

Biofeedback in Orthotics

Research & Application

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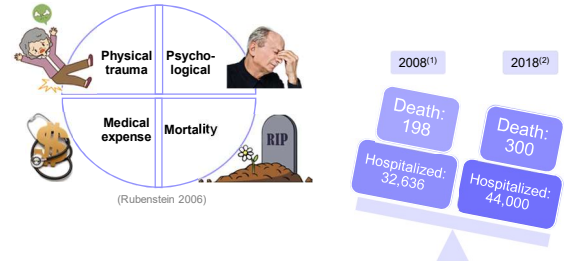
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Falls- major public problem



Source:
1. Community Fall Prevention Campaign, The Chinese University of Hong Kong, 2010
2. Society for Community Organization, 2019

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Handling of fall cases in HK

“Fall prevention clinic” & “Screening program”
(Hong Kong Department of Health, 2019) (Society for Community Organization, 2019)

- “Prevent-after-fall”

Conventional balance training

- Huge demands for manpower
- Cumbersome devices (Janssen et al. 2010)



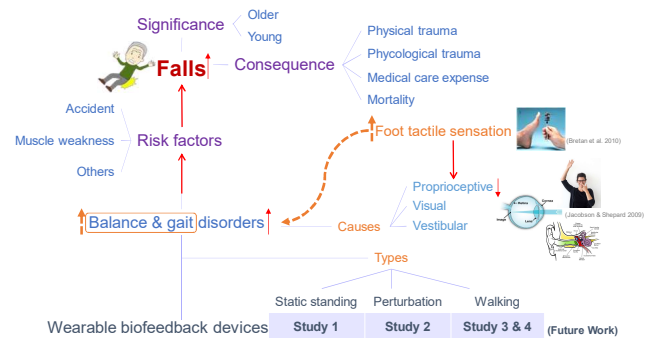
Wearable system?

(Ma et al. Sensors, 2016, 16(4): p. 434.) Christina Zong-Hao MA

(uku i.com, 2019)

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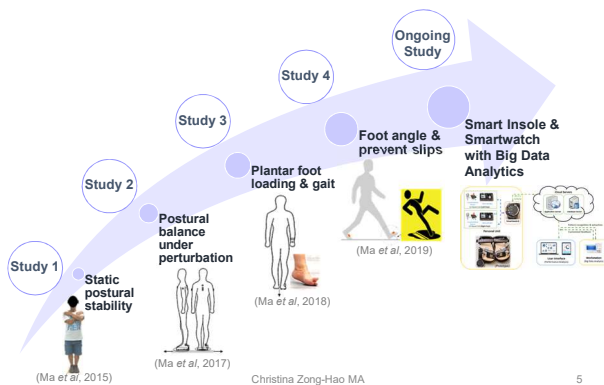
Balance improvement



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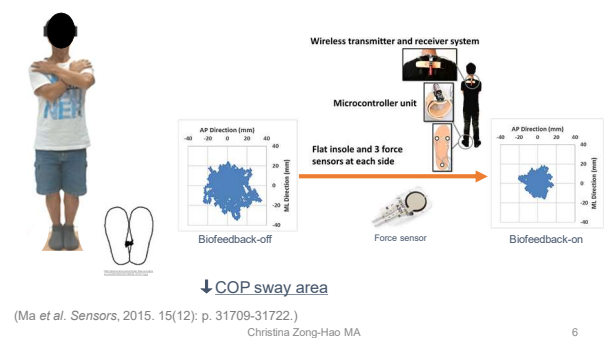
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Balance improvement



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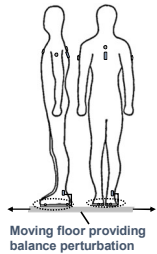
Static postural stability Study 1



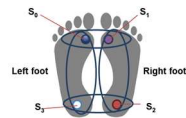
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Postural balance under perturbation

Study 2



- Tackle more challenging tasks
- Most falls: dynamic situation (Tideksaar 2010)
- Acceleration / Deceleration of bus/ship...



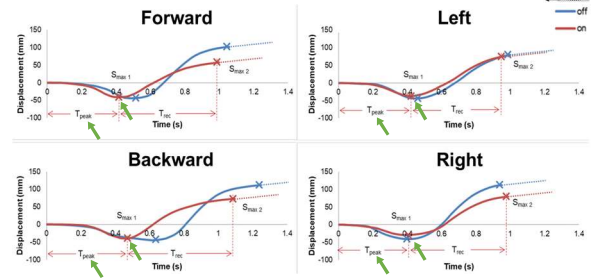
(Ma et al. Human Movement Science, 2017, 55: p. 54-60.)

