New Approaches to Quantification and Improvement of Walking

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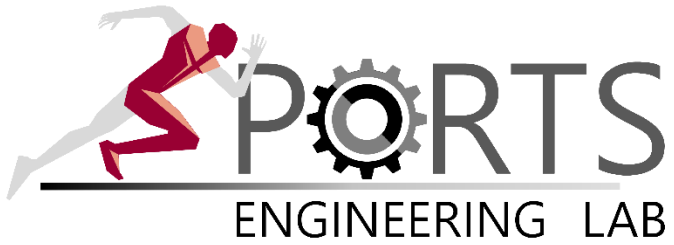
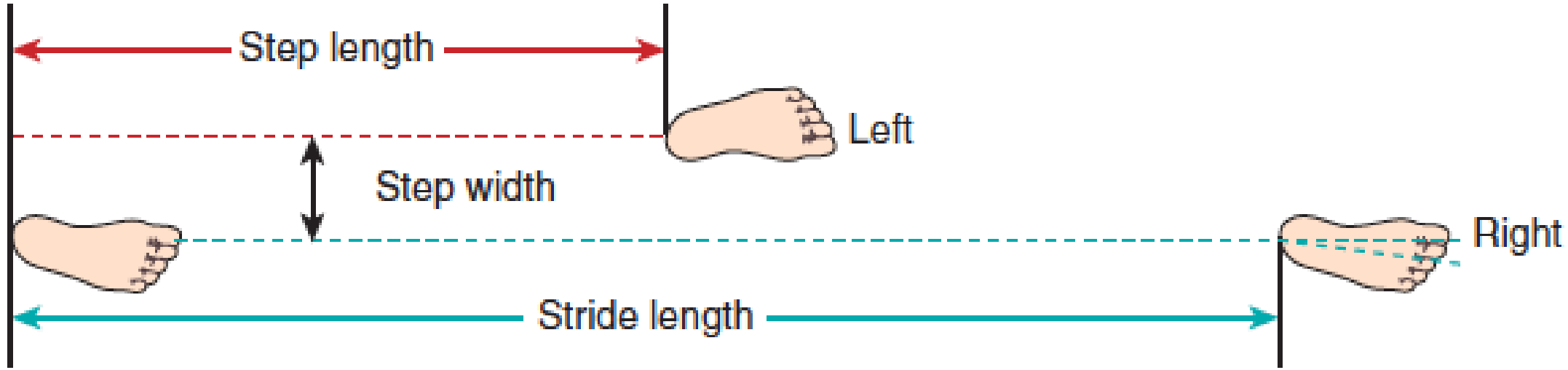


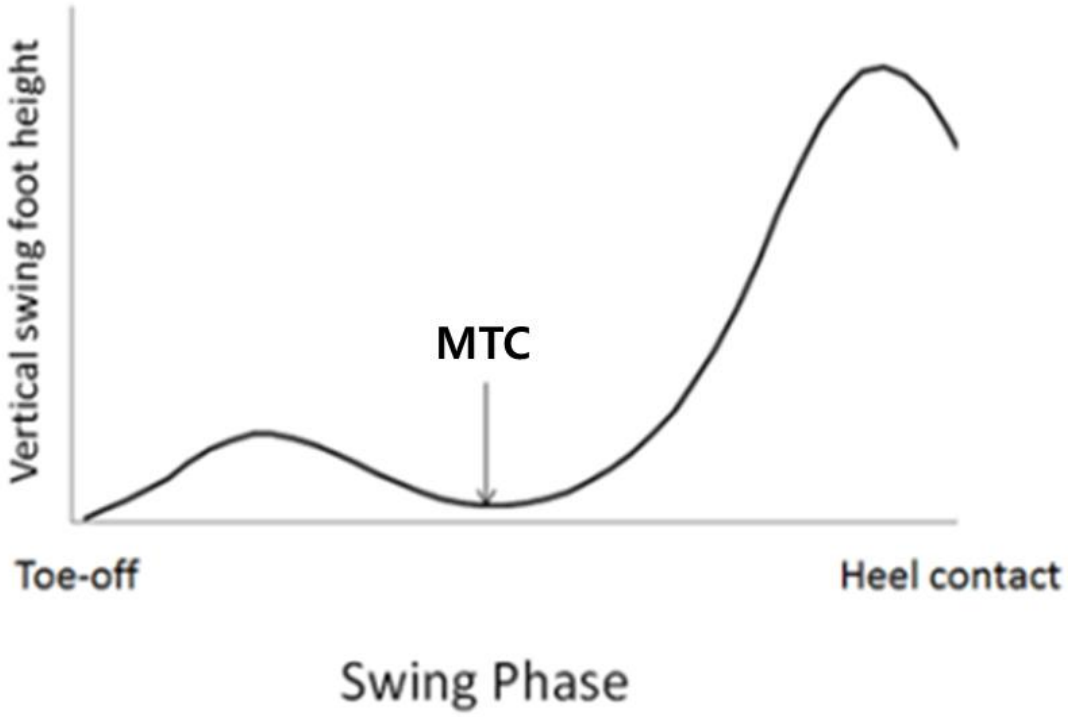
Conventional assessment of walking ability



- Gait speed
  - 6 minute walk test
  - 10m walk test
  - timed up and go test
- Stride length, stride width, duration of double support phase, stride interval

