

Advanced Opportunities in KAFO Fittings: SCO and SSCO

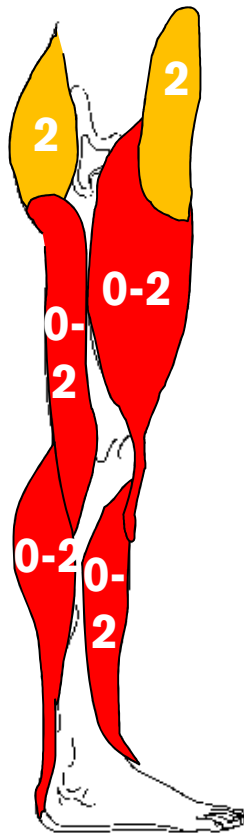
Thomas Schmalz, Heiko Drewitz



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Annual Conference
Manchester, 16 – 18 March

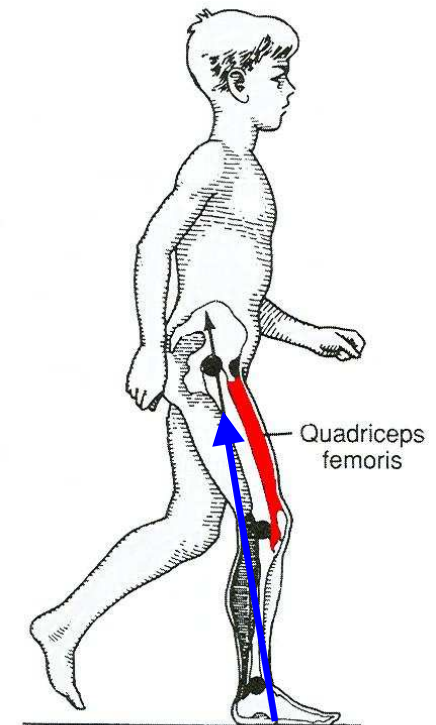


complex lower limb muscle weakness: **K**nee **A**nkle **F**oot **O**rthosis (KAFO)



impairment of patients' safety

(insufficient compensation
of moments acting externally
at knee and hip joint during ADLs)



loading response

functional task of orthosis: safety, highest possible functionality

Knee Ankle Foot Orthosis (KAFO): Principles



principle A:
free knee joint
with posterior off-set



principle B:
locked knee joint



principle C (**SCO**):
knee joint locked (stance)
and unlocked (swing)

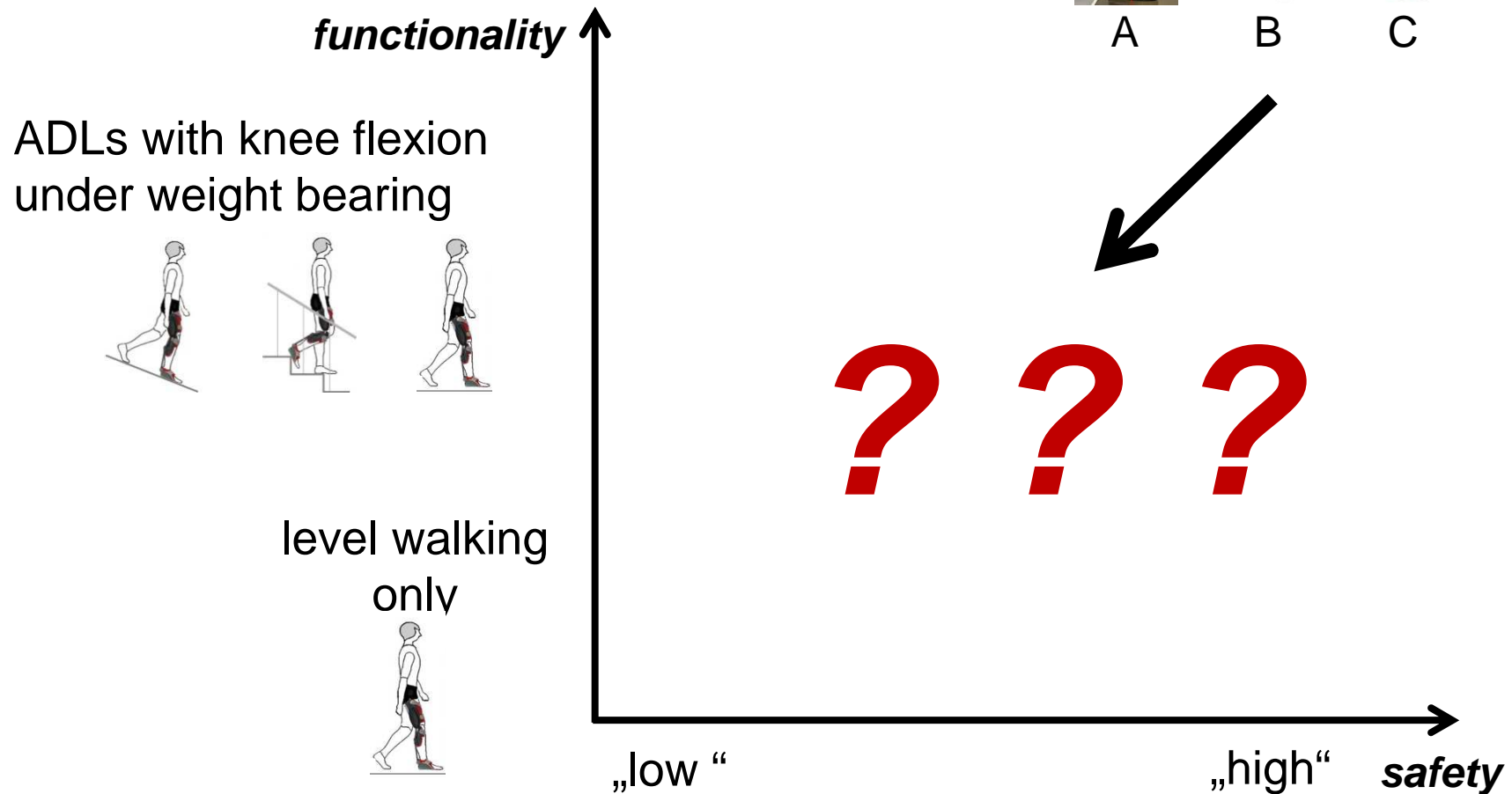


principle D (**SSCO**):
MP controlled
stance and swing
(hydraulics)

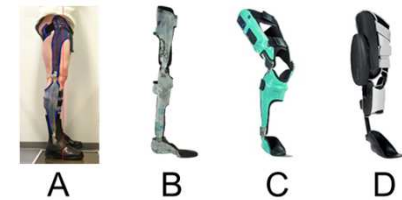
- different level of safety
- restricted functionality (level walking)
- no knee flexion under weight bearing

- safety algorithm
- knee flexion under weight bearing
- swing phase control

KAFO principles: functionality vs. safety



KAFO principles: evaluation of functionality and safety

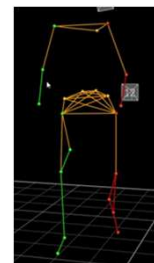


- fitting experiences

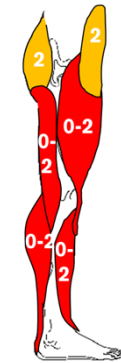


- scientific investigations: walking and standing

- biomechanical parameters
- metabolic parameters
- specific safety parameters

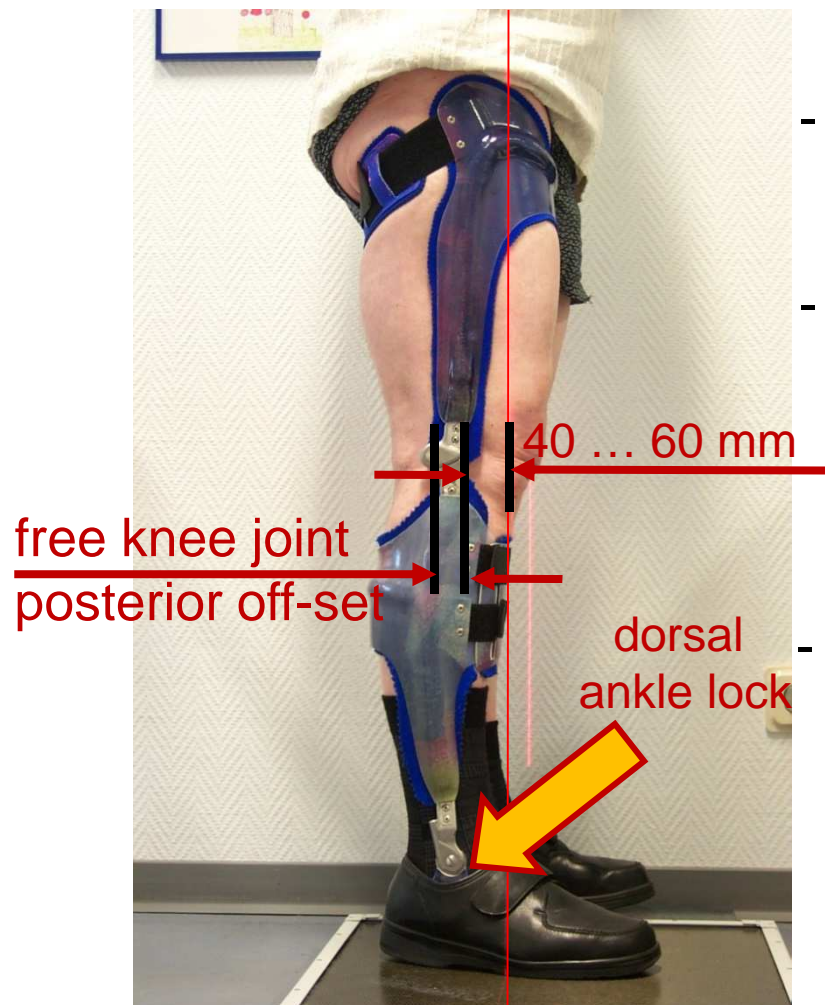


distinct knee extensor weakness: KAFO fitting



principle A: free knee joint / posterior off-set

principle A: free knee joint / posterior off-set



- individual KAFO (free joint / dorsal ankle lock)

- essential: alignment !

