[redacted] [redacted]

Sensor Number-Dependent Accuracy of Ground Reaction Forces and Center of Pressure in Simplified Pressure Sensor Insoles

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Introduction Pressure sensor insoles

BeBop Sensors. https://www.youtube.com/watch?v=QQAf074Fopo

Introduction Pressure sensor insoles

<u>Obtaining:</u>	Ground Reaction Force (**GRF**)	Center of Pressure (**CoP**)
	[redacted]	[redacted]
<u>Relevance:</u>	**Postural control** [1-5]	
	Risk of falling [6]	
	Injury risk [1-3] Performance analyses [1-3] Joint loading [7] Ankle instability [8]	Detecting pathologies [9-11] Pronation/supination [12]
<u>Activities:</u>	Standing, jumping, landing, **gaits** [1-3]	

Introduction Limitation

Strength:	No space-restriction [13,14]
Problem:	Product price prevents wide-spread adoption [14,15]

💡 **Reduce sensor number** to reduce product price

[redacted]

9/10 zones [19,20]

[redacted]

5-13 sensors [15,16,18,21-23]

⚠ Measurement accuracy at reduced sensor number [18]

⚠ Task-dependent measurement accuracy [18]

Introduction Purpose

Goal:	Reduce sensor number with no/acceptable loss of accuracy [14,16,17]
Question:	Promising sensor number for accurate GRF and CoP measurement?
Hypotheses:	1. Relationship (sensor numbers – accuracy) 2. Gait type affects accuracy 3. Promising compromise (sensor number – accuracy)

Participants:

- 15 males
- No injuries/pathology
- All strike patterns
- All arch types

[redacted]

24.6±3.7 years
173.1±6.8 cm

68.5±7.8 kg

27.2±0.8 Pedar size

Protocol:

- Walking, jogging, running (randomized)
- Self-selected speeds
- Along a straight line

[redacted]

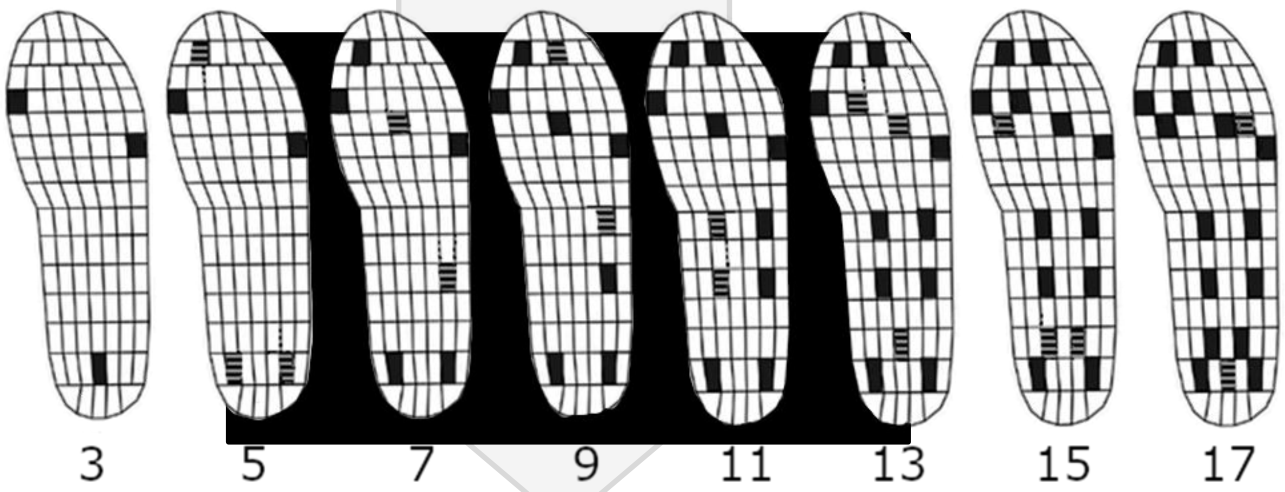
Abu-Faraj. https://doi.org/10.1002/047134608X.W6606.pub2 (edited)

Methods Equipment (simultaneous data collection)