Other measures of “healthiness” of walking

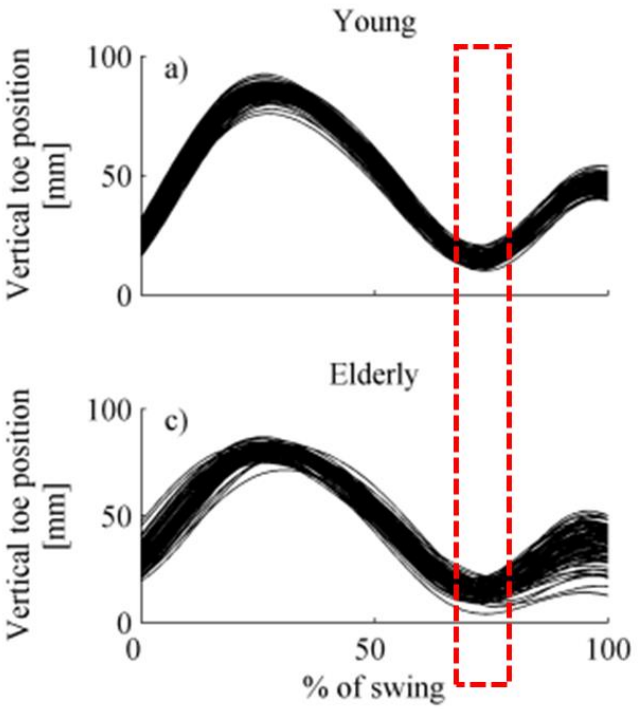
- Minimum toe clearance
  - ➢ Local minimum vertical height of the toe during the swing phase



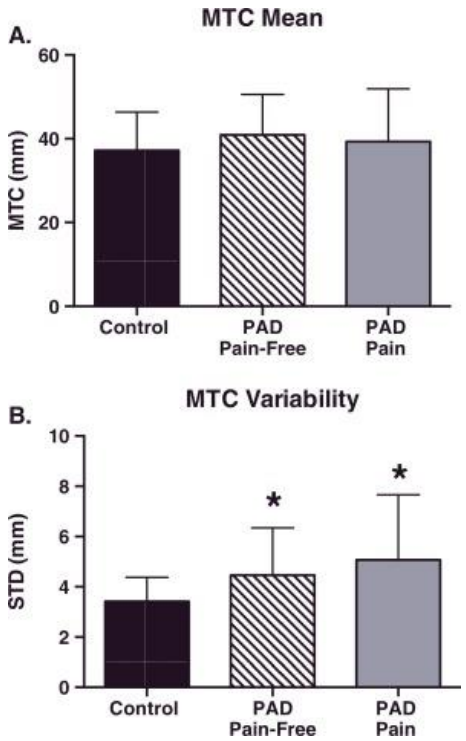
Other measures of “healthiness” of walking

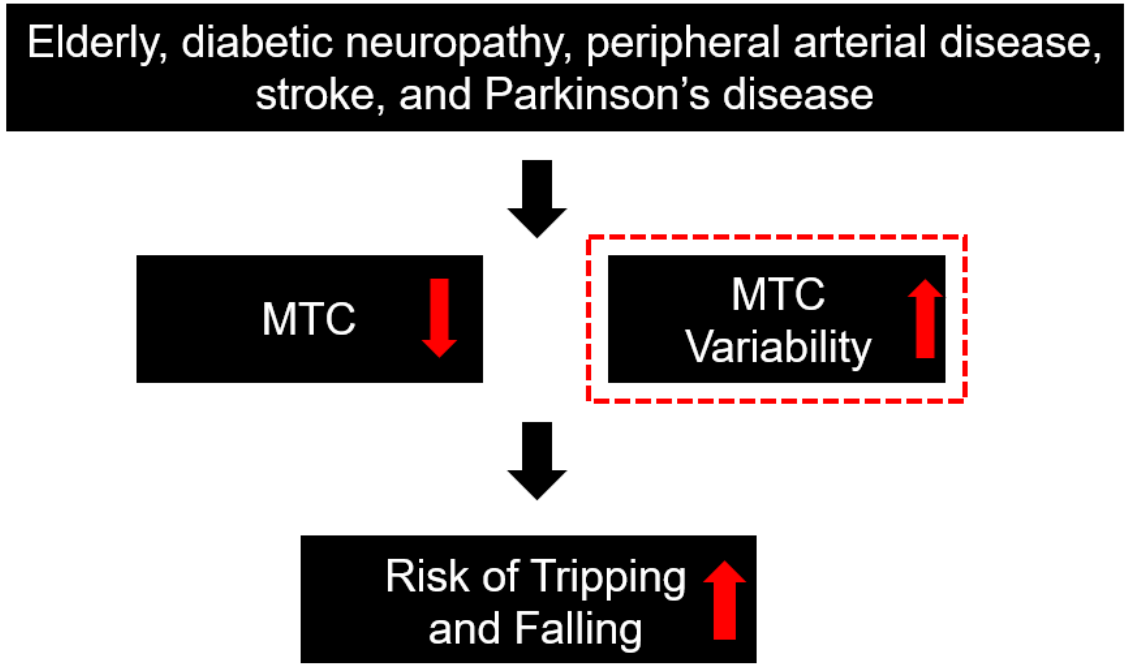
- Minimum toe clearance
  - ➢ Local minimum vertical height of the toe during the swing phase
  - ➢ An important indicator of the risk of tripping and falling (Winter 1992; Begg et al. 2007; Schulz 2017; Rand et al. 2015; Alcock et al. 2016; Suda et al. 2019)