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Postural balance under perturbation

Study 2

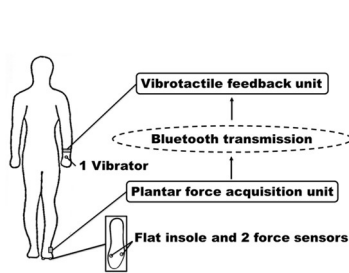
↓ COM displacement ($S_{max1} > 10\%$)

↓ reaction time while standing with perturbation

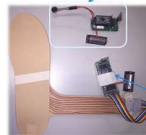
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Plantar foot loading & gait

Study 3



Vibrotactile feedback unit



Plantar force acquisition & processing unit

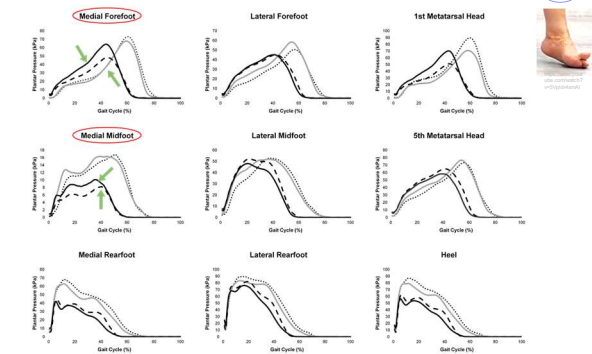
(Ma et al. Topics in stroke rehabilitation, 2018, 25(1): p. 20-27)

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Plantar foot loading & gait

Study 3

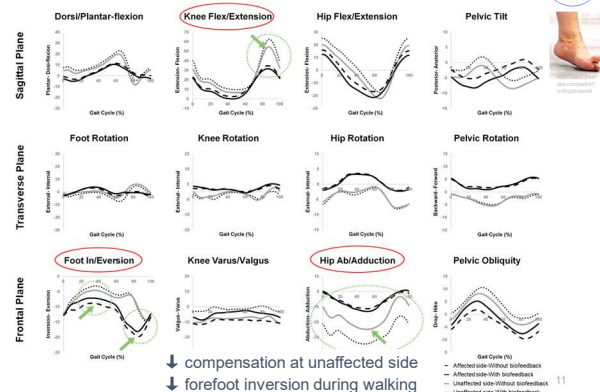


↑ plantar foot loading

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Plantar foot loading & gait

Study 3



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Foot angle & prevention of slips in gait

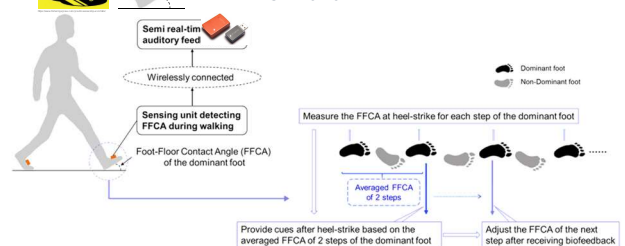
Study 4



Foot-floor Contact Angle (FFCA) > 20° → ↑ Slip

(Cham & Redfern, 2002; Chambers, et al., 2002).

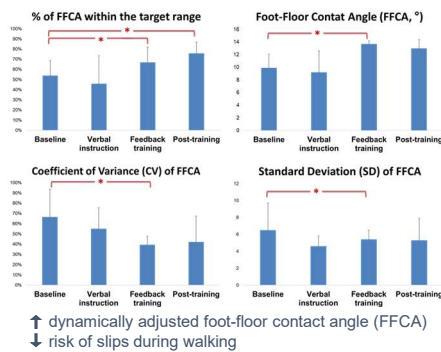
Desired FFCA: 10-20°



(Ma et al. ISPRG World Congress, 2019) Christina Zong-Hao MA

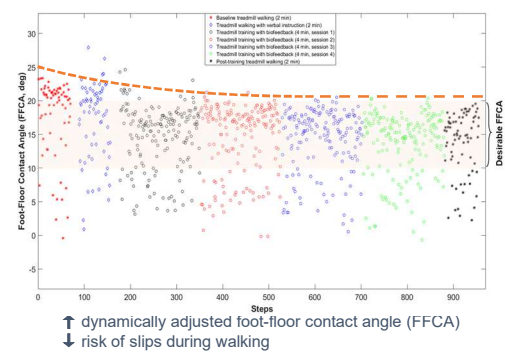
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Foot angle & prevention of slips in gait



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Foot angle & prevention of slips in gait



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Balance / Gait improvement

➤ New intervention strategy for improving balance and gait control, i.e. supplementing foot sensory input

- young & older adults &
- patients with stroke. (Ma et al, 2015, 2017, 2018, 2019)

➤ Potentially reduce the risk of falls.

