Predicting Knee Adduction Moment Response to Gait Retraining with Minimal Clinical Data

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Gait retraining for knee osteoarthritis is promising but not yet prescribed

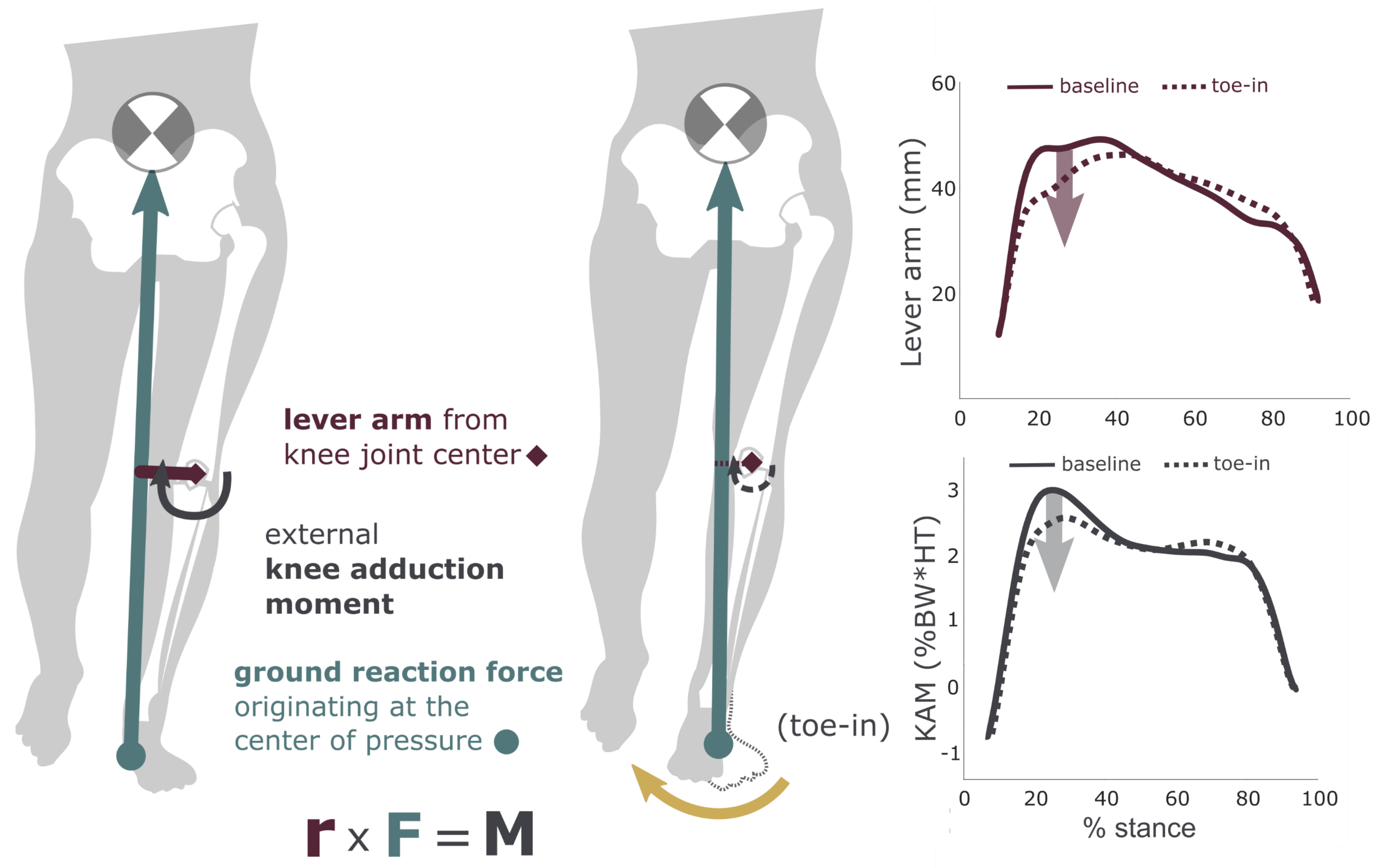
Globally, **1 in 5** individuals aged 40 and older are afflicted by knee osteoarthritis [1]