Elderly



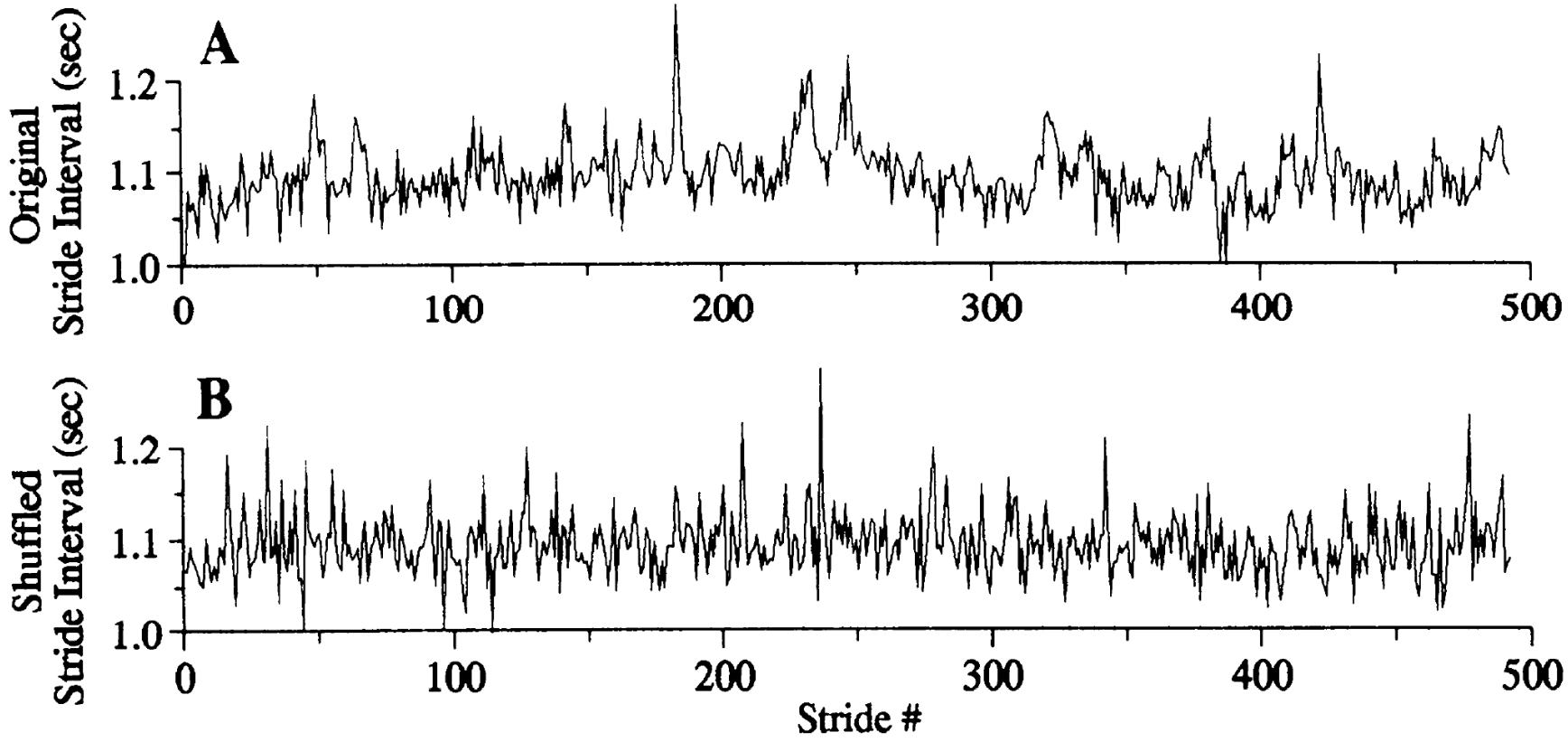
Peripheral arterial disease





Other measures of “healthiness” of walking

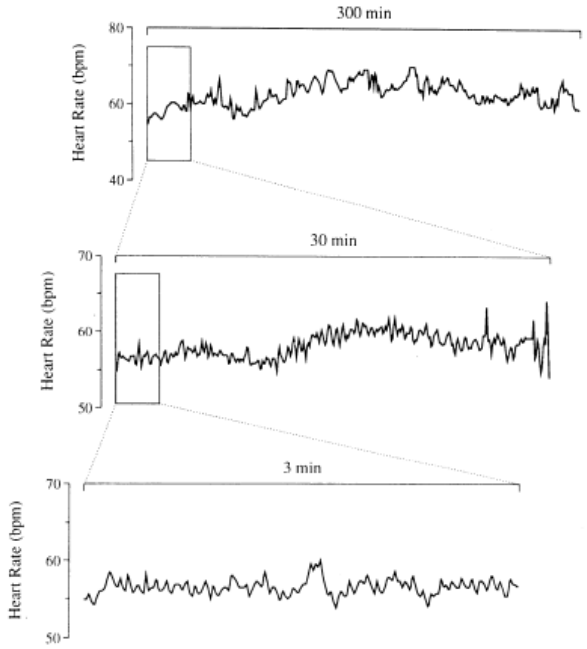
- Long range correlation
  - Variability in human walking is not a white noise; healthy walking has healthy complexity