- limited safety level

functionality: walking on even ground

principle A: free knee joint / posterior off-set



distance load line – knee axis
20mm

insufficient !

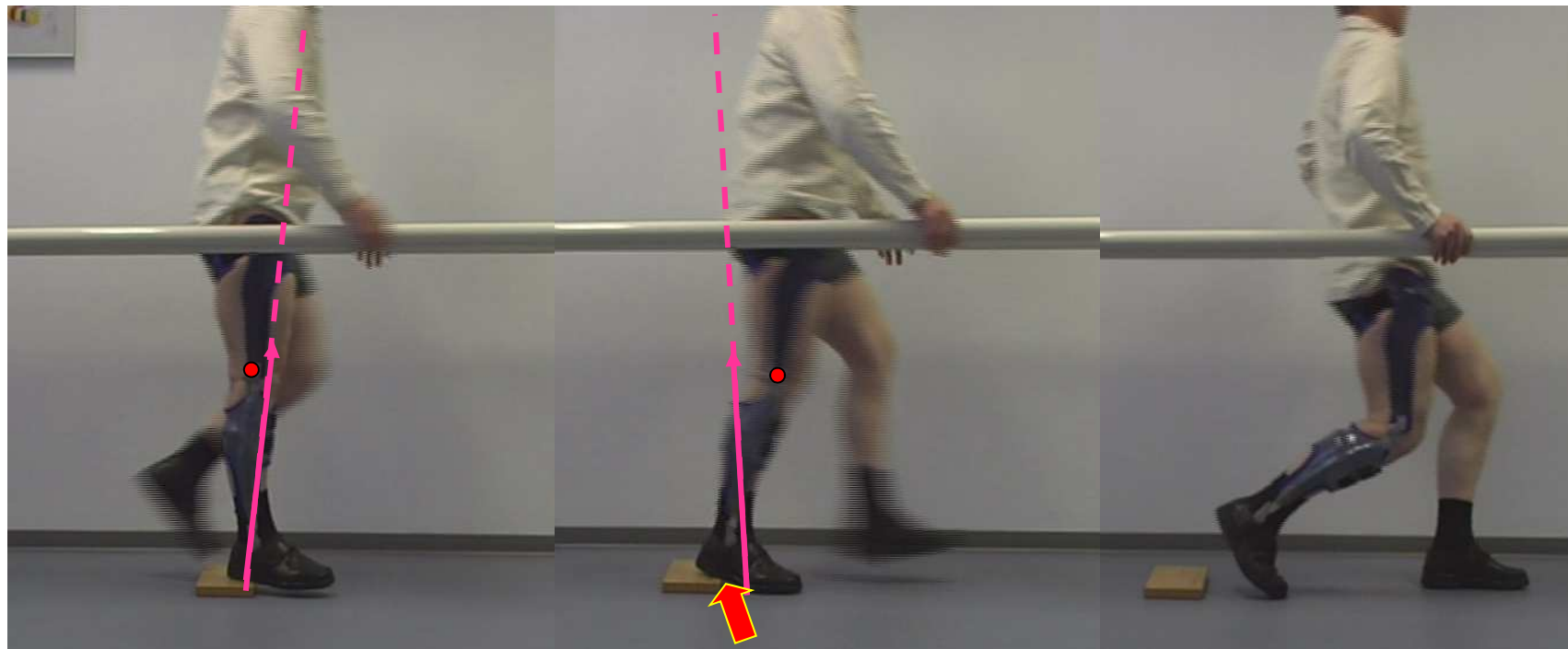


distance load line – knee axis
45mm

recommendation !

principle A: free knee joint / posterior off-set

→ walking on uneven ground: principle A insufficient

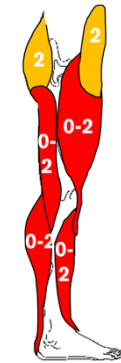


knee extension moment
generated by GRF

knee flexion moment
generated by GRF

risk of falling

distinct knee extensor weakness: KAFO fitting



principle B: completely locked knee joint

distinct knee extensor weakness: KAFO fitting

principle B: completely locked knee joint



level walking:

- extremely safe



other ADLs:

- not possible (or extreme compensations)

completely locked knee: compensations (level walking)



1. increased frontal
pelvic motion
(„hip hiking“)



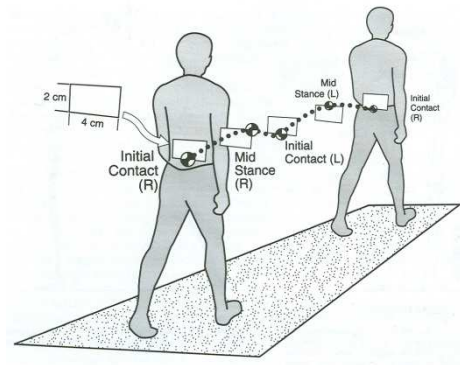
2. circumduction



3. increased sound limb
ankle joint motion
(„vaulting“)

(Perry 1992, Abdulhadi et al. 1996, Waters/Mulroy 1999, Irby et al. 2005)

completely locked knee: biomechanical consequences



normal:

medio-lateral motion: appr. 4cm

vertical motion: appr. 3 ... 5cm

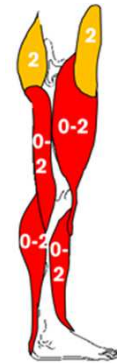
1. vertical COM motion increased about 1.5cm



2. increased metabolic energy consumption: 18 ... 23%

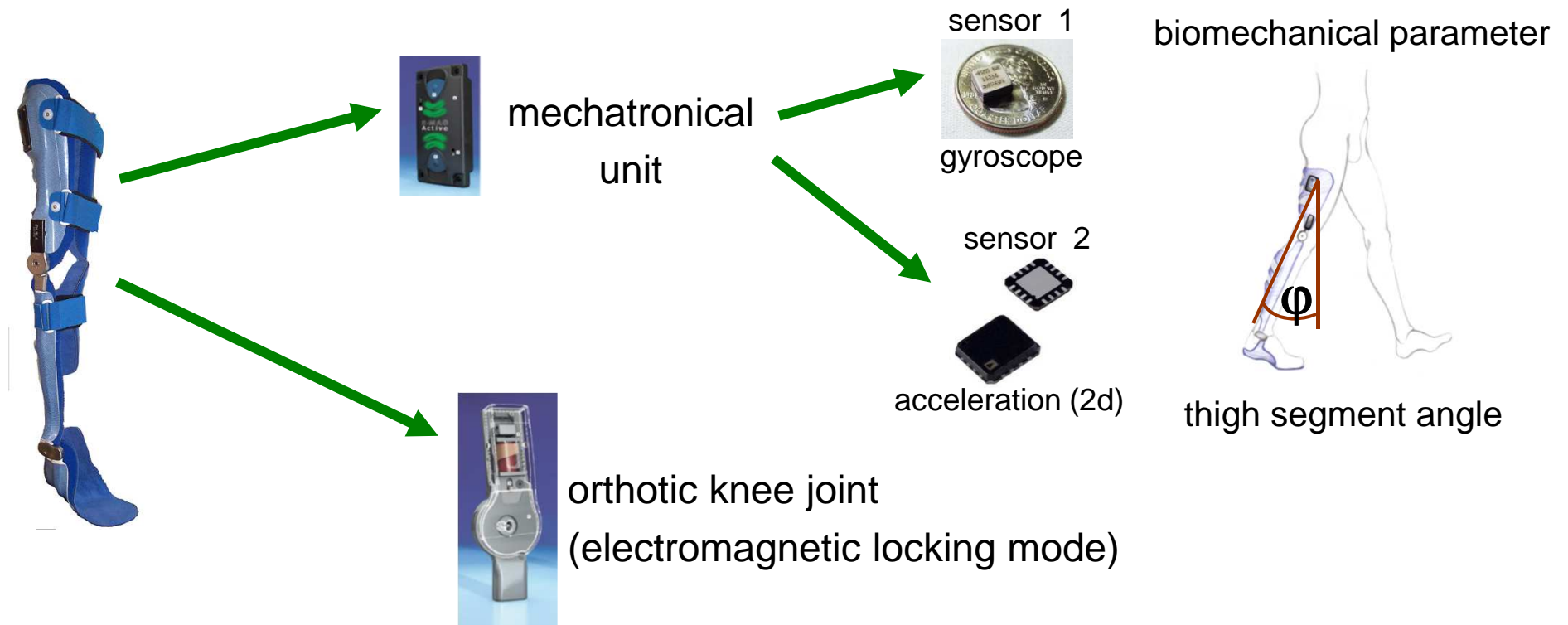
(Kerrigan et al. 1995)

