StepuP: Steps against the b**u**rden of **P**arkinson's Disease

Jaap van Dieën

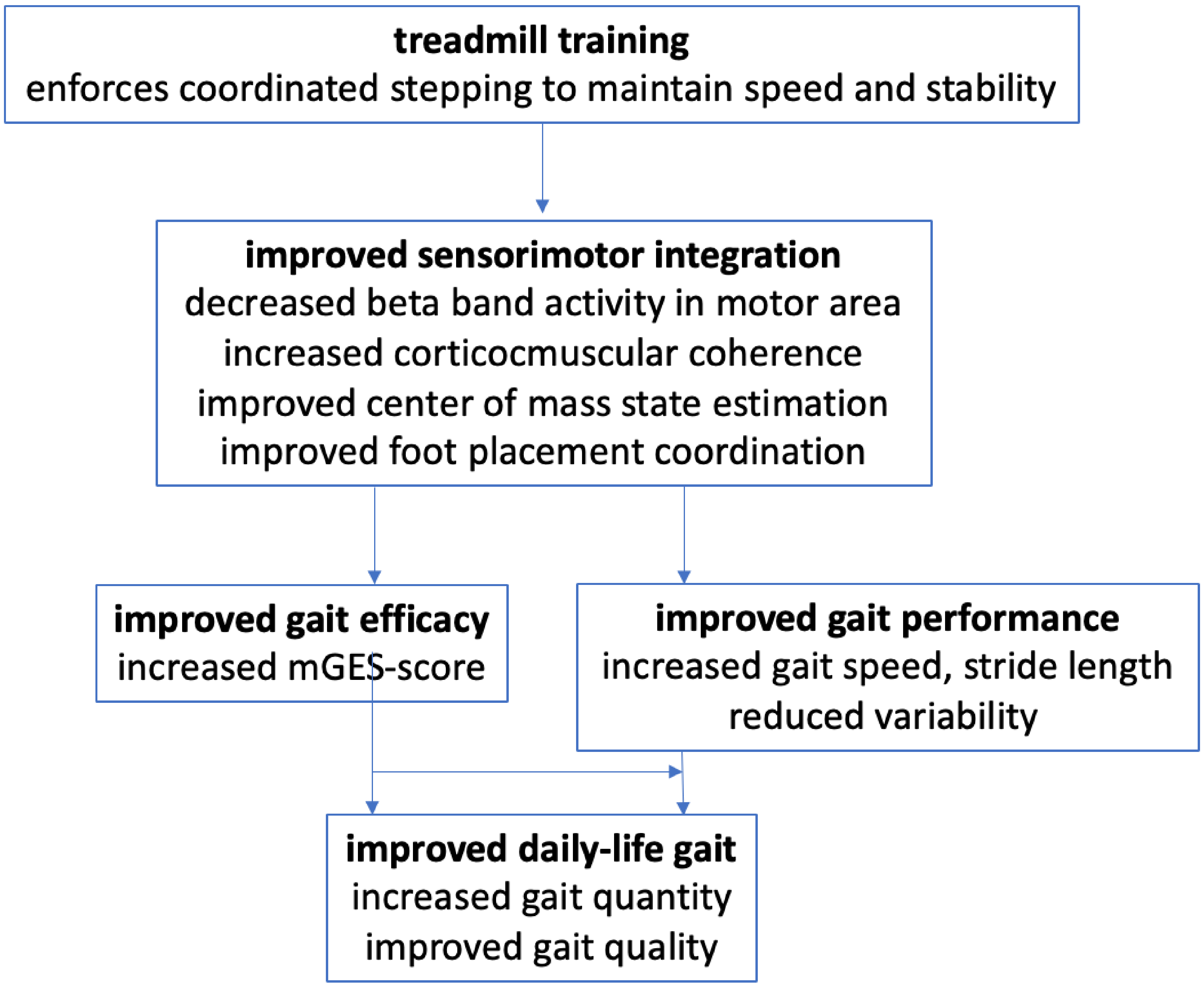
Department of Human Movement Sciences
Vrije Universiteit Amsterdam, the Netherlands

JPND research
EU Joint Programme – Neurodegenerative Disease Research

Amsterdam Movement Sciences

VU Vrije Universiteit Amsterdam

Amsterdam UMC
University Medical Centers



treadmill training
enforces coordinated stepping to maintain speed and stability
improved sensorimotor integration
decreased beta band activity in motor area
increased corticocmuscular coherence
improved center of mass state estimation
improved foot placement coordination
improved gait efficacy
increased mGES-score
improved gait performance
increased gait speed, stride length
reduced variability
improved daily-life gait
increased gait quantity
improved gait quality

treadmill training in PD

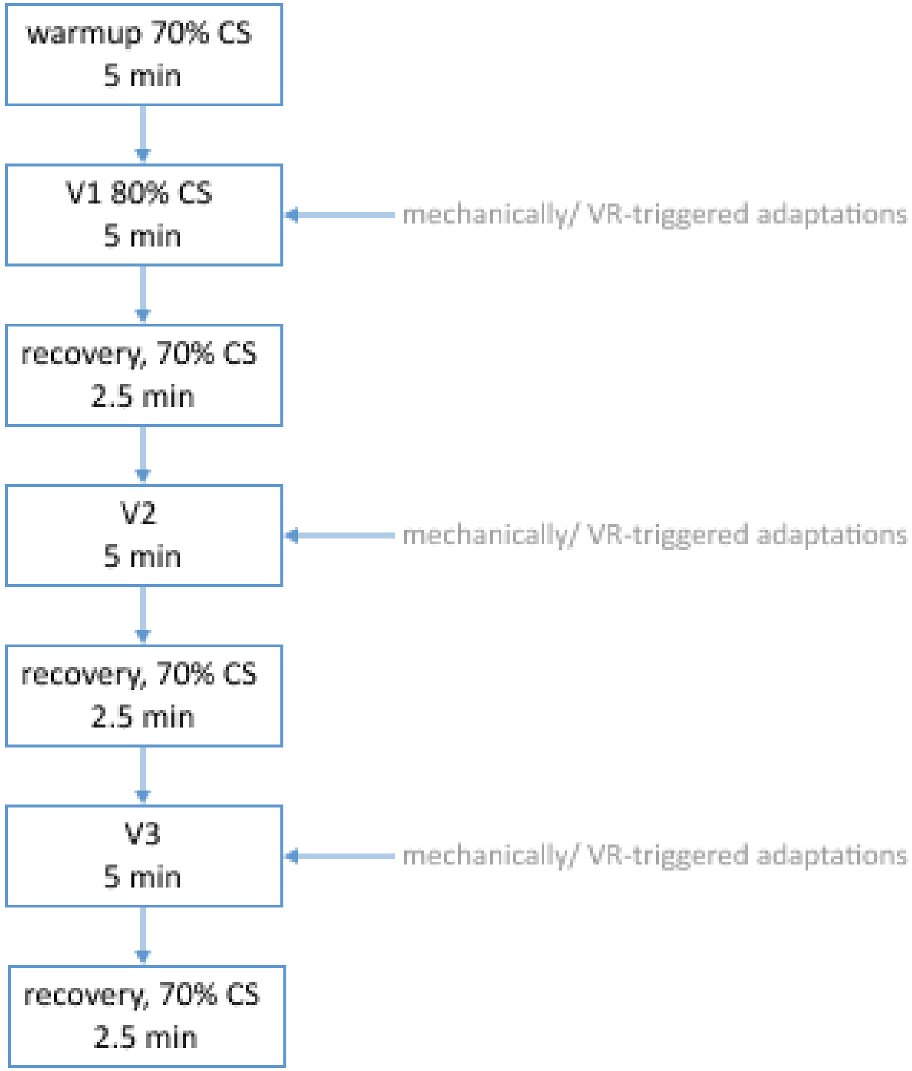
treadmill training
enforces coordinated stepping to maintain speed and stability