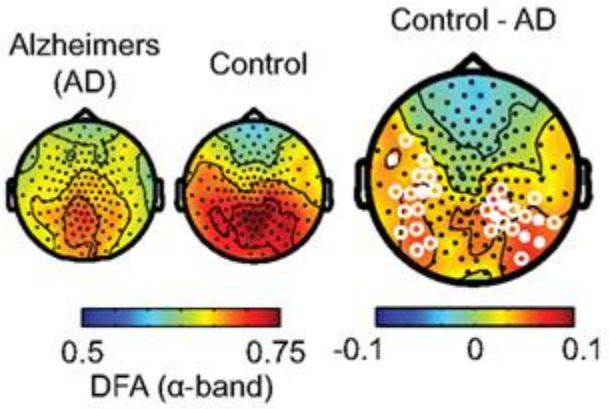


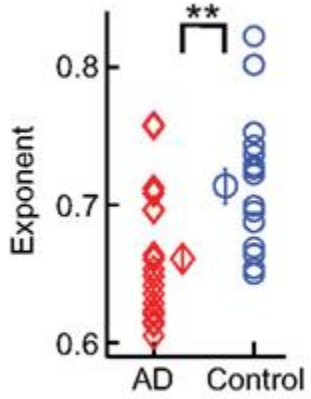
from Hausdorff et al., 1995

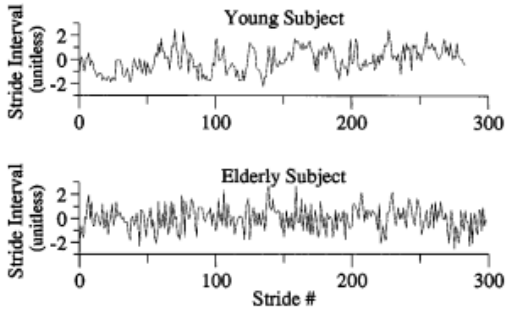
Other measures of “healthiness” of walking

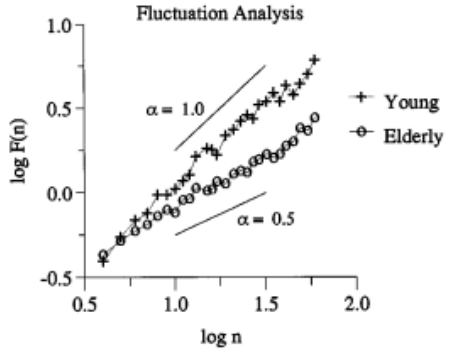
- Long range correlation
  - Variability in human walking is not a white noise; healthy walking has healthy complexity
  - The healthy complexity is lost due to aging, injury, or impairment in the lower limb, brain or heart (Hausdorff et al., 1997; Goldberger et al., 2002; Skinner et al., 1990; Goldberger et al., 1990; Pool, 1989; Nan et al., 1988; Babloyantz et al, 1986)