distinct knee extensor weakness: KAFO fitting



principle C (SCO):
knee locked in stance, free in swing
(partly with sensors)

principle C: E-MAG Active



- unlocking: knee extension moment and thigh segment angle threshold (50 .. 55% GC)
- locking: full knee extension (95% GC)
- both locked and unlocked mode (“SCO mode”) can be tested

distinct knee extensor weakness: KAFO fitting

principle C: knee locked in stance, free in swing



- level walking:
- improved gait pattern
 - reduced level of safety



- other ADLs:
- extreme compensations
(non-physiological joint loading)

comparison: principle B vs principle C



-biomechanical parameters
-metabolic parameters

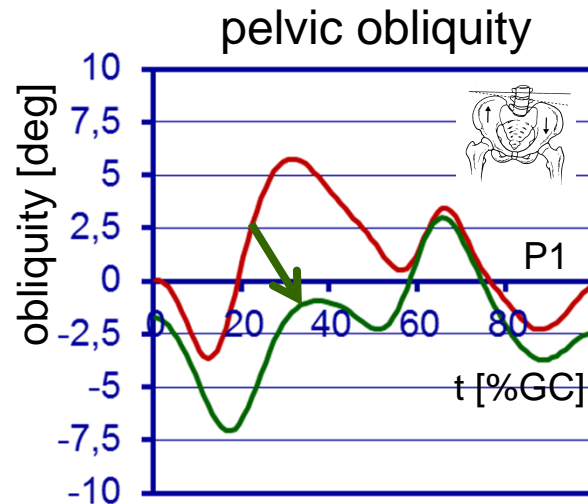
} level walking

(n=8)

comparison: principle B vs principle C

compensatory mechanisms

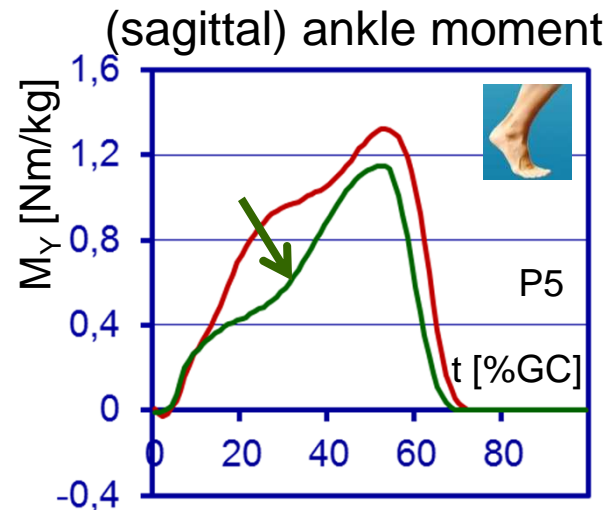
hip hiking



- locked: measured for all

- reduced with SCO: 6/8 patients

(sound side) vaulting

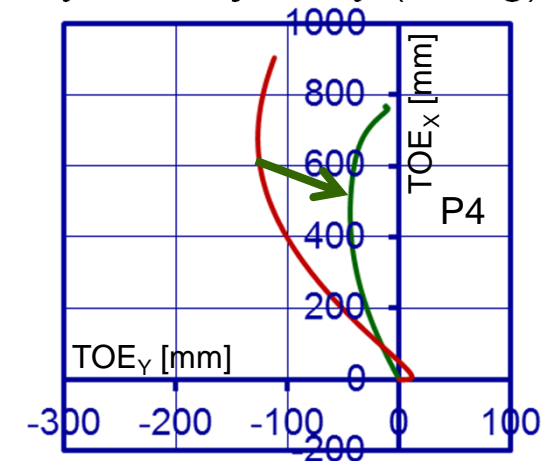


- locked: measured for 3/8

- reduced with SCO
(slightly for 2 patients)

circumduction

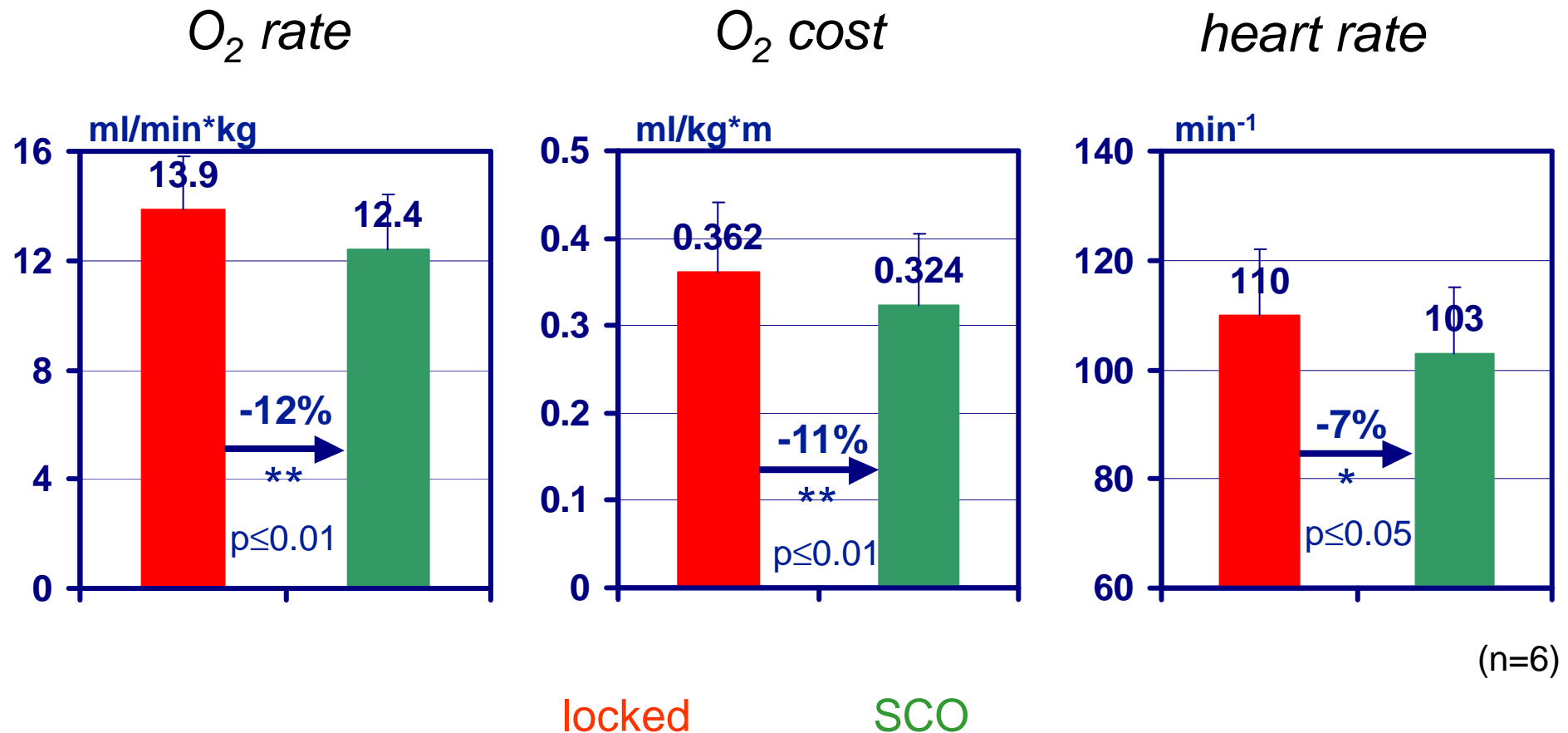
x,y toe trajectory (swing)



- locked: measured for 1/8

- reduced with SCO

comparison: principle B vs principle C
metabolic parameters



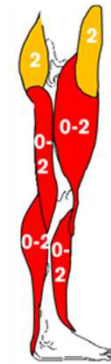
comparison: principle B vs principle C

benefit resulting from principle C:

1. reduced metabolic energy consumption (10 – 15%)
2. reduced effort for initiation of swing phase
3. natural pelvic motion
4. reduced sound limb joint loading
5. significant clinical benefit

————→ valid for level walking

distinct knee extensor weakness: KAFO fitting



principle D: SSCO
microprocessor controlled stance and swing phase
(hydraulic element)

principle D (SSCO)

microprocessor controlled KAFO:

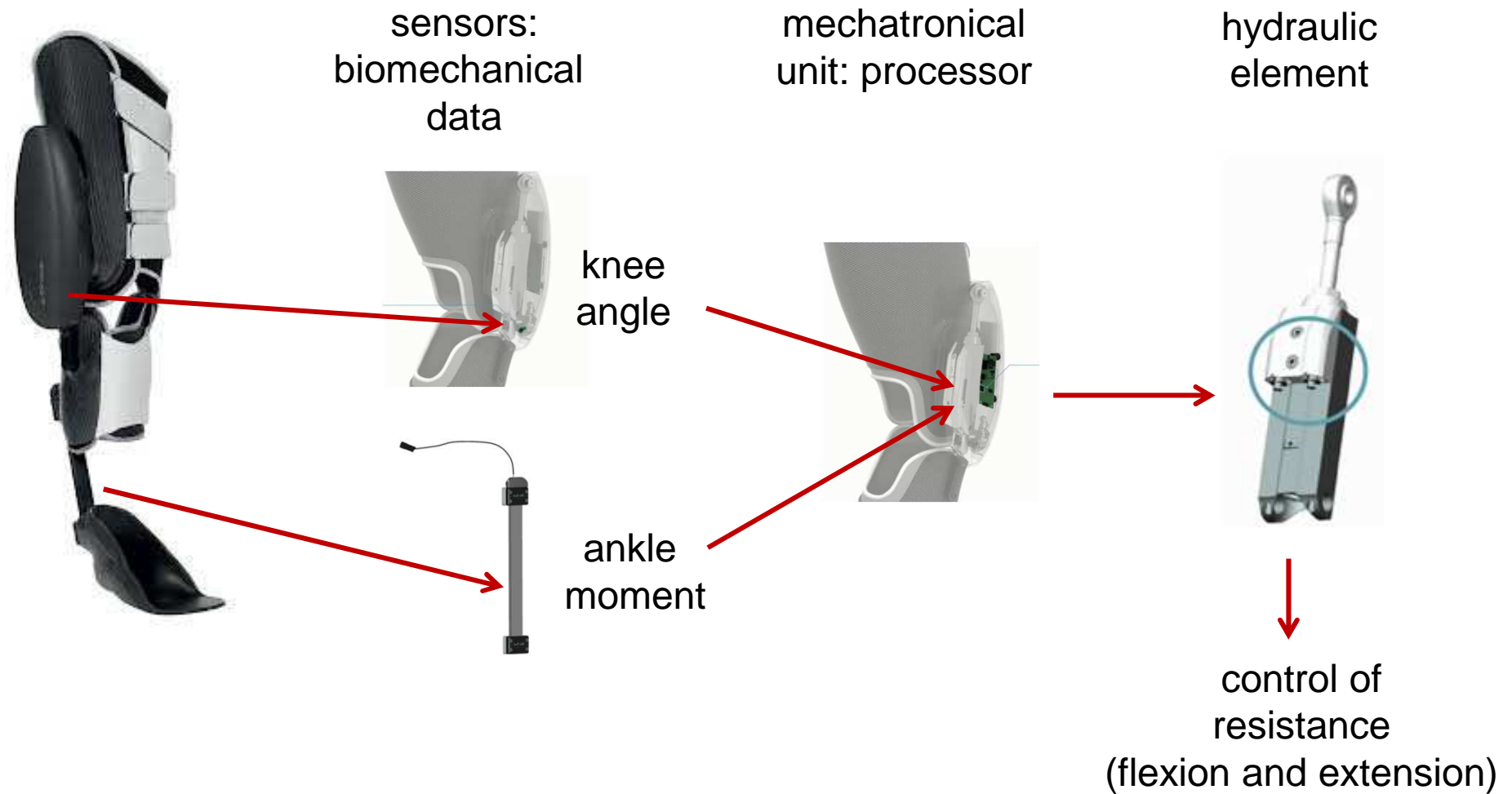
- individual control of stance and swing
- knee flexion under weight bearing (hydraulic element)



- difficult ADLs can be performed nearly natural
- high safety level

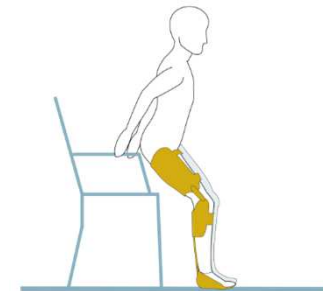
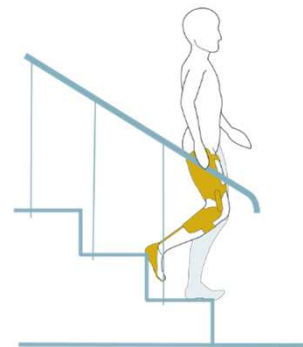
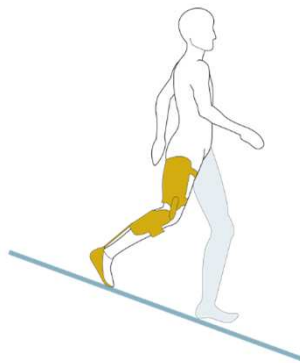


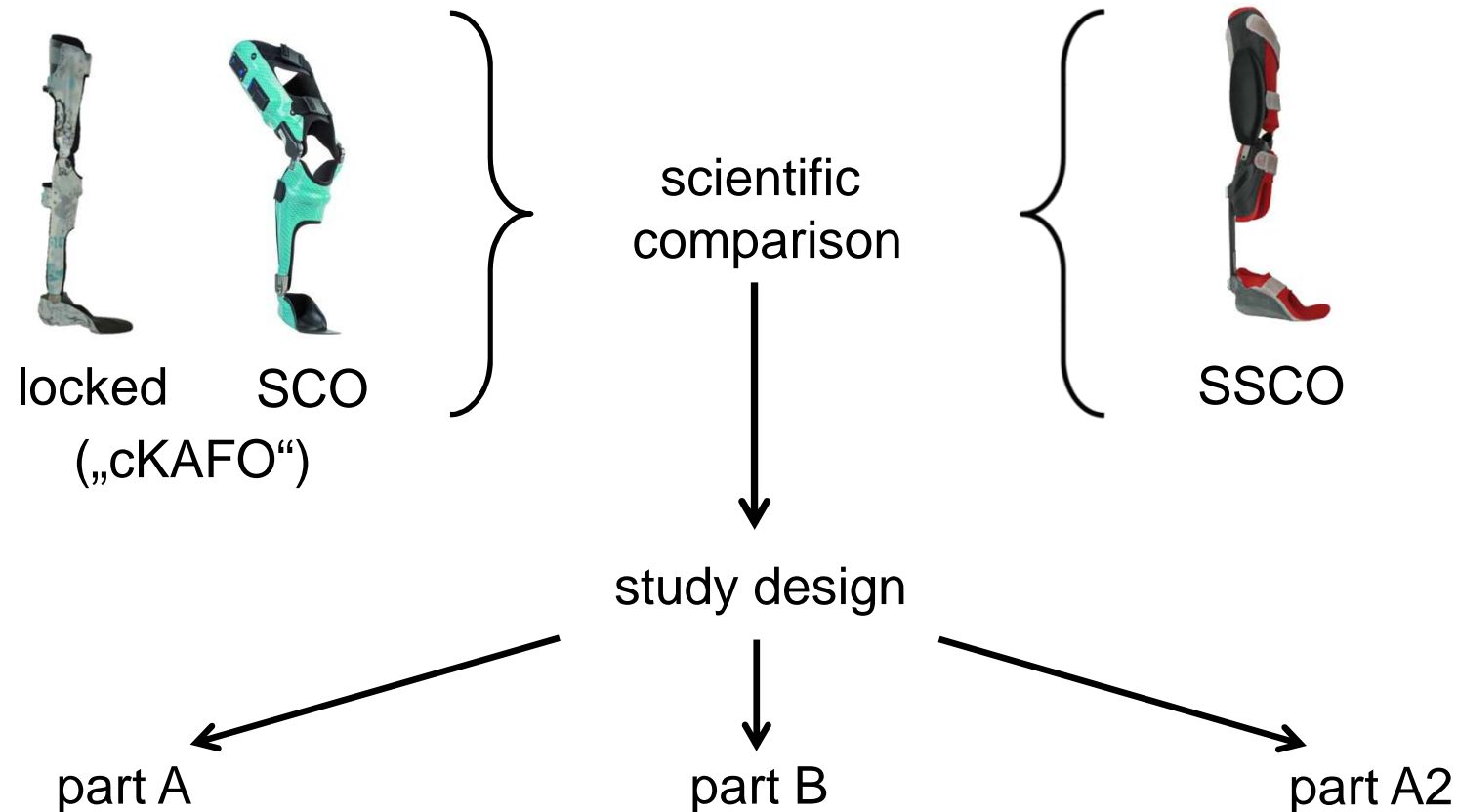
principle D (SSCO)