32 trials (n = 823) compared treadmill training with no exercise or sham treatment. Treadmill training improved gait outcomes, with a moderate effect on the 10MWT and a moderately large effect on gait speed.

Radder et al. Neurorehabil Neural Repair 2020

SDTT:
total walking distance 266 (82) m - 726 (93 ($P < 0.001$).
maximum 1.9 (0.75) km/h - 2.61 (0.77) km/h ($P < 0.001$).
Berg Balance Test ($P < 0.01$)
Dynamic Gait Index ($P < 0.01$)
Falls Efficacy Scale ($P < 0.01$).

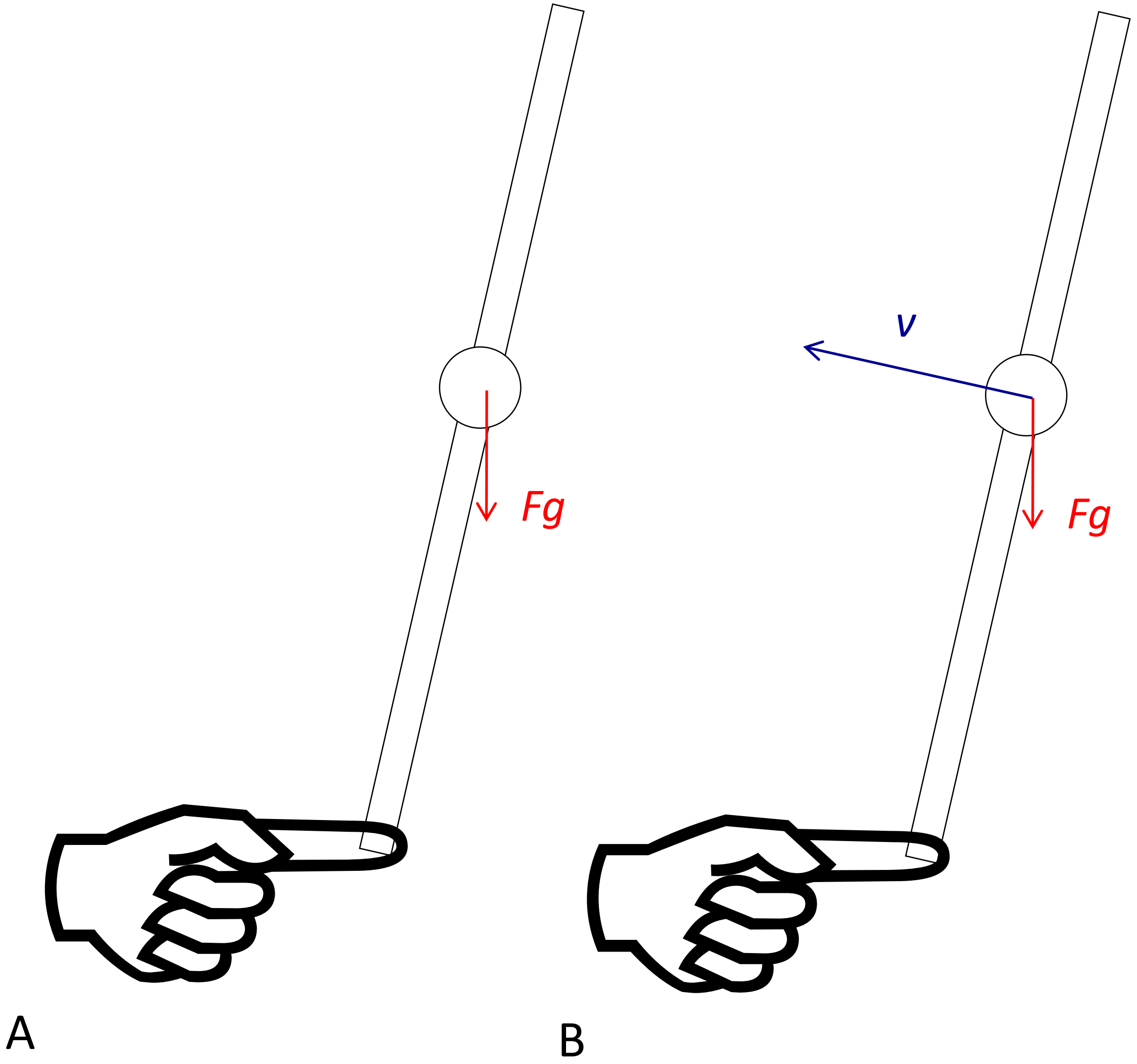
Cakit et al. Clin Rehabil 2007



improved sensorimotor integration

- decreased beta band oscillations in sensorimotor areas
- increased corticulmuscular coherence
- improved center of mass state estimation
- improved foot placement coordination

CoM state feedback



$F_{(i)} = \beta_1 \cdot P_{CoM(i-\delta)} + \beta_2 \cdot v_{CoM(i-\delta)} + c + \varepsilon$

i = phase (% stride)
δ = feedback delay (% stride)

β_1, β_2 = position and velocity feedback gains

position and velocity feedback are needed

control mechanisms

shifting the CoP

changing angular momentum

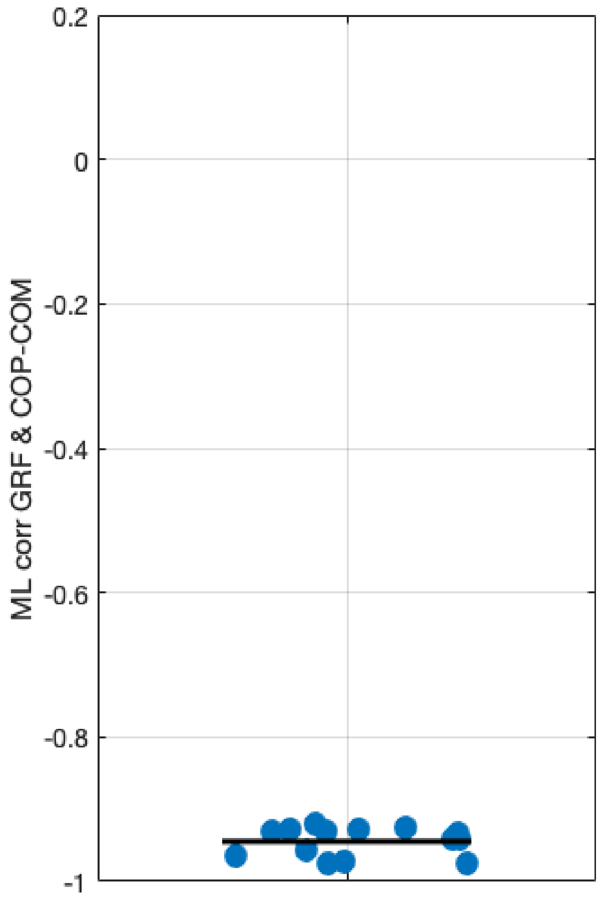
$$\frac{-(r_{CoP} - r_{CoM''}) \times F_g + \frac{dH}{dt}}{(r_{CoM} - r_{CoM''})} = m a_{CoM}$$