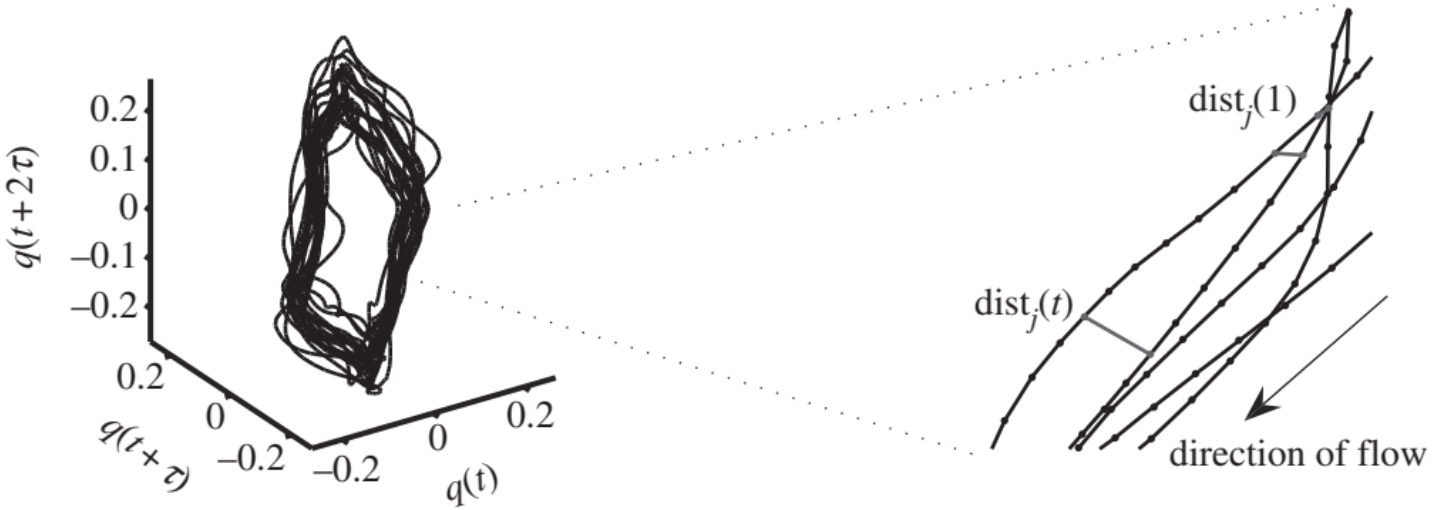




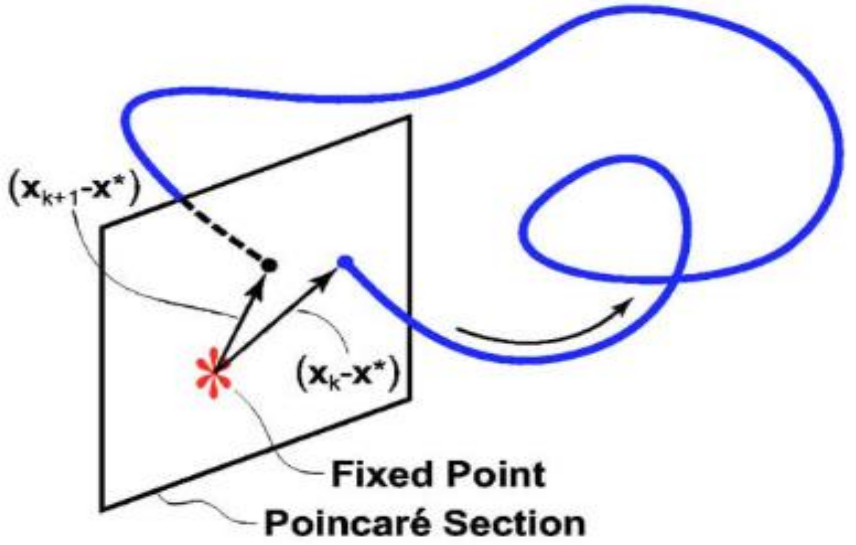


We also need to quantify “stability”

Maximal Lypunov exponents



Floquet multipliers



However,

The measured value of maximal Lypunov exponent heavily depends on