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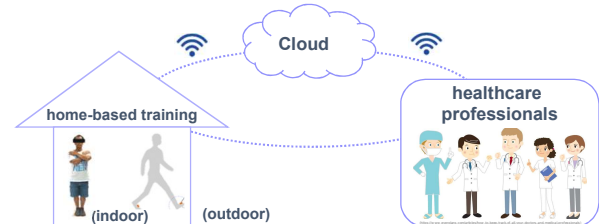
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Balance / Gait improvement

➤ Repetitive targeted gait training & motor control in both indoor & outdoor environments.

(Ma et al, 2015, 2016, 2017, 2018, 2019)



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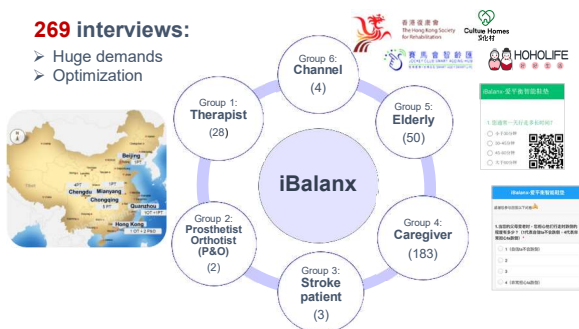
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Knowledge transfer (iBalanx)

269 interviews:

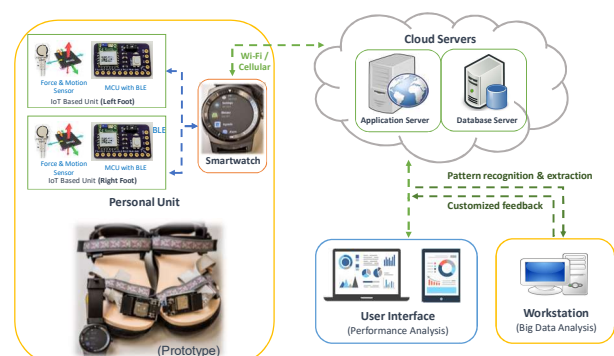
- Huge demands
- Optimization



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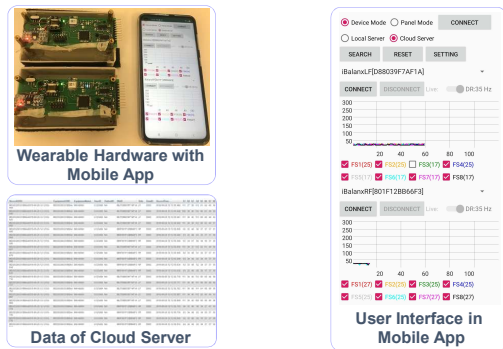
Ongoing Work (iBalanx)



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Ongoing Work (iBalanz)

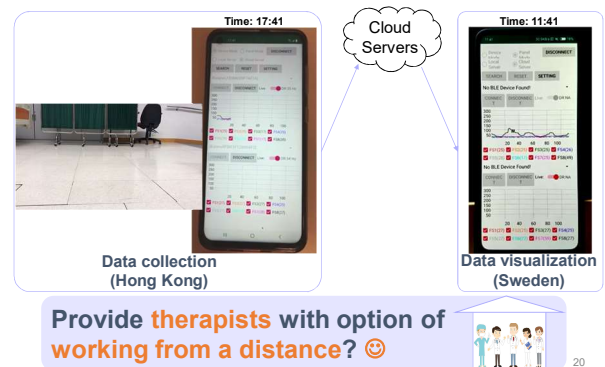


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Ongoing Work (iBalanz)

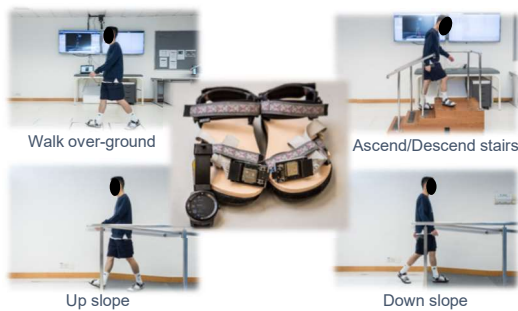


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Ongoing Work (iBalanz)

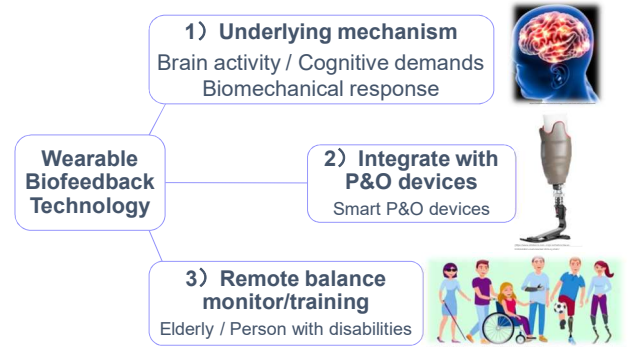
- 1) Daily activities
- 2) Training tasks



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Future directions



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In the future...