Hof J Biomech 2007
van Dieën & Lemaire J Biomech 2023

correlation CoP-CoM and F_{hor}

shifting the CoP

$$\frac{-(r_{CoP} - r_{CoM''}) \times F_g + \dfrac{dH}{dt}}{(r_{CoM} - r_{CoM''})} = m a_{CoM}$$

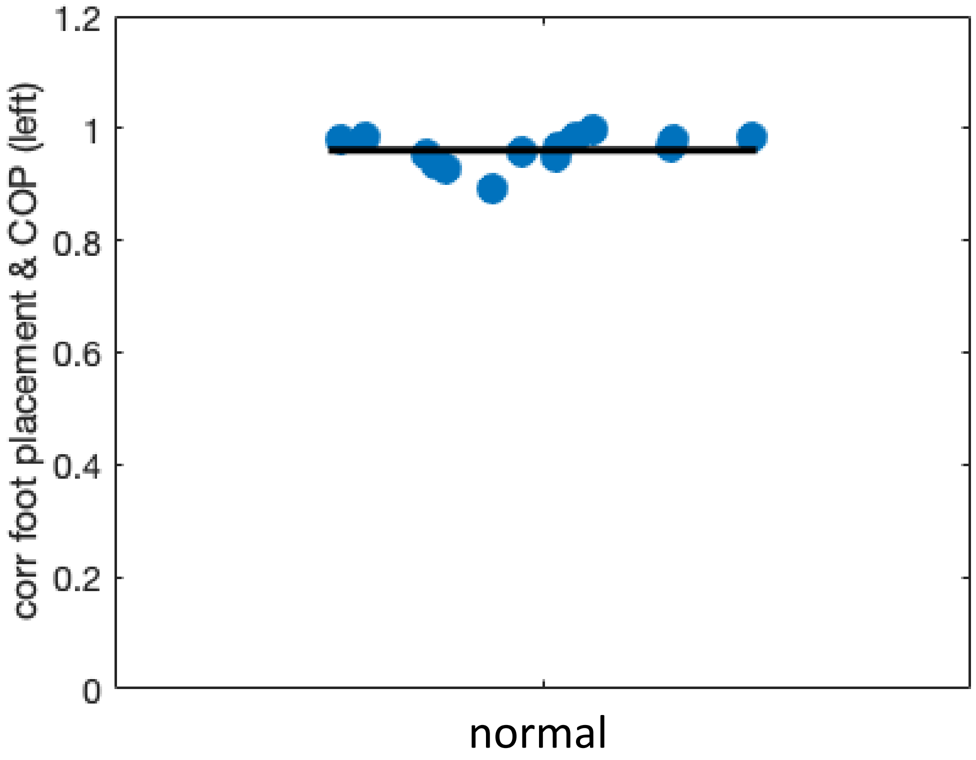


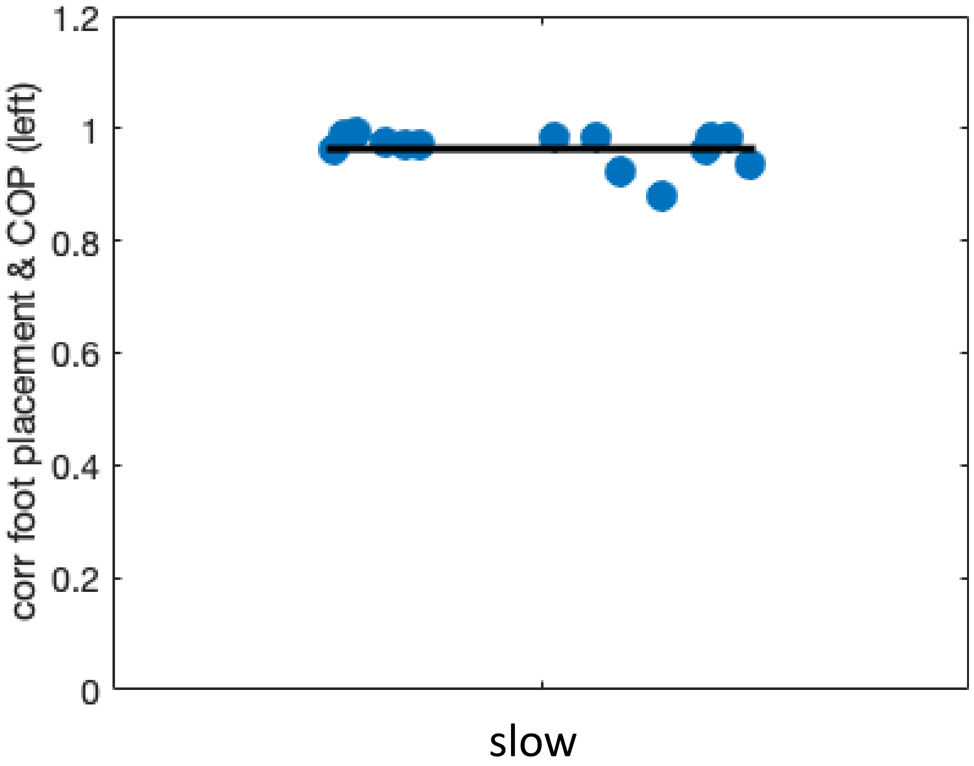
shifting the CoP is the dominant mechanism in the control of the CoM