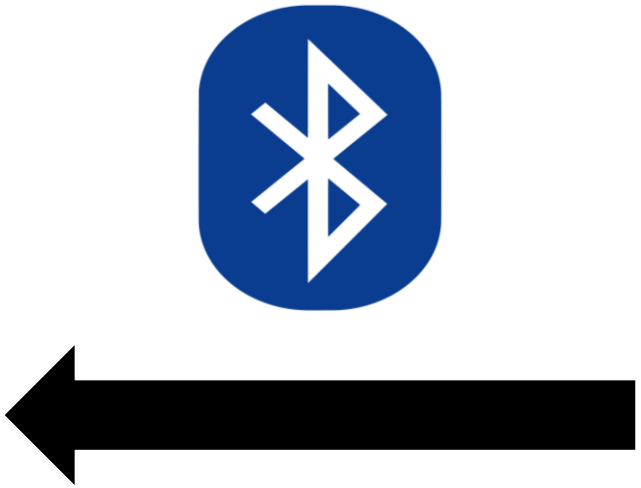
- human factors,
- the choice of variable ,and
- noise

The measured value of Floquet multiplier is biased due to

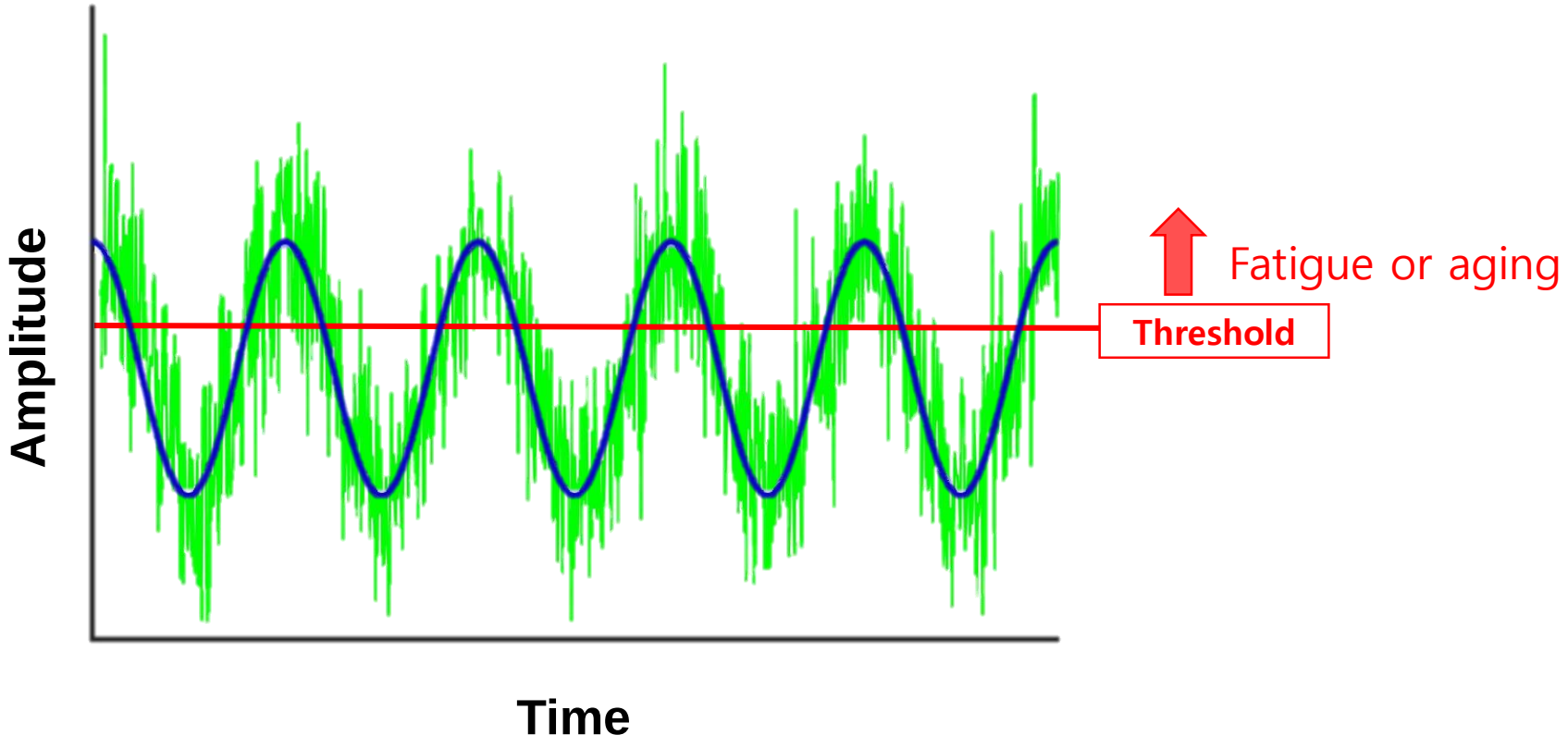
- noise, and
- limited length of the data