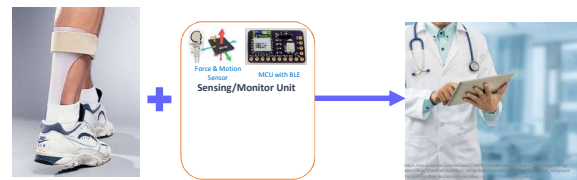


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In the future...



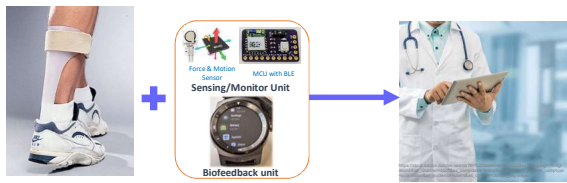
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- Monitor
 - Objective assessment of orthotic fitting?
 - Remote monitor of orthoses?
 - Progressive adjustment of orthosis?

In the future...



- Monitor + Biofeedback
 - Objective reminder of balance & gait?
 - Remote balance & gait training?
 - Prevent falls?

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Benefits...



- Assist objective evaluation of orthotic fitting
- Enable remote monitor/evaluation
- Improve follow-up & progressive adjustment of orthoses
- Build up a balance & walking ability database
- Early detection of poor balance/gait & advance warning

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Take-home message



- Wearable biofeedback devices to improve balance & gait, & prevent falls
- → Future smart orthoses with monitoring & biofeedback function to
 - assist objective evaluation of orthotic fitting
 - monitor & improve balance & gait
 - assist balance & gait training

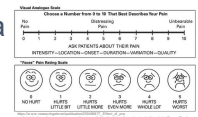
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Limitation & Some thoughts...

- Ethics
 - Privacy of persons
 - Protection of data
- User-friendly of the system
- Scales of assessment criteria
- In lab setting only
- Short-term effect only
- Small sample size (≤ 30)...

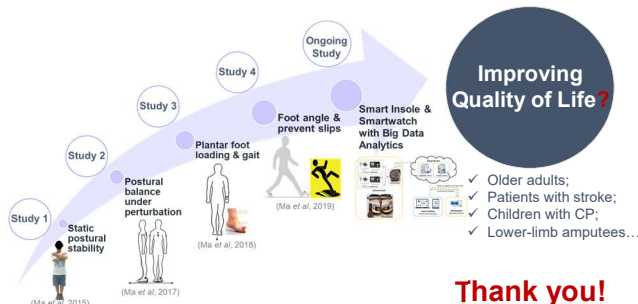


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Acknowledgement



- HKSTP STEP Pre-Incubation Programme (STEP ID: 219)
- PolyU Research Studentship (RTNR)
- Innovation and Technology Commission (ITS/I30/13)

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Thank you!



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Publications

Peer-reviewed Journal Papers (SCI)

- 1) Ma C.Z.-H., Zheng Y.-P., & Lee W.C.-C.* (2018). Changes in gait and plantar foot loading upon using vibrotactile wearable biofeedback system in patients with stroke. *Topics in Stroke Rehabilitation*. 2017, 25 (1): 20-27; DOI: 10.1080/10749357.2017.1380339.
- 2) Ma C.Z.-H., & Lee W.C.-C.* (2017). A wearable vibrotactile biofeedback system improves balance control of healthy young adults following perturbations from quiet stance. *Human Movement Science*. 2017, 55: 54-60; DOI: 10.1016/j.humov.2017.07.006.
- 3) Ma C.Z.-H., Wong D.W.-C., Lam W.-K., Wan A.H.-P., & Lee W.C.-C.* (2016). Balance improvement effects of biofeedback systems with state-of-the-art wearable sensors: a systematic review. *Sensors*. 2016, 16 (4), 434; DOI: 10.3390/s16040434.
- 4) Ma C.Z.-H., Wan A.H.-P., Wong D.W.-C., & Lee W.C.-C.* (2015). A vibrotactile and plantar force measurement-based biofeedback system: Paving the way towards wearable balance-improving devices. *Sensors*. 2015, 15, 31709–31722; DOI: 10.3390/s151229883.

Patent

- 5) Ma C.Z.-H., Zheng Y.-P. & Huang Z. (2018). Big data and machine learning based smart wearable biofeedback system for repetitive targeted balance and gait training. Chinese Patent (Filed Aug 2018, Ref: 201811005548.X).

Conference abstract

- 6) Ma C.Z.-H., Bao T., Le V., Chambers A., Shull P., Zheng Y.-P., Cham R., Sienko K.H.* (2019). A feasibility study for gait training with foot-floor contact angle feedback. International Society of Posture and Gait Research (ISPGR) World Congress 2019, 30 June-4 July, Edinburgh, Scotland.

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