F ~ (CoP – CoM)

c.f. van den Boogaart et al. J Biomech 2020; 2022

CoP and foot placement

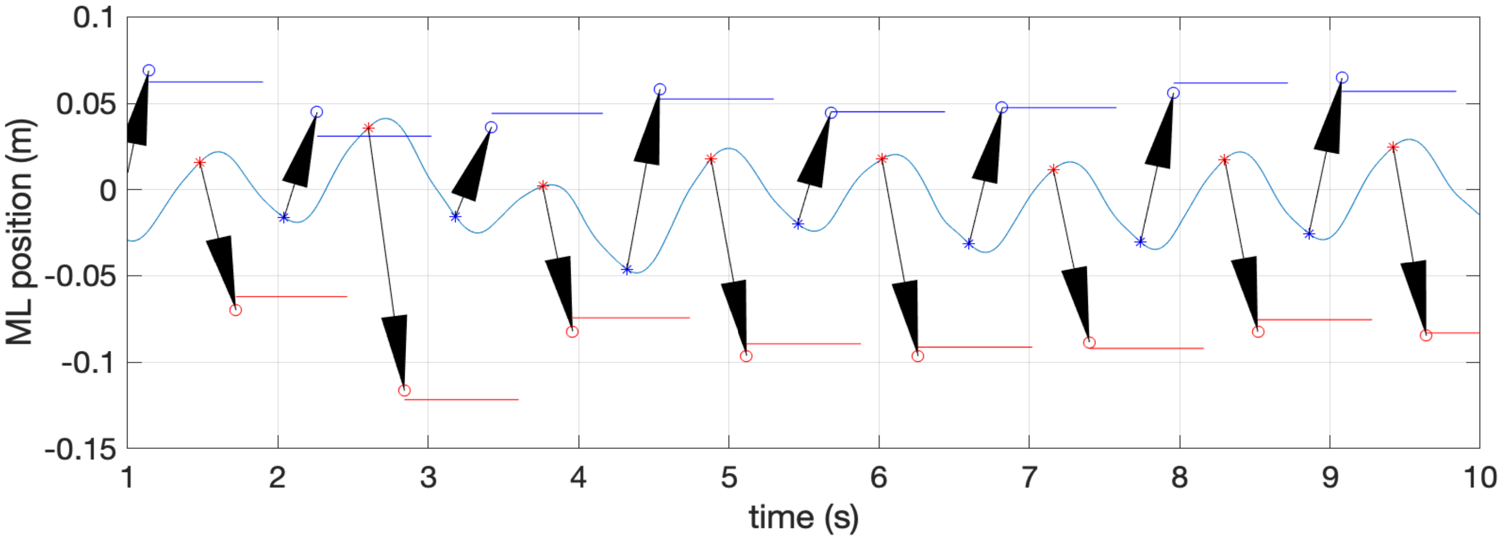


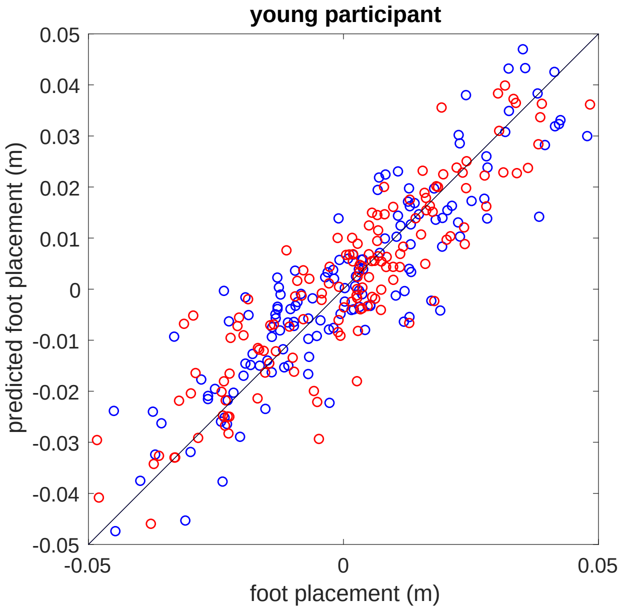


between-step variance CoP is due to foot placement

F ~ (CoP – CoM) ~ (FP – CoM)

foot placement coordination, ML





$FP = \beta_{1s} \bullet P_{COM(MidSwing)} + \beta_2 \bullet v_{COM(MidSwing)} + \varepsilon$

12 healthy young adults
preferred speed

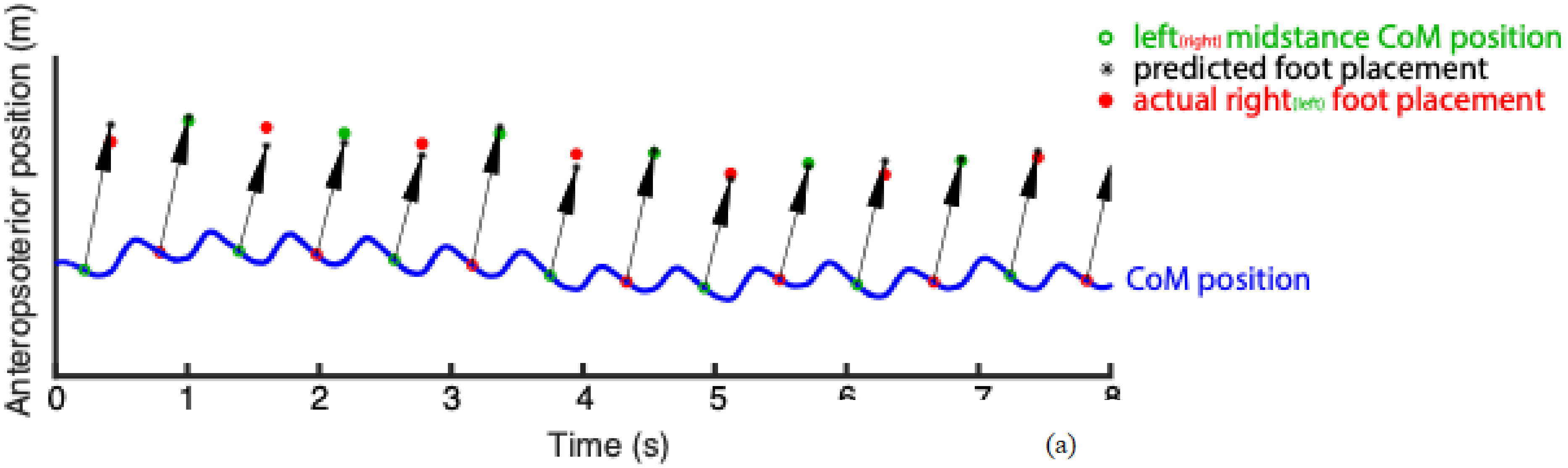
$R^2 = 0.73$ (SD 0.11)

