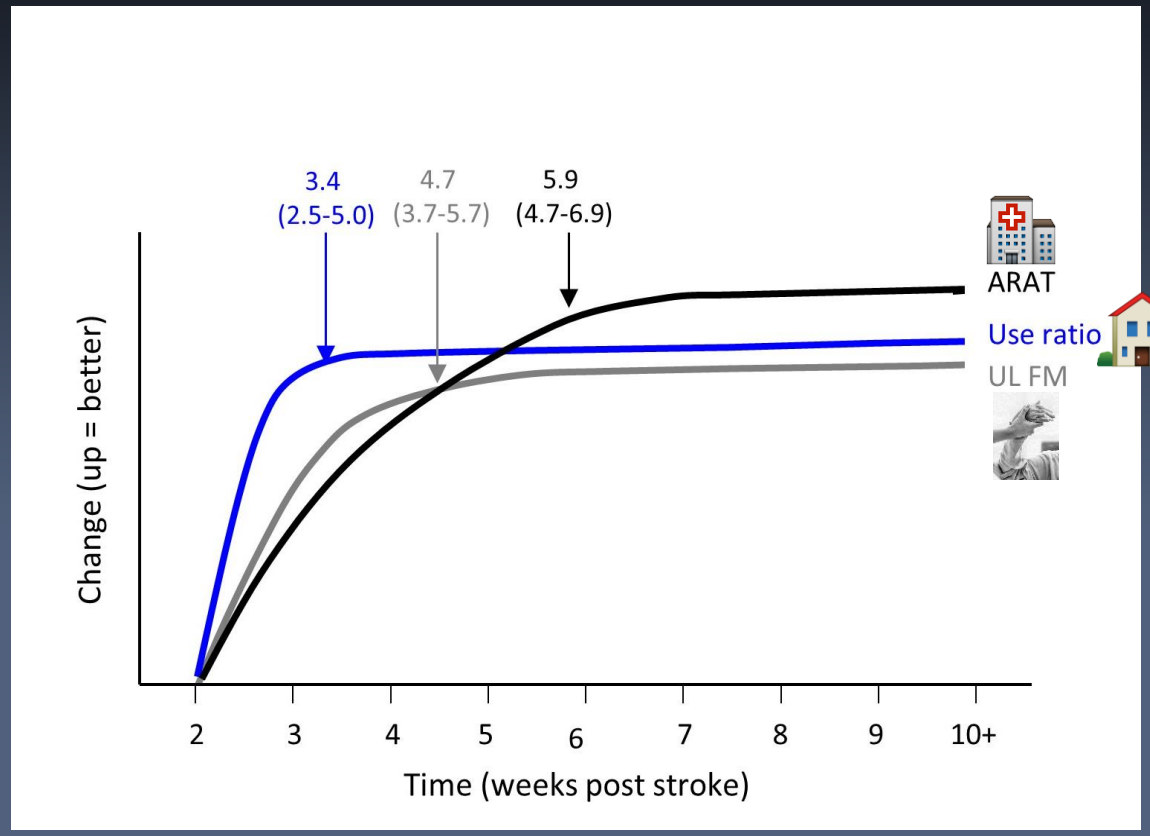


Harmonized accel. & clinical data to NIH repository soon, https://dash.nichd.nih.gov/