Force plate:
- Kistler 9827
- 90x60 cm
- 1000 Hz

Pressure sensor insole:
- Pedar-X
- 99 sensors
- 100 Hz

3D motion capture:
- 12 Vicon cameras
- 1 marker at C7
- 200 Hz

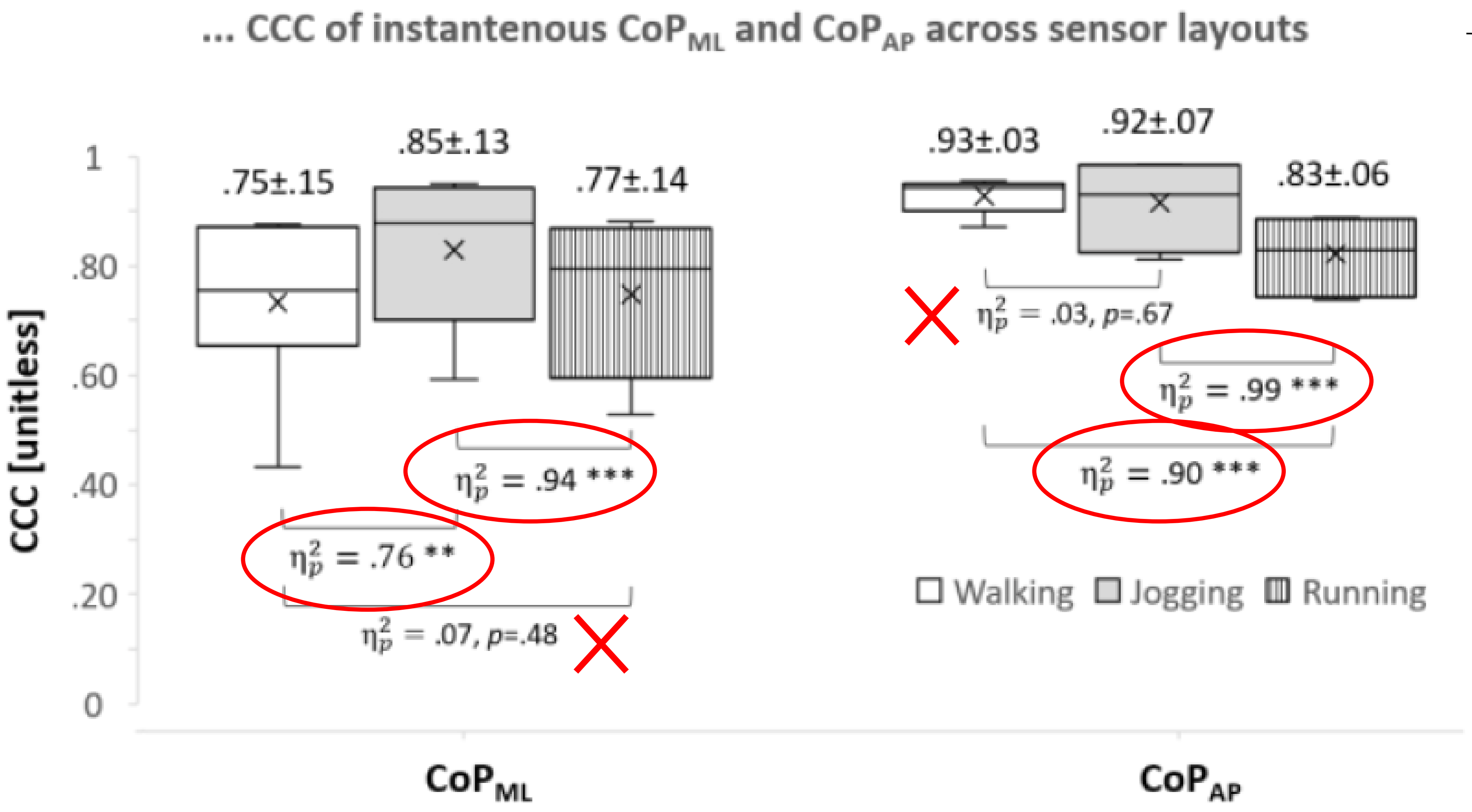


8 simulated sensor layouts

Methods Statistical analysis

Test:	**Note:**
• Root mean square error (RMSE) • Coefficient of variation (CV)	• Descriptive expression of discrepancy
• Pearson‘s Product-Moment correlation (*r*) • Concordance correlation coefficient (CCC)	• Between sensor layout and reference (relationship) • Between sensor layout and reference (exact agreement)
• Analysis of variance (ANOVA; η_p^2)	• Effect of gait type
• $\Delta r_{rel} = (r_{i+2} - r_i)/[(n_{i+2} - n_i)/n_i]$	• Quantified „promising compromise“

Results Differences between gait types in ...