β_1, β_2 = position and velocity feedback gains

R^2 and RMS(ε) quantify quality of control

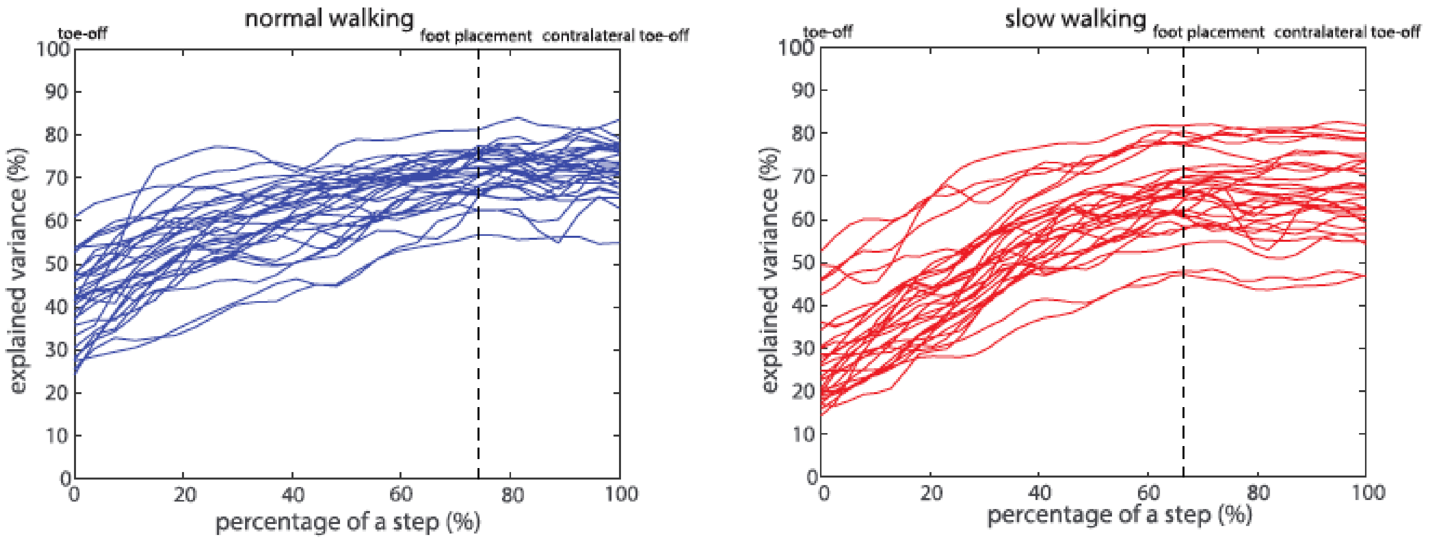
Arvin et al. Front Physiol 2018
cf. Hurt et al. J Biomech 2010
Wang & Srinivasan Biol Lett 2014

foot placement coordination, AP



(a)

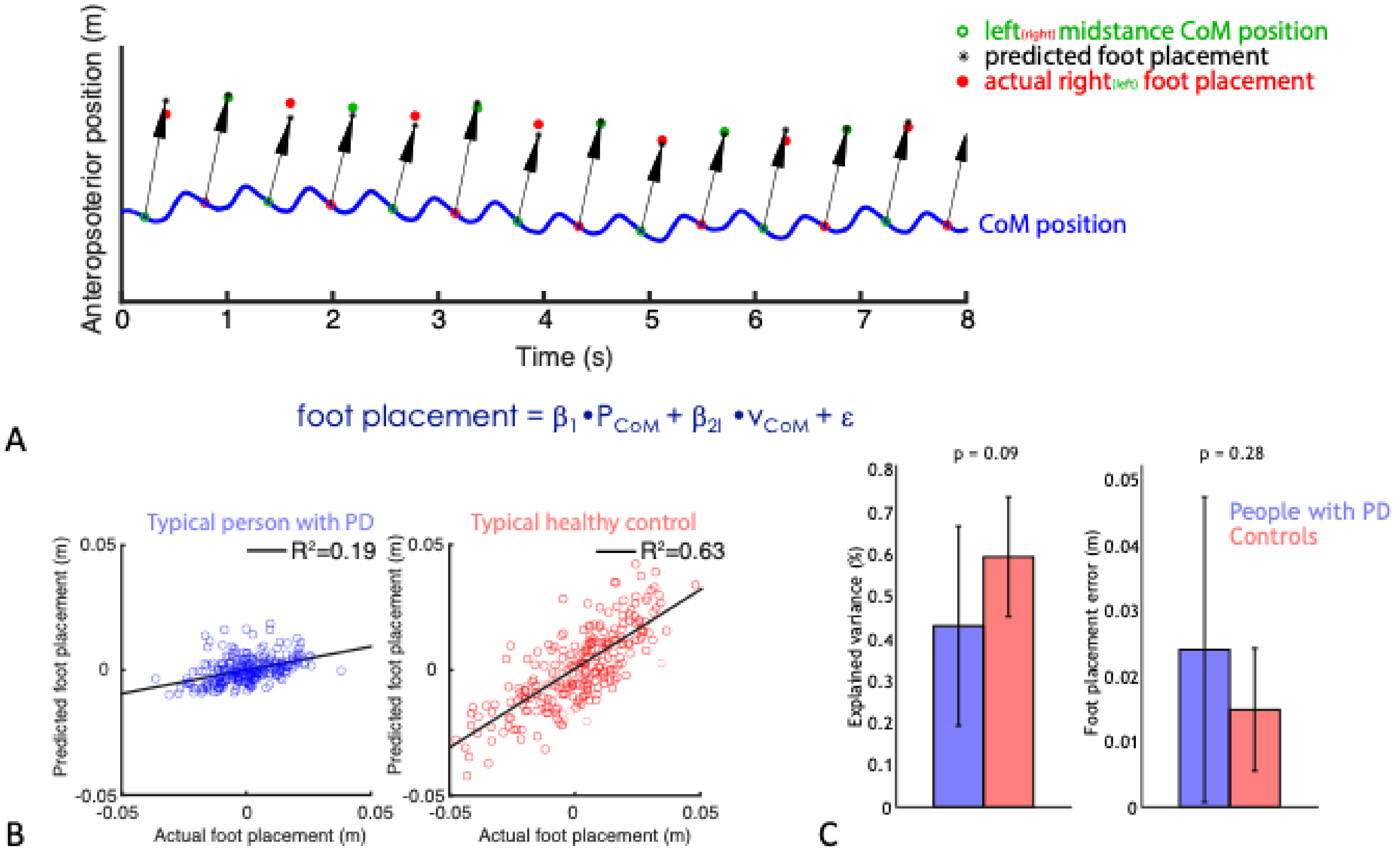
(b)



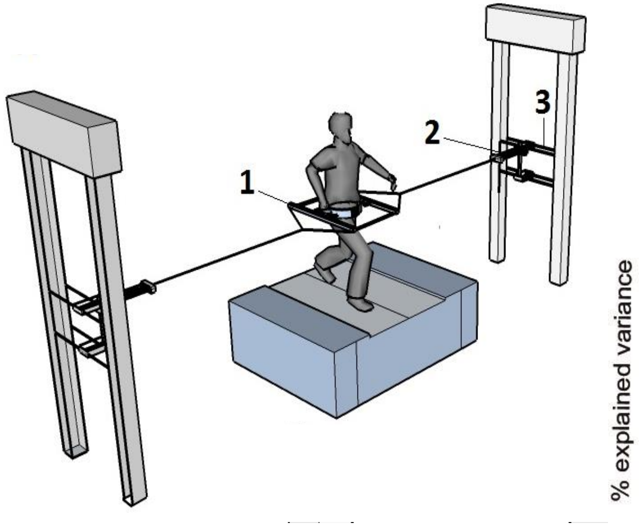
$$FP = \beta_1 \bullet P_{COM(i)} + \beta_2 \bullet v_{COM(i)} + \varepsilon$$