principle D (SSCO)

learning process: use of knee flexion under weight bearing





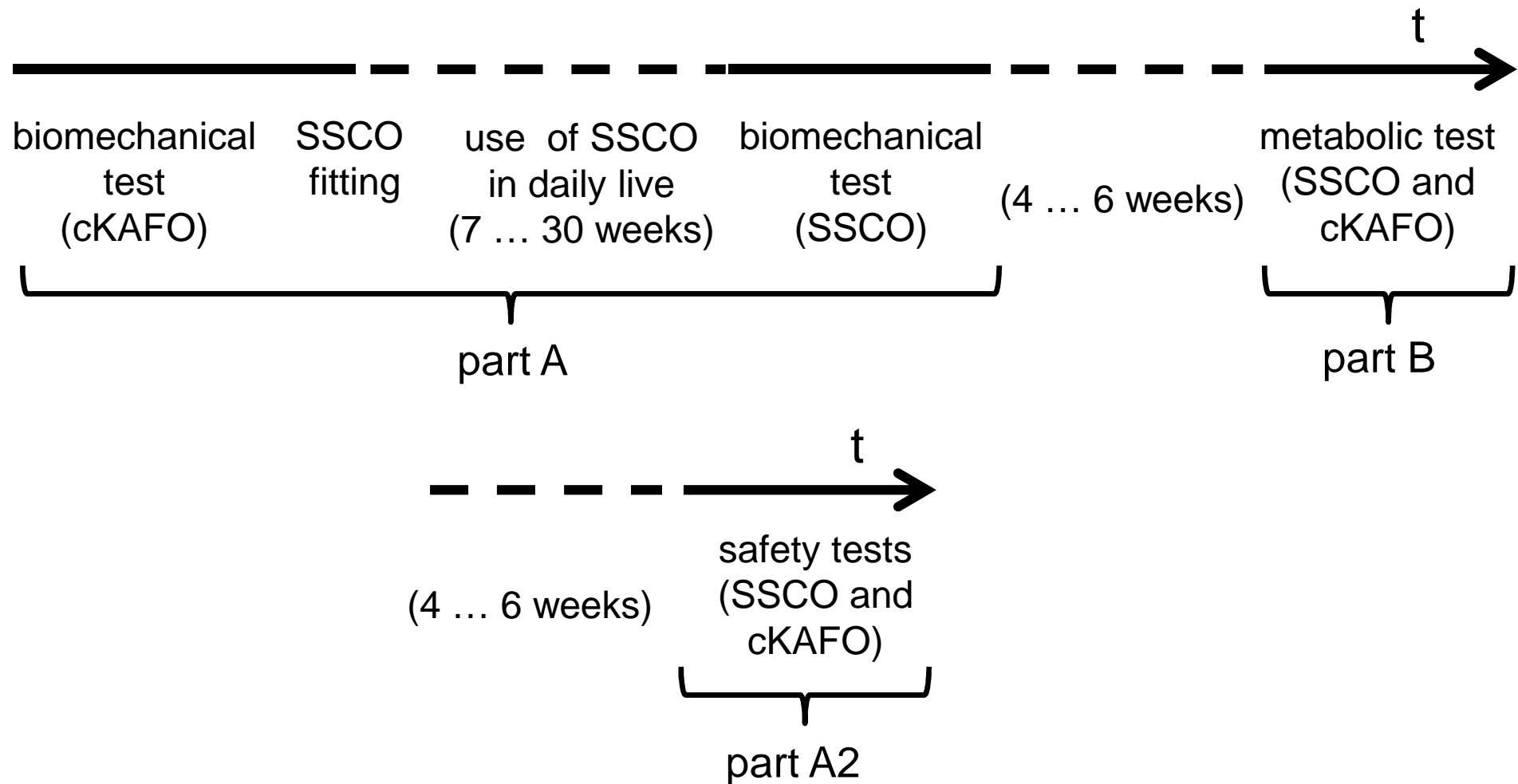
- biomechanical parameters
- different motions

[Schmalz et al. 2014, 2016]

- metabolic parameters
- level walking

- test of safety
- level walking
(even / uneven ground)

6 patients with cKAFOs: 4 SCO, 2 locked
(3m / 3w; 32 ... 70y; 150 ... 176cm; 51 ... 89kg)



SSCO vs cKAFOs

biomechanical tests



level walking
(3x at different v)



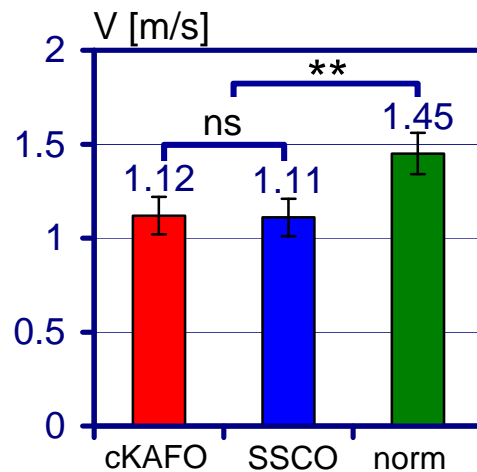
ramp
(10°, descending)



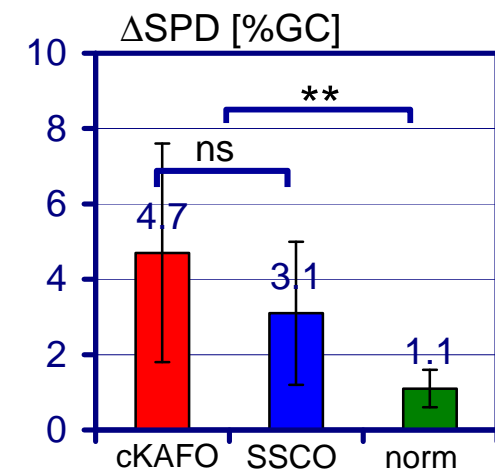
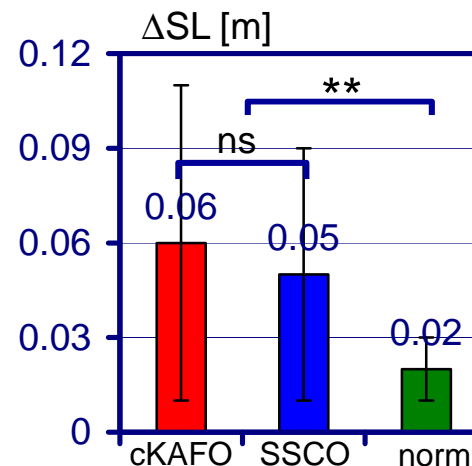
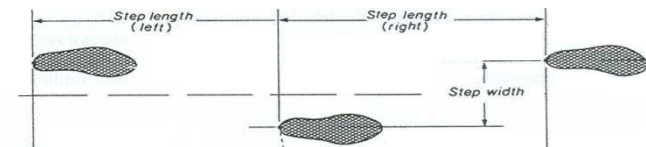
stair
(descending)

time - distance - parameters

walking speed

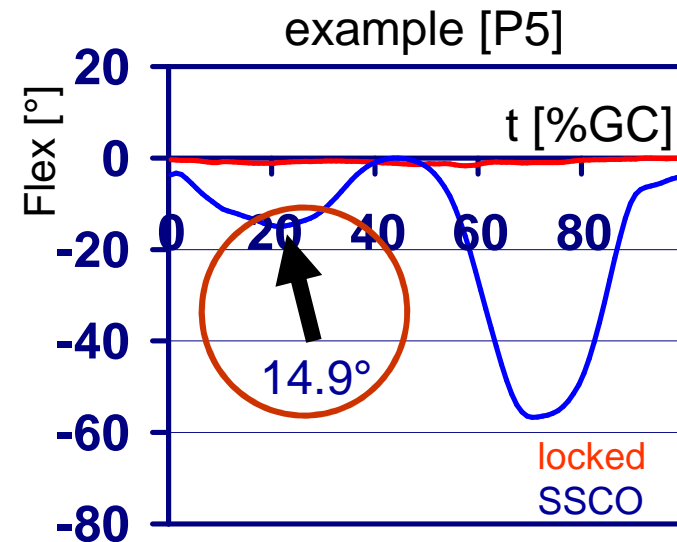
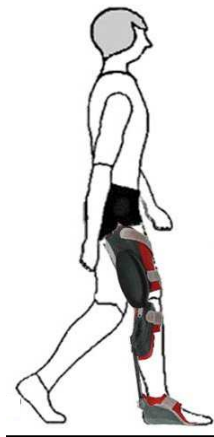
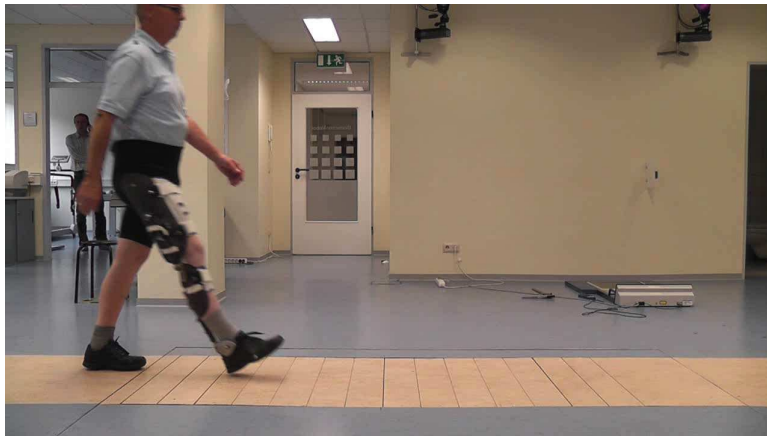


gait symmetry



- patients: walking speed reduced, gait symmetry reduced
- no significant differences between SSCO and conventional KAFOs