Sensor data from adult cohorts @ https://simtk.org/projects/referentaccdata

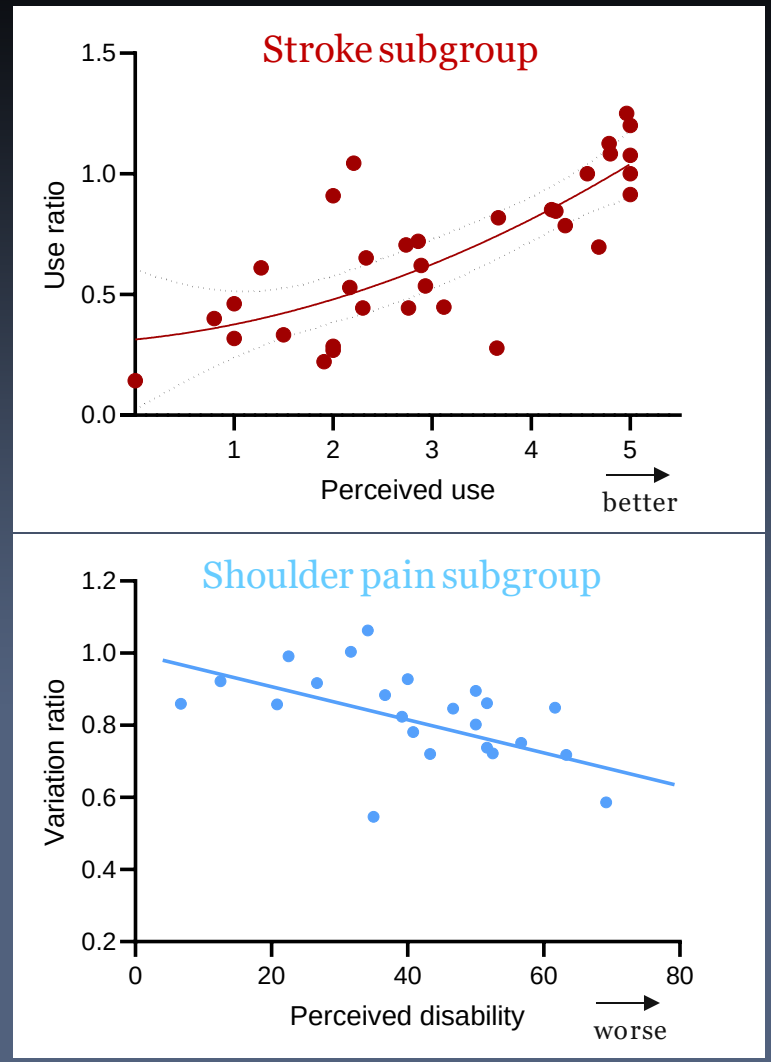
Miller et al. in preparation

We are evaluating how sensor variables correspondence to clinical measures & patient perceptions.



Stroke cohort mean changes over time from Lang et al. 2021

Ongoing study:



We are working with Actigraph and the WU Informatics team to close the loop, providing sensor information to clinical providers.

Data Collection

Insight or LEAP watches

Cloud-Based Data Storage and Processing

Raw Data

TIME	X	Y	Z
9/9/2022 10:01	121	116	238
9/9/2022 10:01	39	34	143
9/9/2022 10:01	17	137	191
9/9/2022 10:01	28	15	28
9/9/2022 10:01	17	45	14
9/9/2022 10:01	0	0	0
9/9/2022 10:01	0	0	0
9/9/2022 10:01	0	0	0
9/9/2022 10:01	1	44	32
9/9/2022 10:01	60	15	48
9/9/2022 10:01	62	57	0
9/9/2022 10:01	7	33	0
9/9/2022 10:01	71	29	8
9/9/2022 10:01	42	22	13
9/9/2022 10:01	167	130	90
9/9/2022 10:01	105	57	62
9/9/2022 10:01	263	160	152
9/9/2022 10:01	111	59	166

Summary Variables

Use Ratio & Hours of Affected Limb Activity

Centrepoint

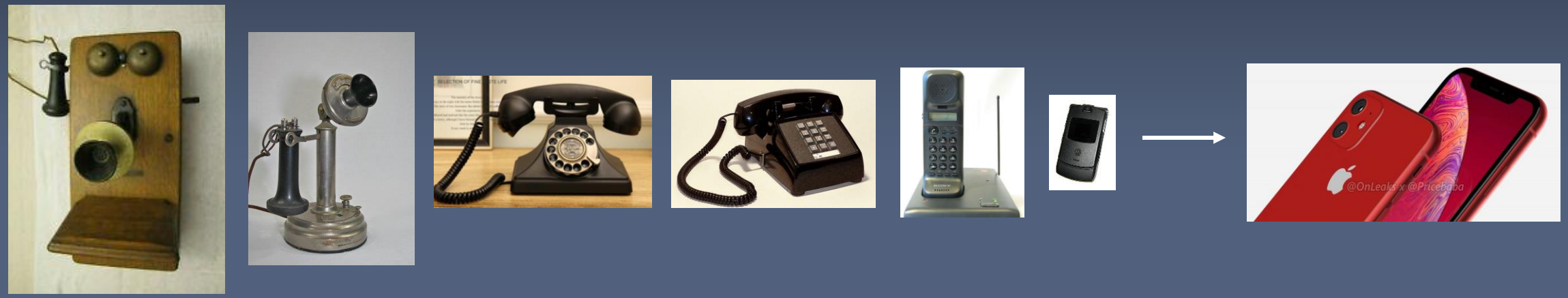
Data Integration into Electronic Health Record

EPIC

Looking forward, it is still early in the wearable motion sensor field and collectively we can do so much more.

- *Wrist worn sensors can do so much more than measure daily physical activity.*
- *There is lots of work to be done by all.*

e.g. the telephone



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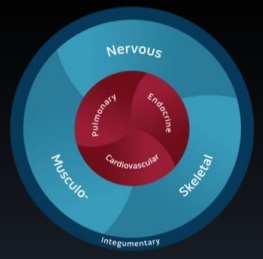

PhD or Postdoc in Movement Science

- Study at the biological intersection of mechanics, energetics, and control systems
- Choose from the full spectrum of investigation: fundamental discovery through clinical application
- Learn to be a movement scientist in an energetic, dynamic, and collaborative environment
- Be part of the next generation of scientists improving health

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