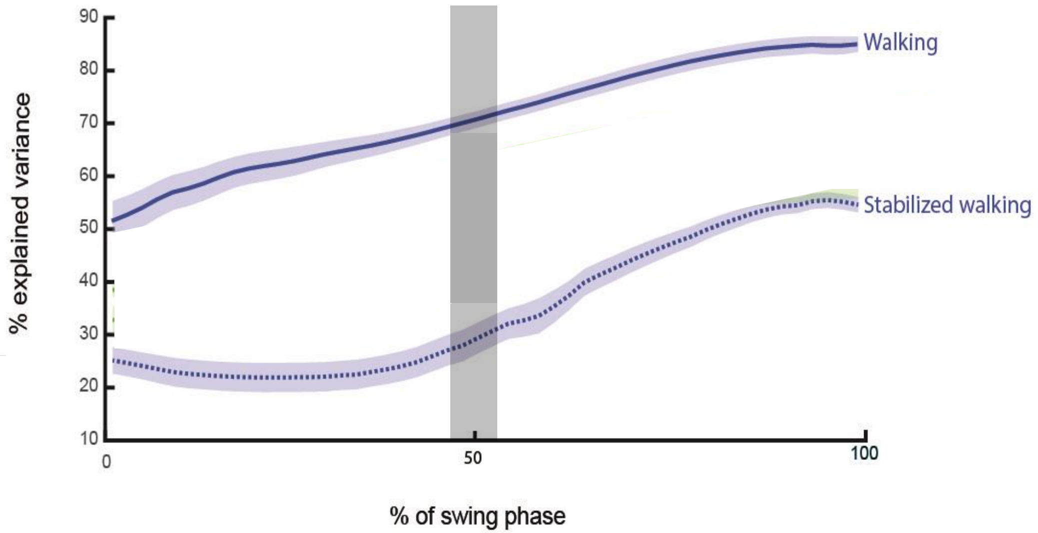
Jin et al. PeerJ 2023

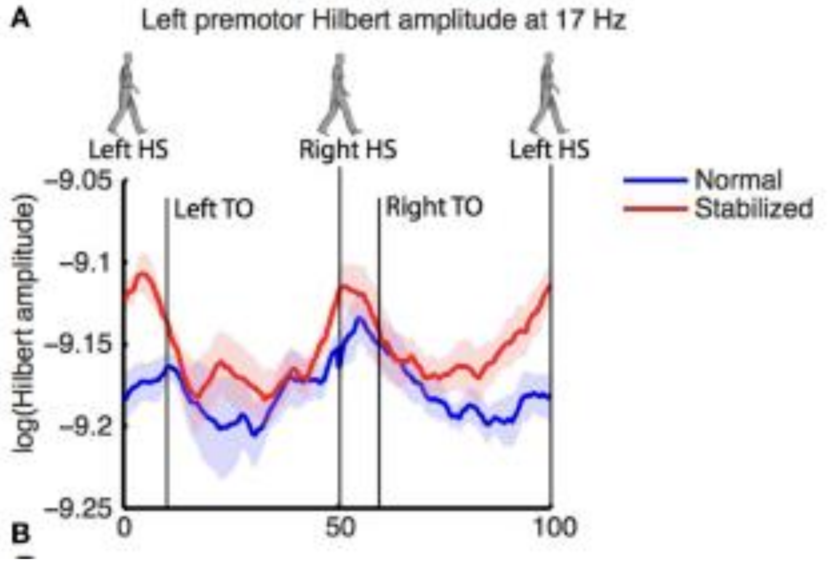
foot placement coordination in PD



effects of external mediolateral stabilization







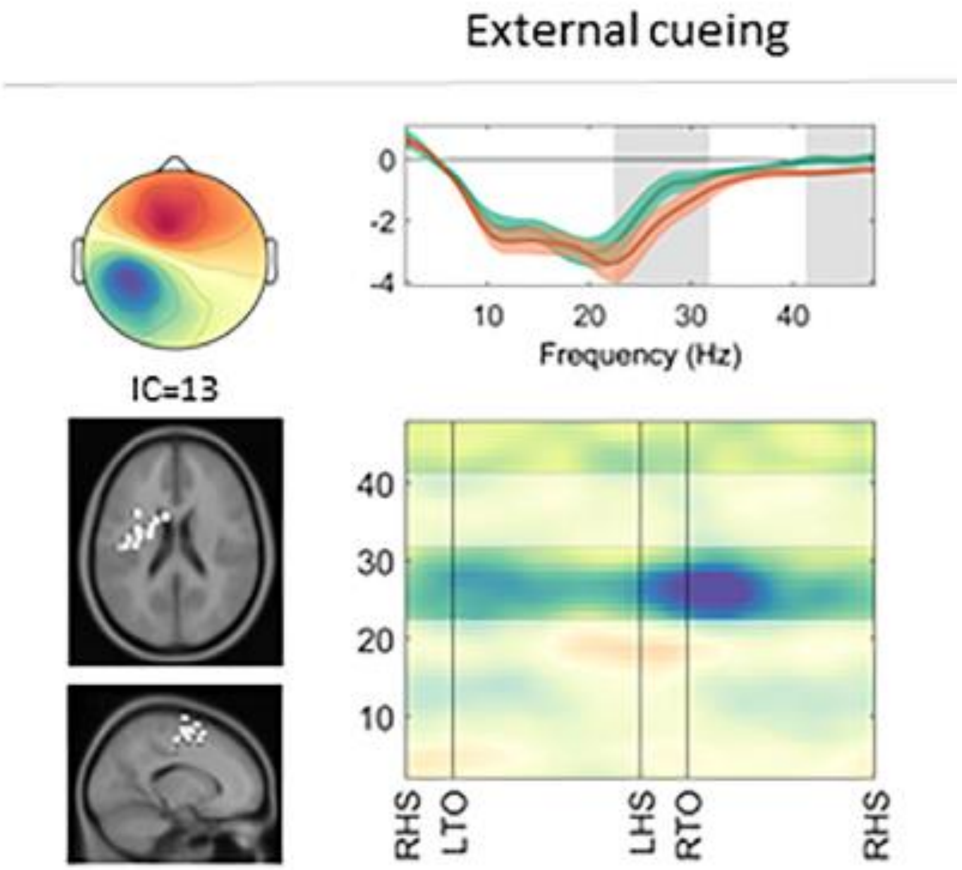
$$FP = \beta_1 \bullet P_{COM(i)} + \beta_2 \bullet v_{COM(i)} + \varepsilon$$