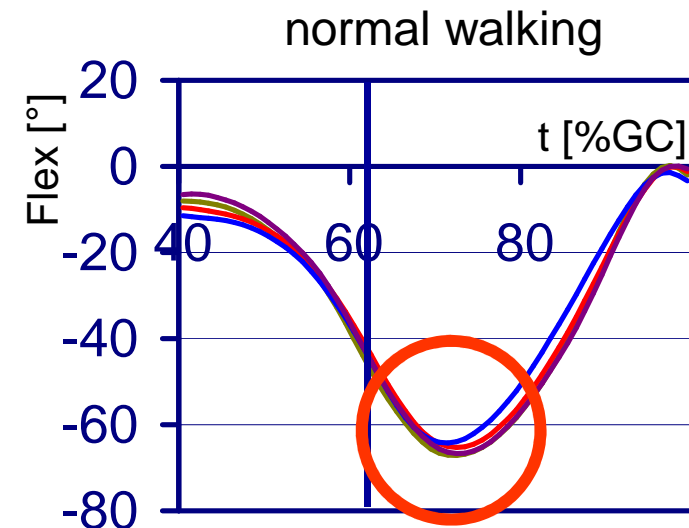
stance phase flexion (Yielding)



Yielding is used mostly:

- 5 / 7 orthotic limbs (4 / 6 pat.)
- mean $11.0 \pm 5.6^\circ$

swing phase control

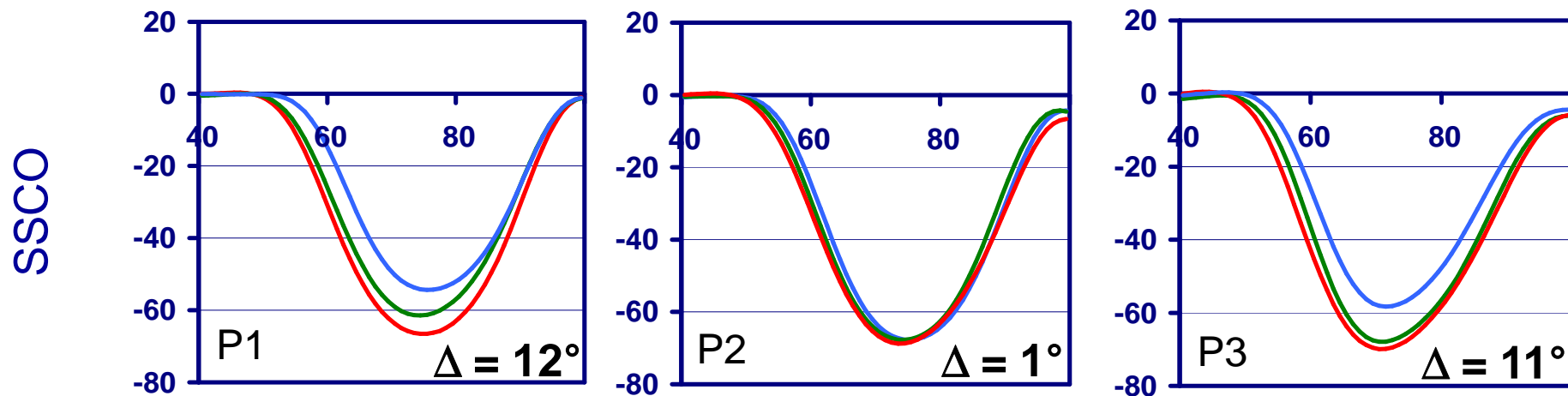
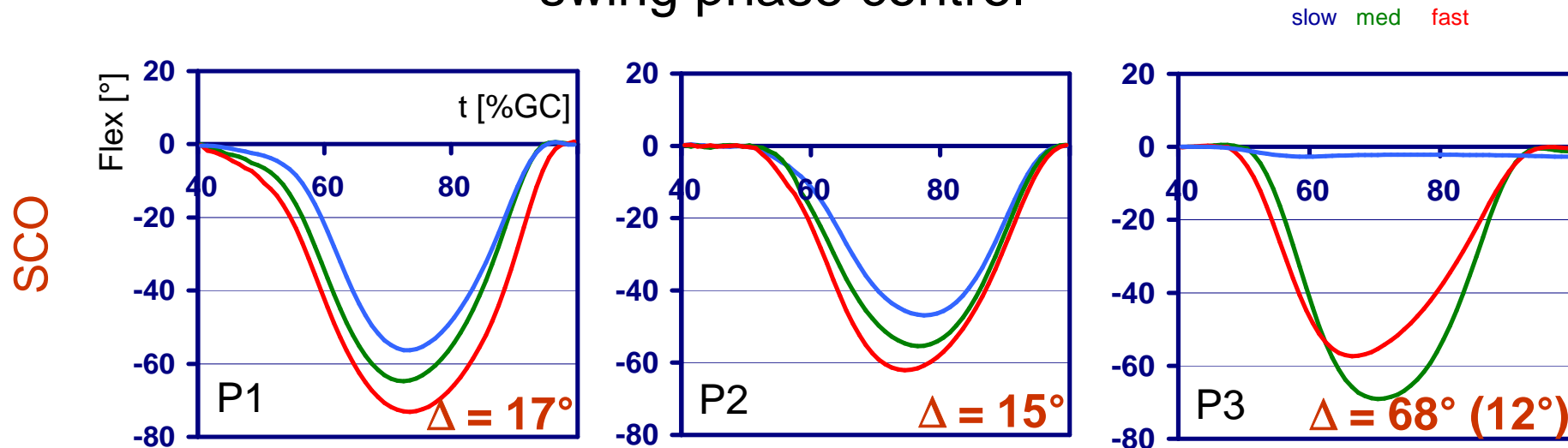


flexion: 63 ... 66°



nearly constant
max swing phase flexion angle

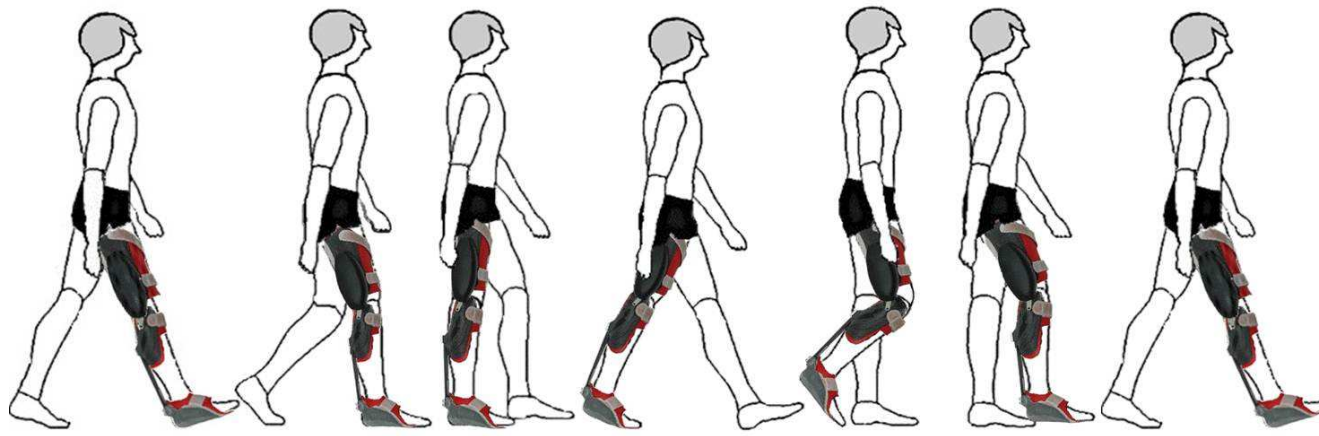
swing phase control



Level walking

- stance phase flexion is mostly used
- microprocessor controlled swing phase: easier speed variation, gait appears more natural
- joint loading: SSCO vs SCO: similar