Can we improve gait with simple and practical intervention?

We all wear shoes and bring smart phones



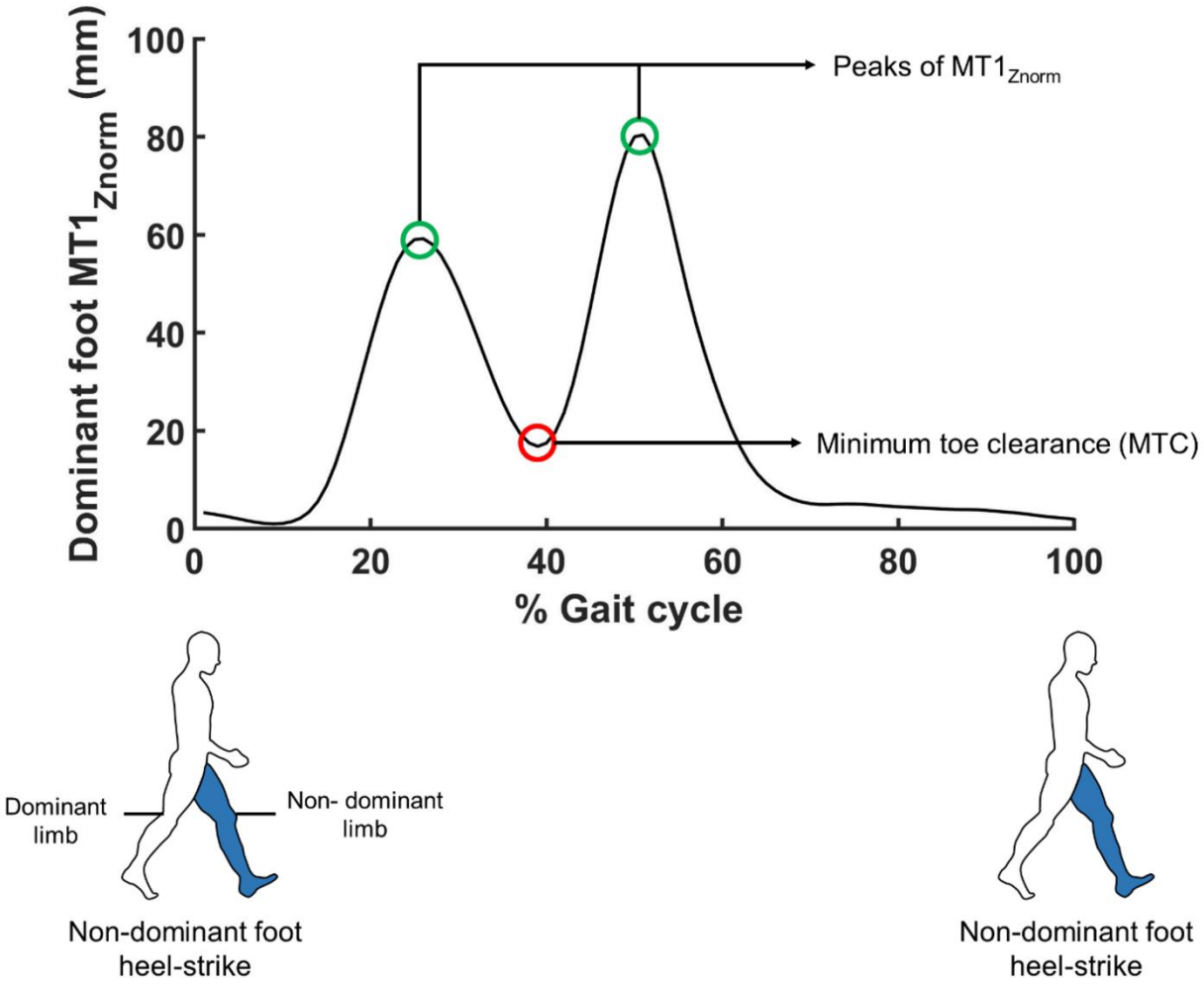
Working principle: stochastic resonance

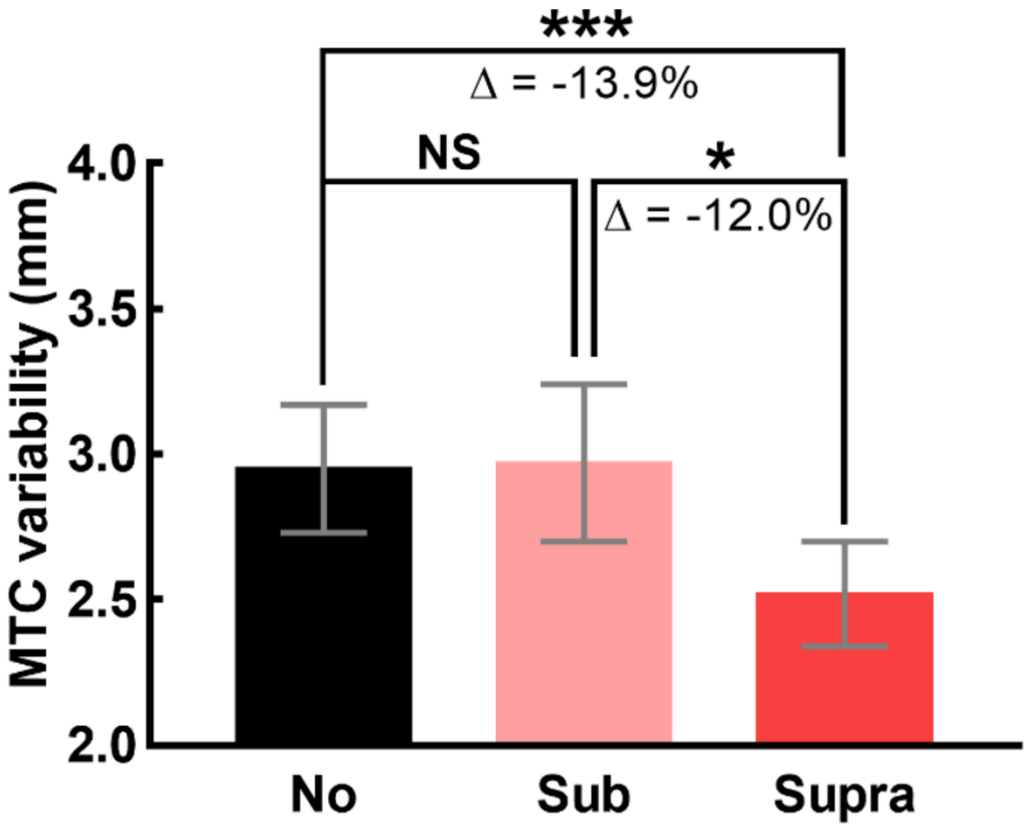


Equipment design

J Moon, P Pathak, S Kim, S Roh, C Roh, Y Shim, and J Ahn*, ***Scientific Reports***, 2020

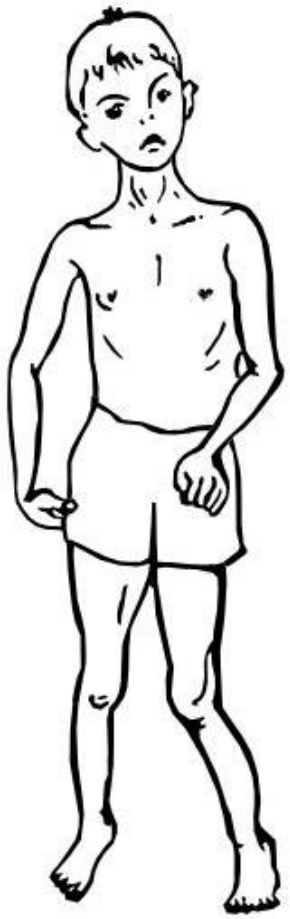
Vibration reduces variability of toe-clearance