Mahaki et al. PeerJ 2019

Bruijn et al. Front Hum Neurosci 2015

mediolateral foot placement coordination decreases
beta oscillations increase (decreased processing)

effects of cueing on beta oscillations in PD



one of three clusters in sensorimotor area

mean stride time variability (in CV, %):
- 2.38 (SD = 0.82, range = 1.41–4.48) normal waling,
- 2.30 (SD = 0.73, range = 1.21–4.16) externally cued

all participants reported subjective improvement

decrease in beta oscillations:
- walking vs standing
- cued walking vs walking

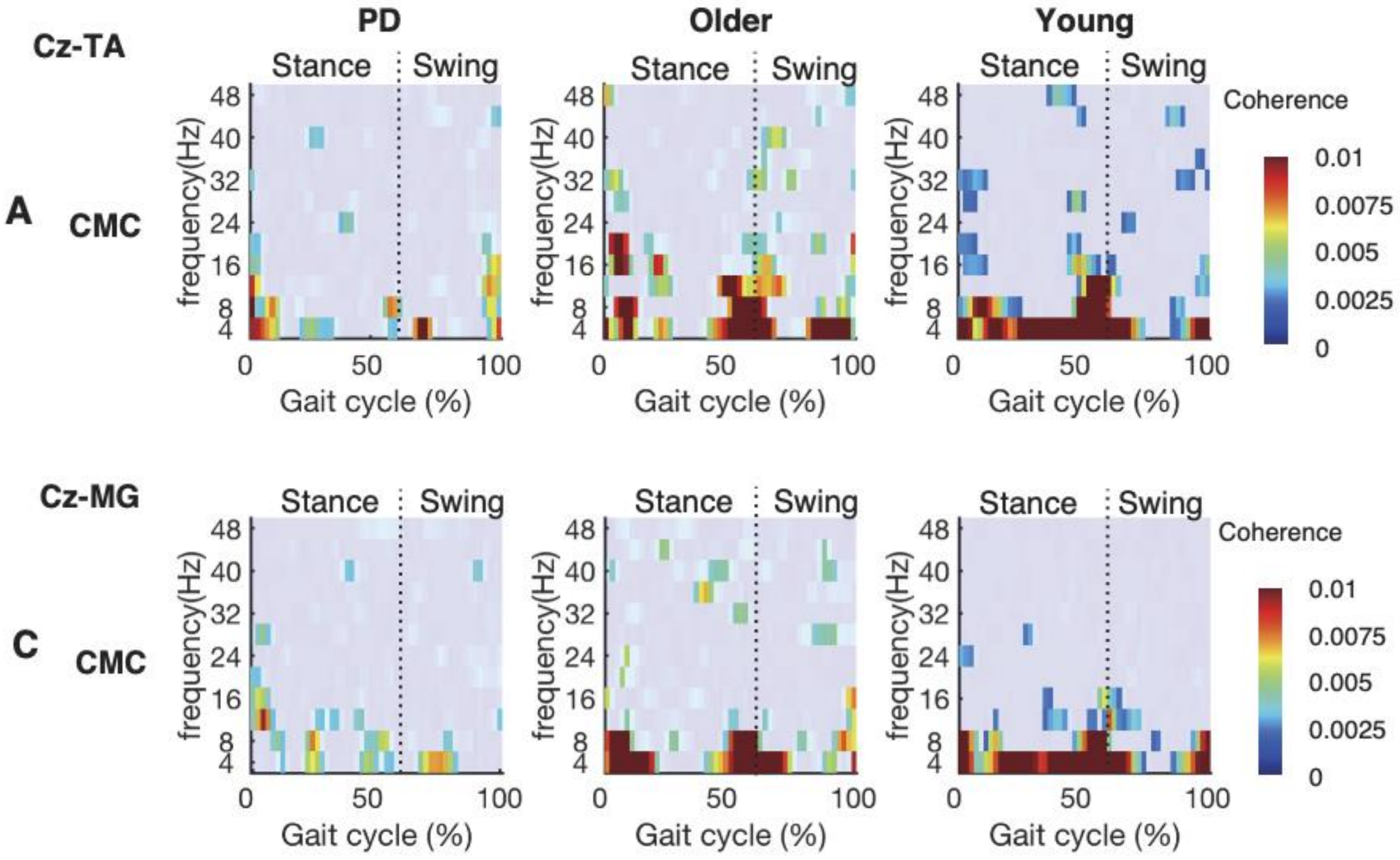
Tosserams et al. Ann Neurol 2022

cortico-muscular coherence in PD

Cz-TA 90–10% gait cycle (Terminal swing to weight acceptance)

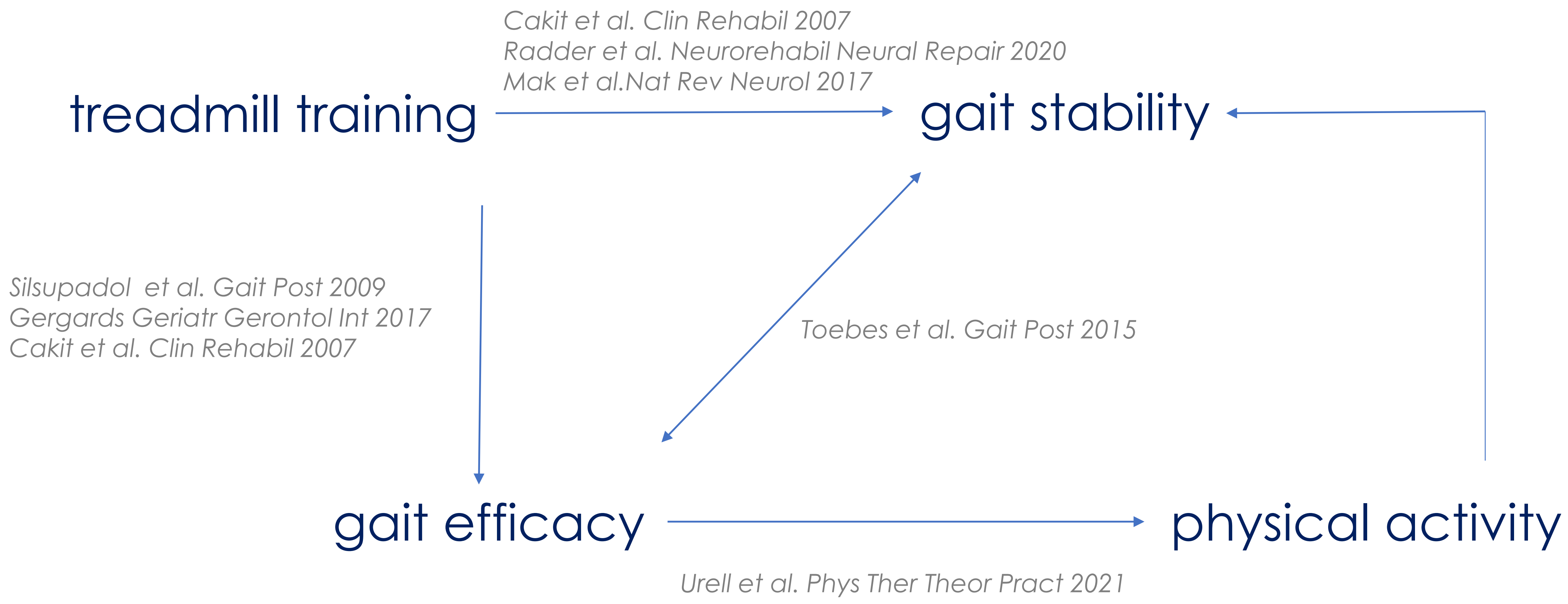
Cz-TA 50–70% gait cycle (Pre-swing to initial swing)