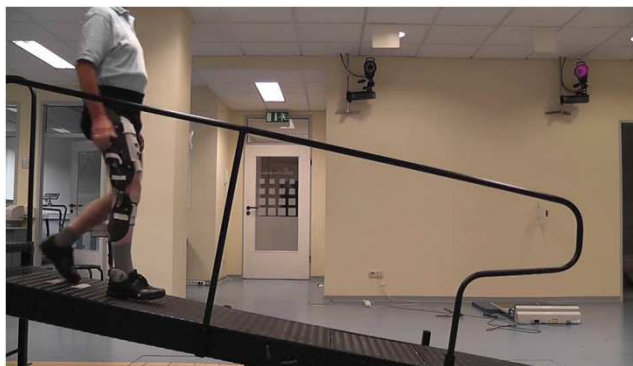
SSCO vs locked KAFO: reduction



conventional KAFO: 4/6 with step-over-step pattern (hand rail: 4/4)



SSCO: 6/6 with step over step pattern (hand rail: 1/6)



conventional KAFO: 0/6 with step-over-step pattern

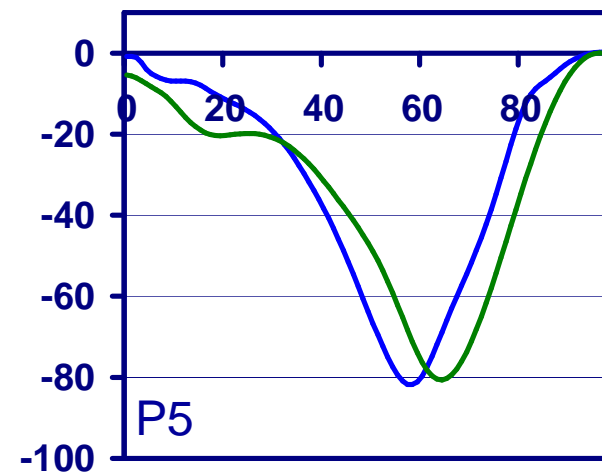
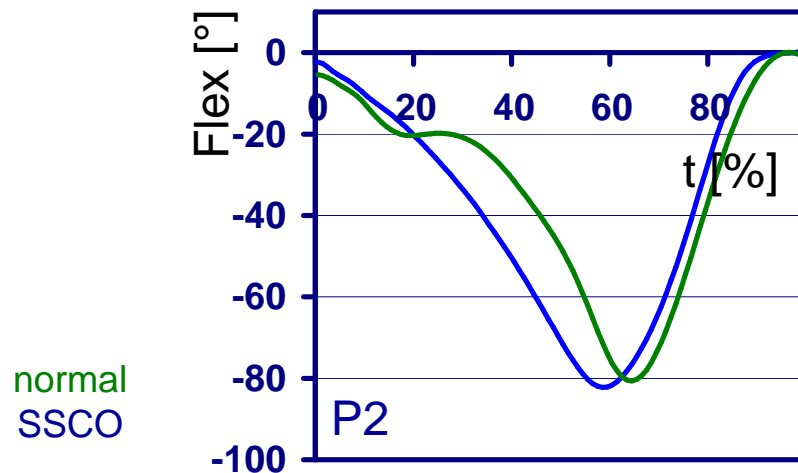


SSCO: 6/6 with step-over-step pattern (hand rail: 5/6)





knee angle (orthotic limb)



→ continuous knee flexion under weight bearing in each case
(independent from the previous fitting)

Descending ramps and stairs

- flexion under weight bearing with SSCO:
 - a) enables a nearly natural motion pattern
 - b) patients use this feature with a high degree of confidence
- SSCO vs. conventional KAFO: reduction of joint loading



Measurement of metabolic energy consumption



- 1 outdoor measurement
(SCO: 3.0 km/h; SSCO: 3.6 km/h)
- 5 treadmill measurements
(2.1 ... 3.0 km/h)
- data analysis: last minute of a 6 min test, randomized order, break: 30min.
- parameters of evaluation: oxygen rate, oxygen cost, heart rate

metabolic energy consumption: additional lower limb mass

cKAFO



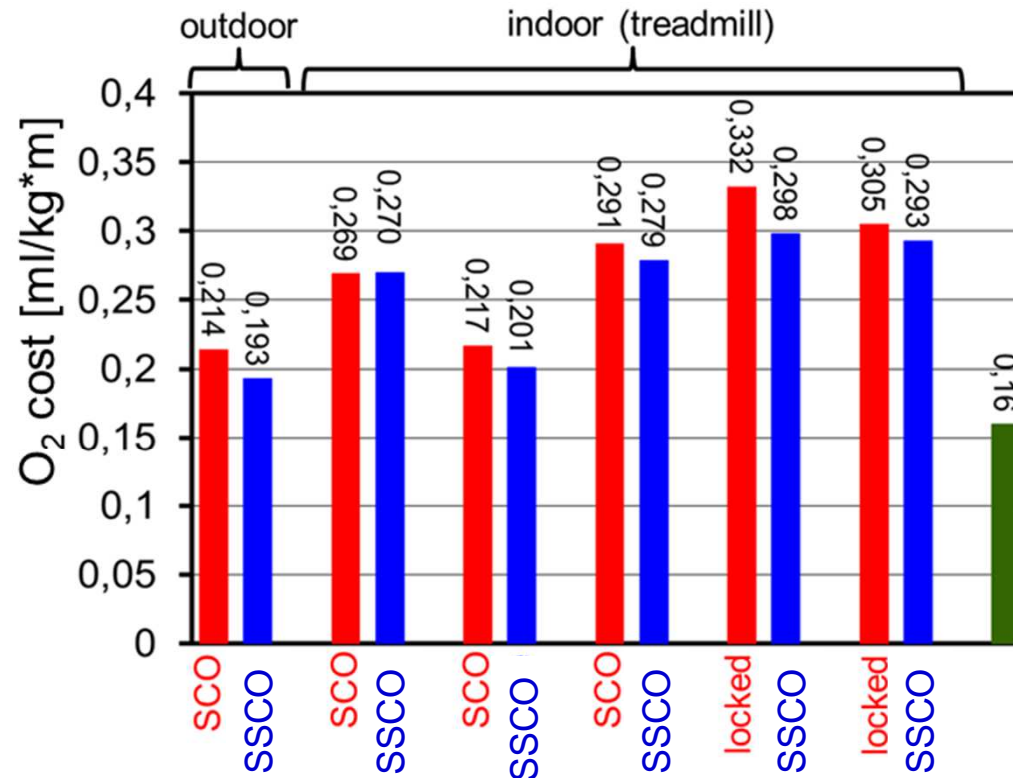
SSCO



mass difference:
1 ... 1.5kg

- additional mass lower limb mass (1 ... 2 kg):
 - increased energy consumption (5 10%)
[Skinner et al. 1990, Browning et al. 2007]
- effect depends on location of additional mass [Schertzer & Riemer 2014]
- corresponding perceptions not reported by the patients

O₂ cost (independent of speed)



normal (mean)
locked KAFO /SCO
SSCO

- SSCO vs. cKAFO: -10% 0% -7% -4% -10% -4%

- statistics not useful (mixture of indoor/outdoor testing and locked KAFO/SCO)

- metabolic energy consumption: slightly decreased with SSCO

possible reasons for compensation of „mass factor“:

- a) additional mass of SSCO located relatively proximal
- b) use of SSCO functions with high degree of confidence



use of handrail: 1 / 6 patients

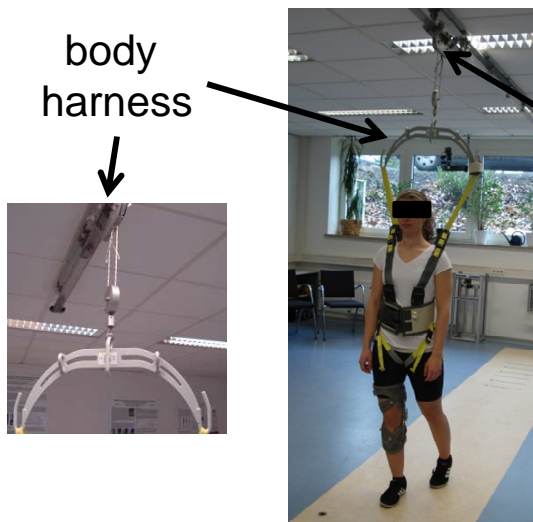
→ results indicate a considerably increased safety level of SSCO