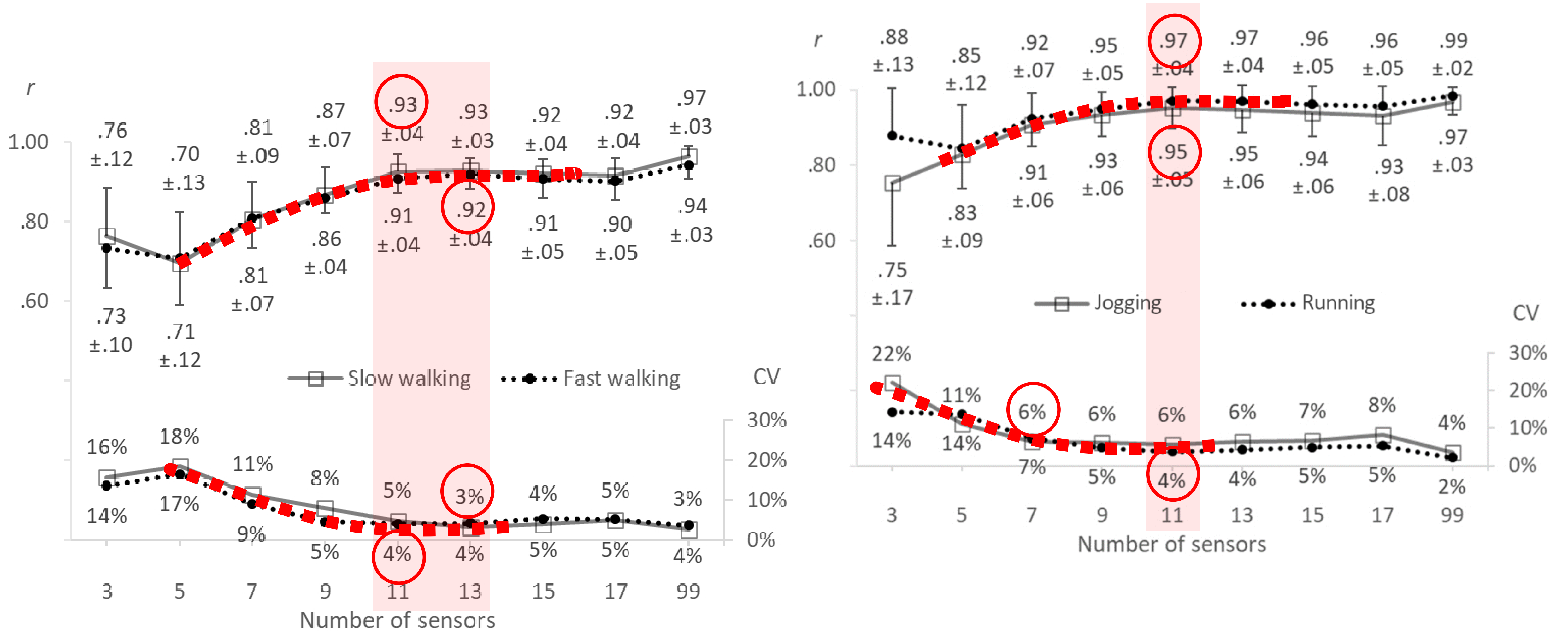


4/6: $p<.05$

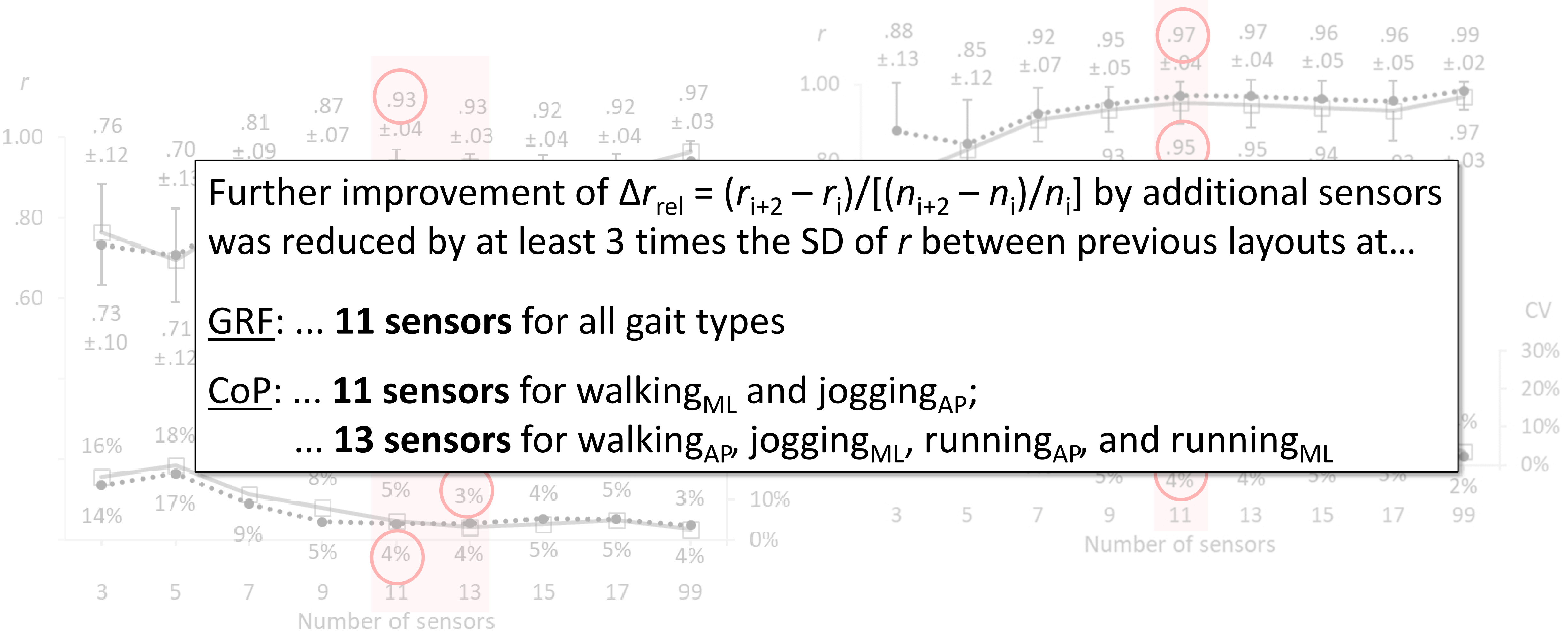
also for RMSE

also for GRF

Results Correlation (*r*) and coefficient of variation (CV) of GRF between Pedar-X and force plates



Results Quantified „promising compromise“ between sensor number and accuracy

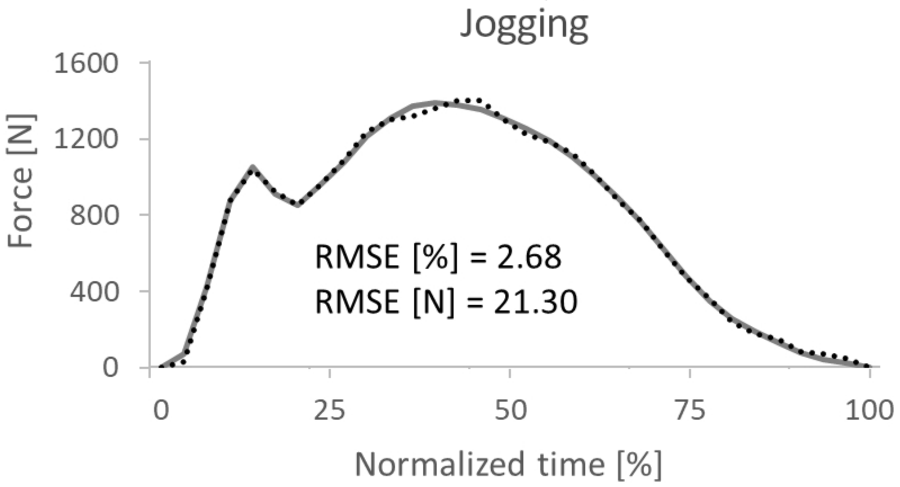


Further improvement of $\Delta r_{rel} = (r_{i+2} - r_i)/[(n_{i+2} - n_i)/n_i]$ by additional sensors was reduced by at least 3 times the SD of r between previous layouts at…

GRF: … **11 sensors** for all gait types

CoP: … **11 sensors** for walking$_{ML}$ and jogging$_{AP}$;
… **13 sensors** for walking$_{AP}$, jogging$_{ML}$, running$_{AP}$, and running$_{ML}$

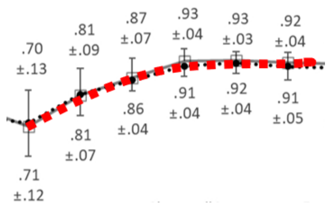
Results Regression-based estimation of absolute GRF



- 11-sensor layout
- Participant with median r

Discussion Interpretation of outcomes

- Sensor number-dependent accuracy of GRF and CoP
- Non-linear relationship between accuracy and sensor number
  - ➢ Range of a „**promising** compromise“ (i.e., 11-13 sensors)



	r (GRF)	CCC (CoP)
95% confidence interval (across conditions and ML/AP)	.92 – .96	.88 – .94

⚠ Sensor placement was not optimized
- ➢ Smaller sensor numbers may be considered

⚠ Effect of gait type

⚠ Difference between GRF and CoP
- ➢ Relevant for development, validation, and application

Conclusion

- Current findings give an **idea** for future research (i.e., not a final recommendation)
- Future research: Optimization of sensor placement [24]…

  … for both GRF and CoP

  … within a promising range of sensor numbers (and less)

  … including cross-validation

  … accounting for different gaits (and other tasks [18])

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