Cz-MG 30–60% gait cycle (Mid-stance to pre-swing)



Yokoyama et al. J Neurophysiol 2020

improved gait efficacy and transfer to daily-life



Thanks for your attention

j.van.dieen@vu.nl

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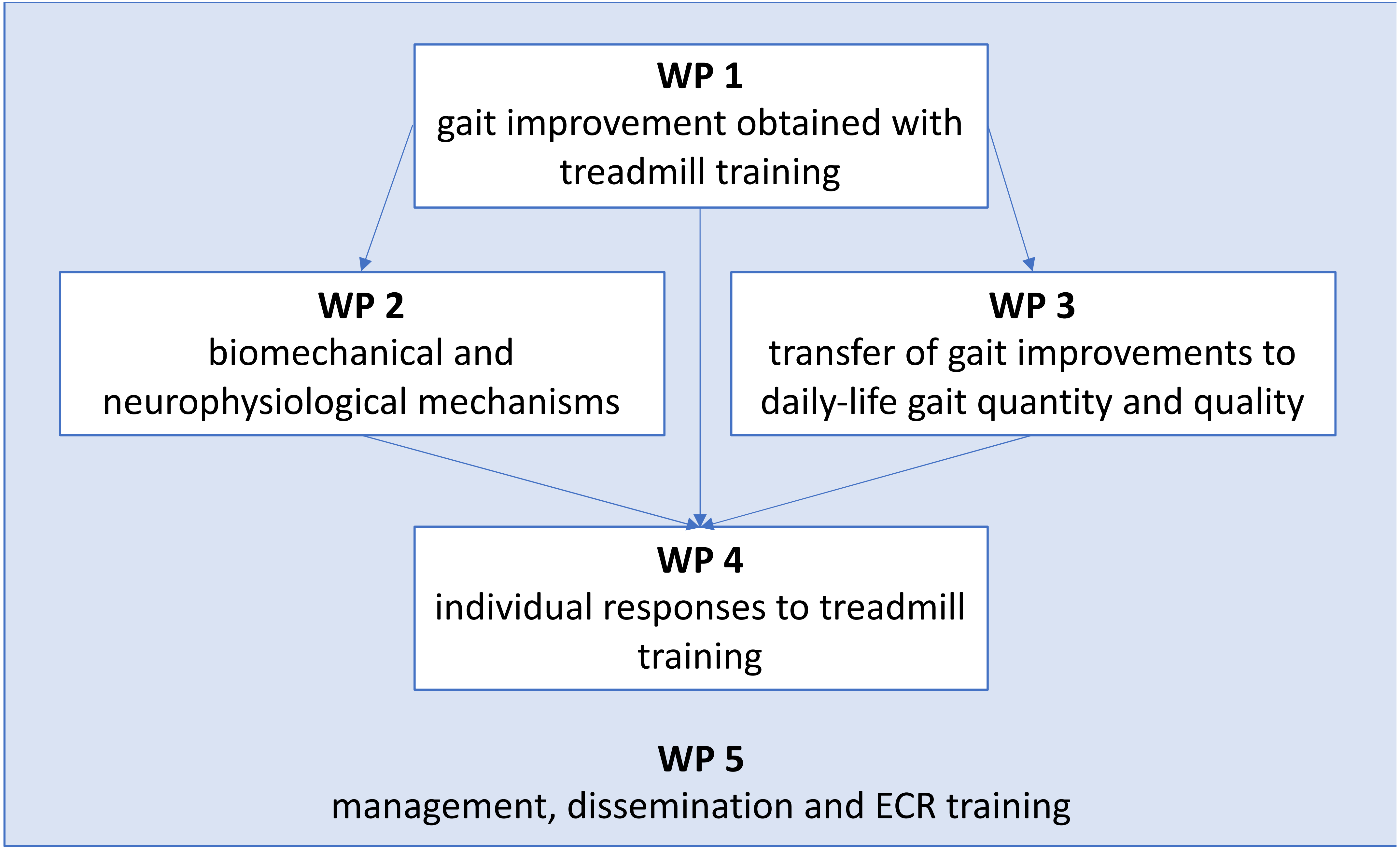
Netherlands, Vrije Universiteit Amsterdam
Germany, University Hospital Schleswig-Holstein Kiel
Israel, Tel Aviv Sourasky Medical Center
Australia, University of New South Wales
Switzerland, Swiss Federal Institute of Technology (ETH Zürich)
Italy, IRCCS Istituto delle Scienze Neurologiche di Bologna

- Comparison to no intervention: Initial total walking distance of the training group on treadmill was 266.45 82.14 m and this was progressively increased to 726.36 93.1 m after 16 training session (P < 0.001). Tolerated maximum speed of the training group on treadmill at baseline was 1.9 0.75 km/h and improved to 2.61 0.77 km/h (P < 0.001). Berg Balance Test, Dynamic Gait Index and Falls Efficacy Scale scores of the training group were improved significantly after the training programme(P < 0.01). There was no significant improvement in any of the outcome measurements in the control group (P > 0.05).
- Comparison to cued walking: Immediate within-group training effects revealed significant gains in CGS, 6MWT, and FGA for the RAC group, and in FGS, 6-MinuteWalk Test, and FGA for the SDTT group. Retention effects were found at 3-month follow-up for all gait measures in the RAC group, and for FGS and FGA in the SDTT group.
- Comparison to limited incremental treadmill training, conventional training and rest: STT and LTT improved all basic gait parameters and the double stance duration compared with preintervention values (*P*<.05). No changes were found after CGT and the control intervention (*P*<.05). Significantly higher gains were observed in all basic gait parameters after STT and LTT when compared with CGT and the control intervention (*P*<.05). Additionally, a greater reduction of double stance duration was found after STT than after the control intervention (*P*<.001). No significant differences in gains were observed between STT and LTT, or between CGT and the control intervention, in all gait parameters.


WP 1
gait improvement obtained with treadmill training
WP 2
biomechanical and neurophysiological mechanisms
WP 3
transfer of gait improvements to daily-life gait quantity and quality
WP 4
individual responses to treadmill training
WP 5
management, dissemination and ECR training

center	training intervention	control	duration
Bologna	Speed-dependent treadmill training (SDTT)	placebo	4 weeks
Kiel	SDTT+ anteroposterior perturbations	SDTT	2-3 weeks
Sydney	SDTT+ multi-directional perturbations	SDTT	4 weeks
Tel Aviv	SDTT+ VR-triggered adaptations	SDTT	4 weeks