Testing of safety: protocol approved in prosthetics



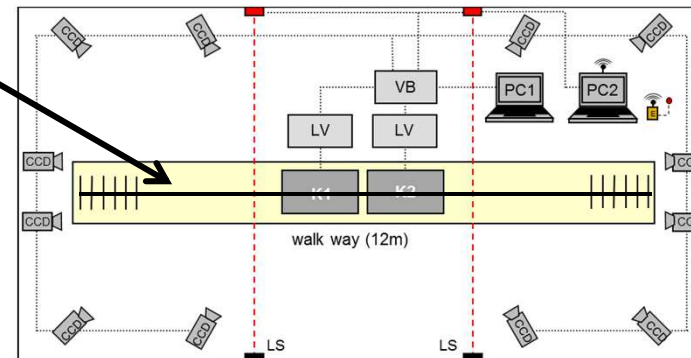
The Safety of C-Leg: Biomechanical Tests

Siegmur Blumentritt, PhD, Thomas Schmalz, PhD, Rolf Jarasch, CPO



measurement of biomechanical parameters
(during level walking at self selected speed)

track
(ceiling)



test 2:
simulating of tripping
(disruption of swing extension)

test 1: step on an obstacle



SCO

SSCO

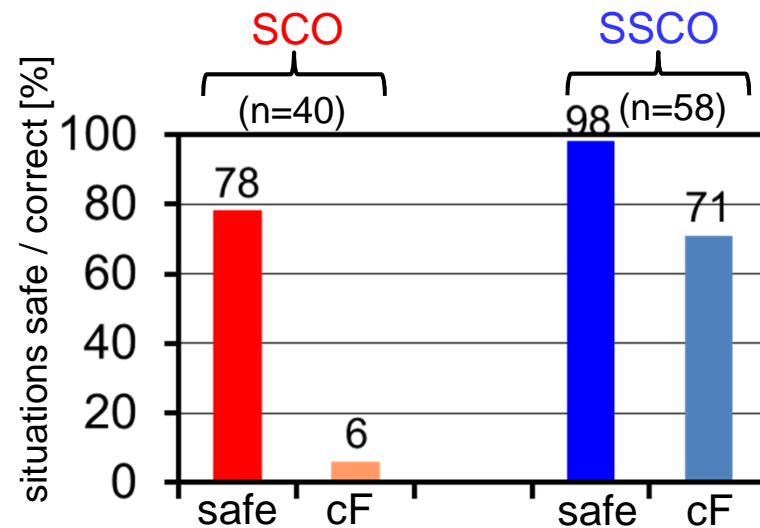
fore foot contact

risk of falling

(unlocking condition reached too soon)



safe



heel contact



SCO

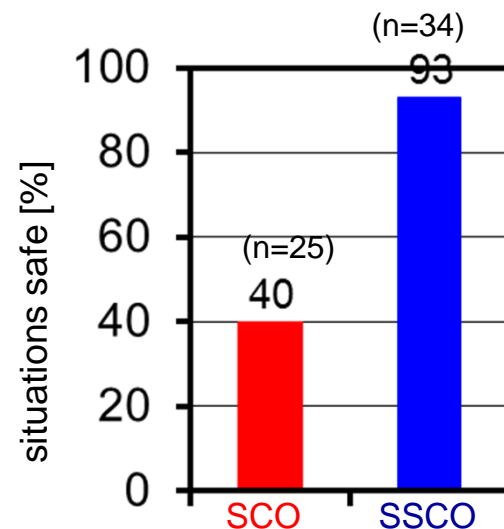
safe, but no correct function
(unlocking conditions not reached
→ no unlocking procedure)

test 2: simulating of tripping (disruption of swing extension)

25 test trials with SCO



34 test trials with SSCO



- SSCO: only 2 /34 trials with risk of falling (when swing phase is disrupted near maximum flexion angle)
- damped flexion during weight bearing most important feature for fall prevention



- SSCO principle expands range of ADLs with nearly physiological gait patterns

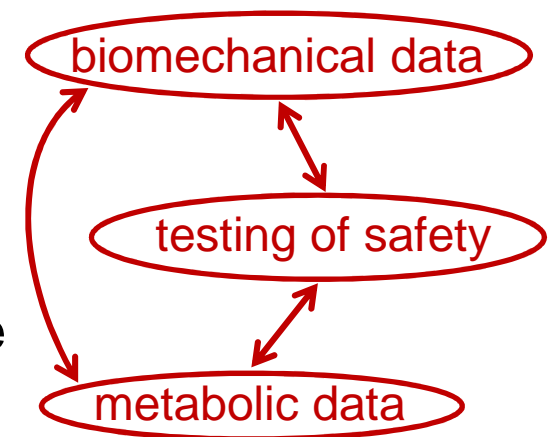
→ effects of loading reduction

- with SSCO considerably increased level of safety

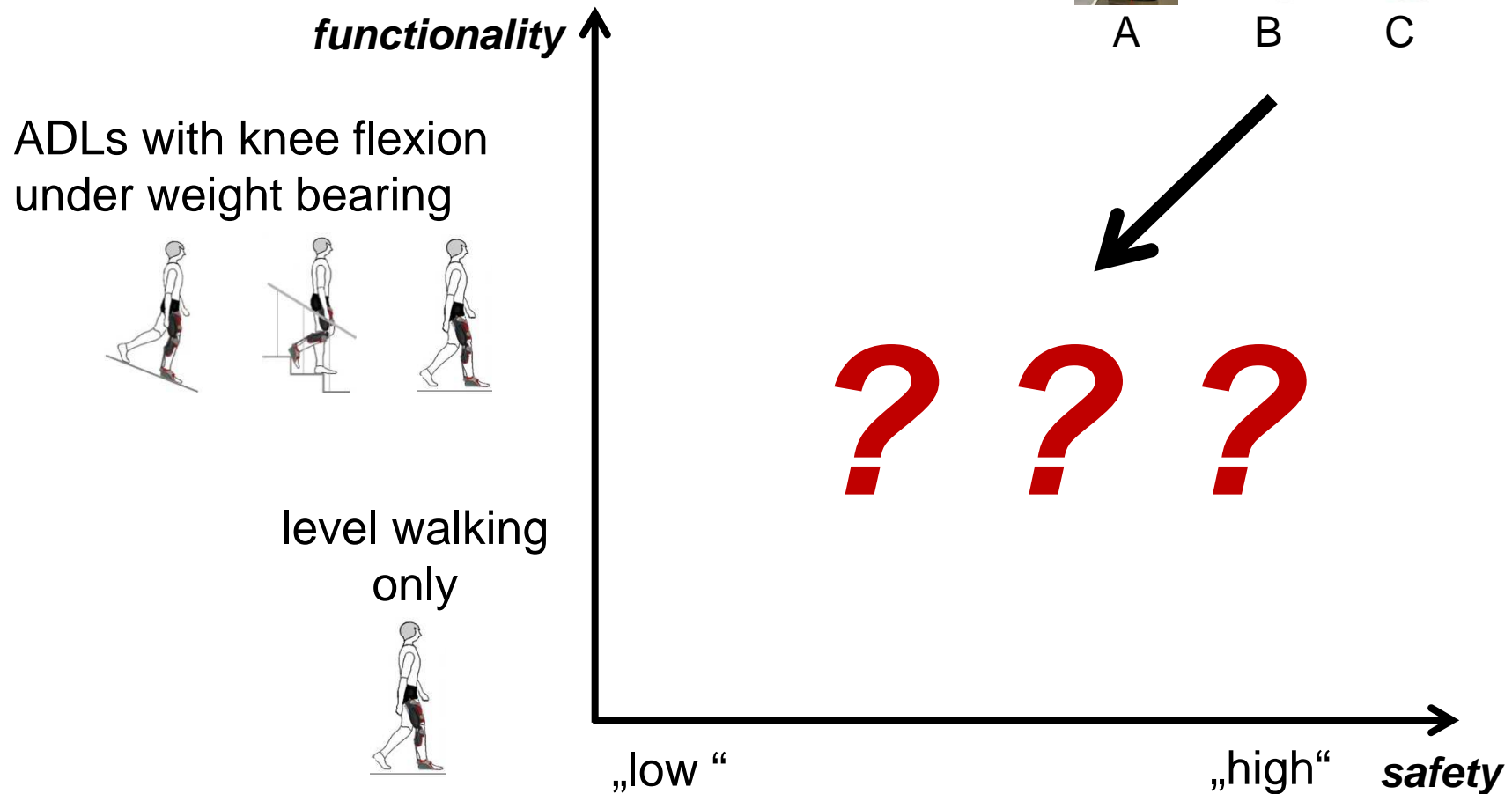
→ use of functions with high degree of confidence

→ slightly reduced metabolic energy consumption

- period of adaptation: 8 ... 12 weeks



KAFO principles: functionality vs. safety





KAFO fitting: Which principle is suitable for a patient?

there is no universal assignment rule – patient might be fitted with all KAFO types

priority: evaluation of individual situation

- environmental conditions
- individual demands regarding activity and safety
- cosmetic aspects



Thank you!