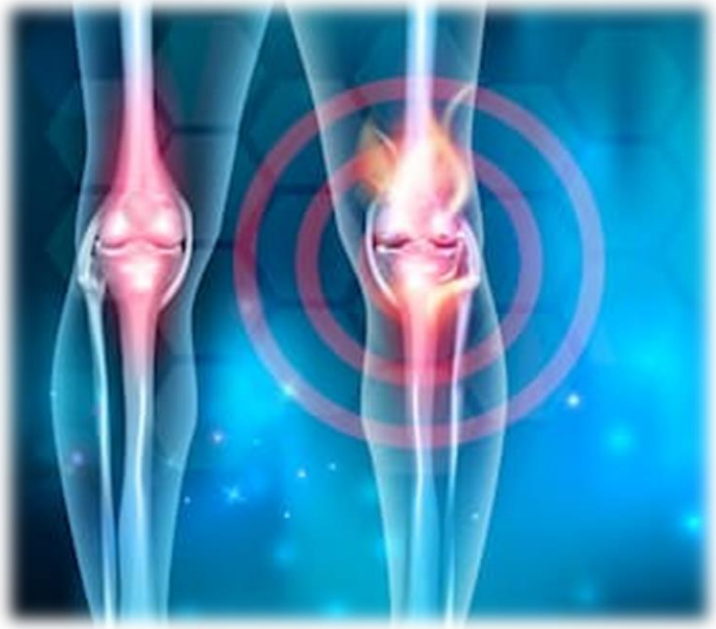


P Pathak, J Moon, S Roh, C Roh, Y Shim, and J Ahn*, ***PLoS ONE***, 2022

In-toeing and out-toeing

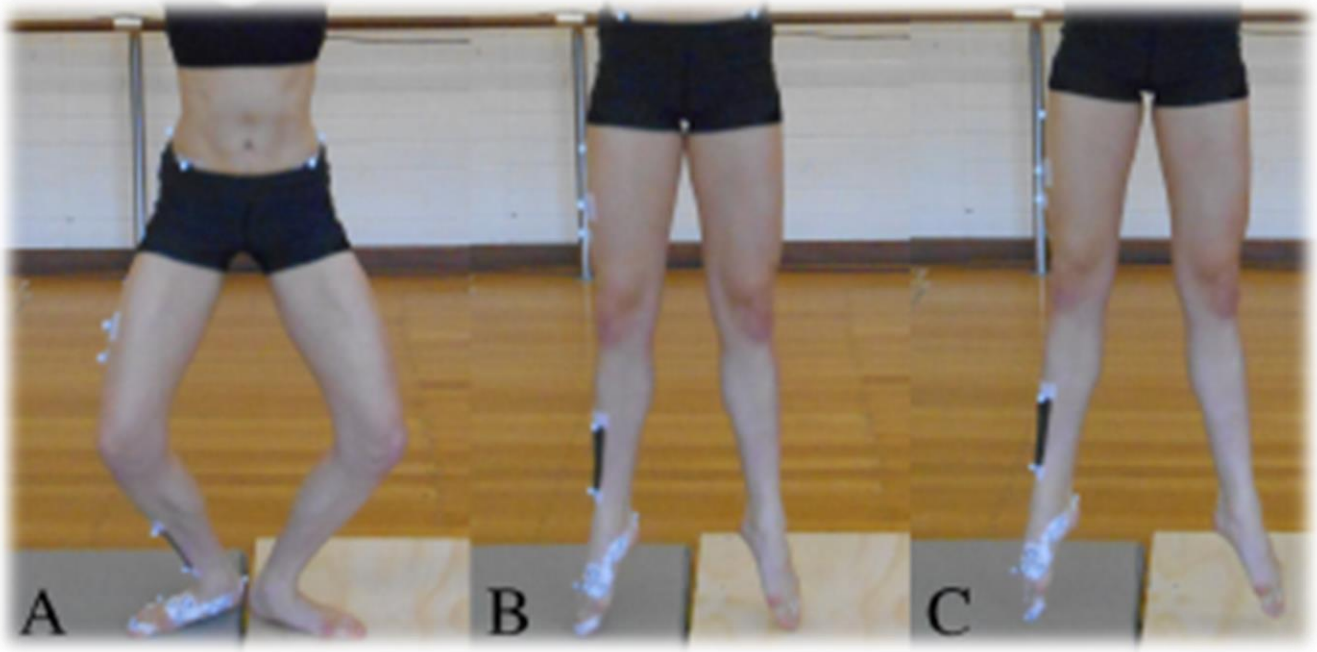


Cerebral Palsy Patients (In and Out Toeing)



Osteoarthritis Patients (Out Toeing)

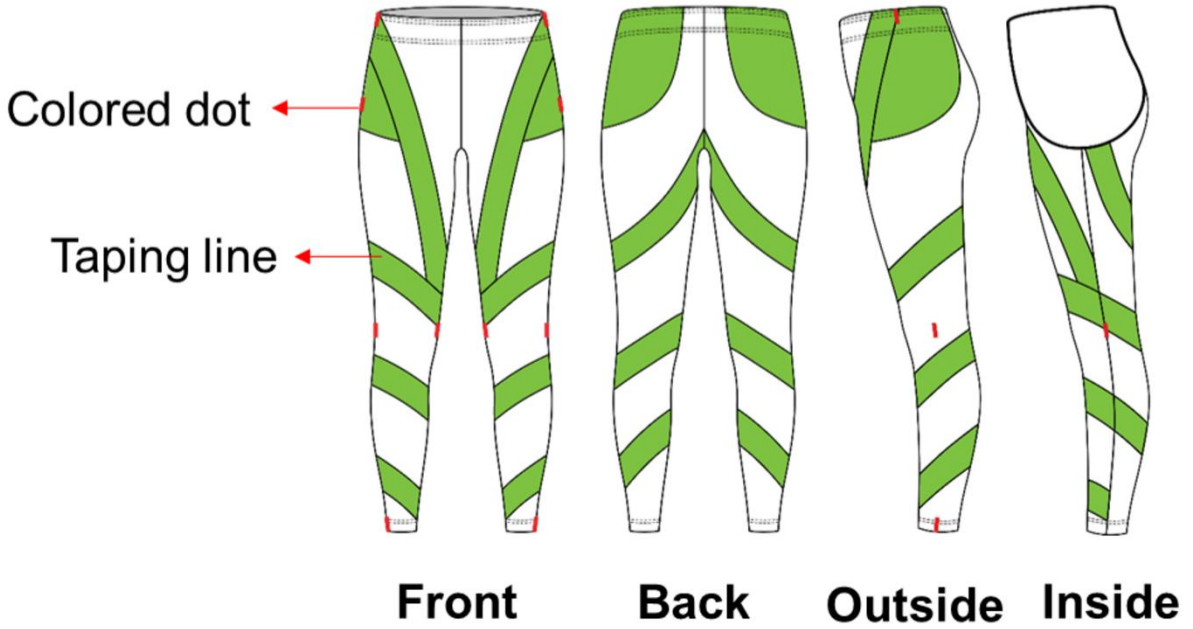
Out-toeing is also common among dancers



Foot outward directing movement (Sauté) → Out-toeing gait → Excessive tibia, knee, and hip rotation → Gait dysfunction and increased injury risk

[Hamilton 1988; Grossman et al. 2008; Teplá et al. 2014; Lee 2019]

Compression tights with taping lines can help



Thanks to

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