Patients spend **28.4 years** on average living with symptoms before a knee replacement [2]

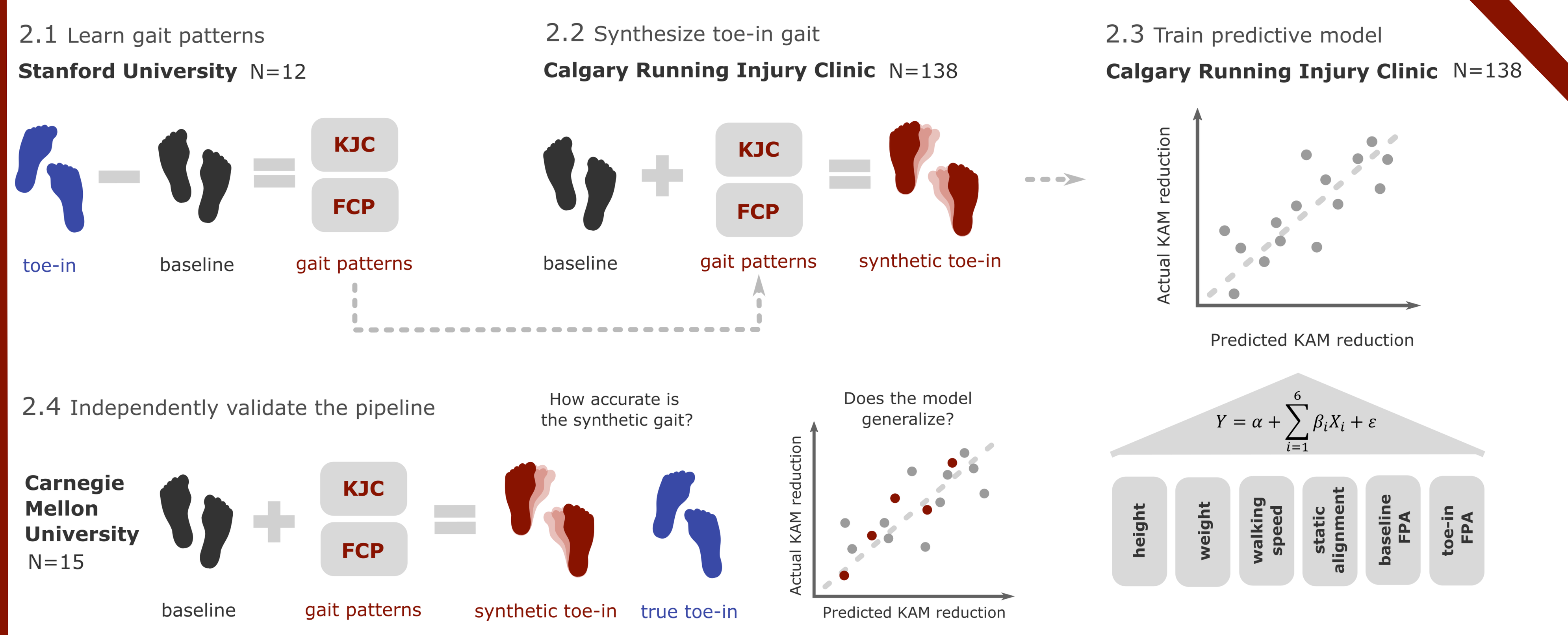
- Personalized gait retraining has shown promise as a non-invasive intervention for slowing knee osteoarthritis (KOA) progression [3].
- Changing the foot progression angle is an easy-to-learn gait modification that often reduces the knee adduction moment (KAM), a correlate of medial joint loading.
- Prescribing gait retraining is challenging because customizing rehabilitation still requires gait lab instrumentation.

A toe-in gait reduces the knee adduction moment (KAM) and slows cartilage degeneration

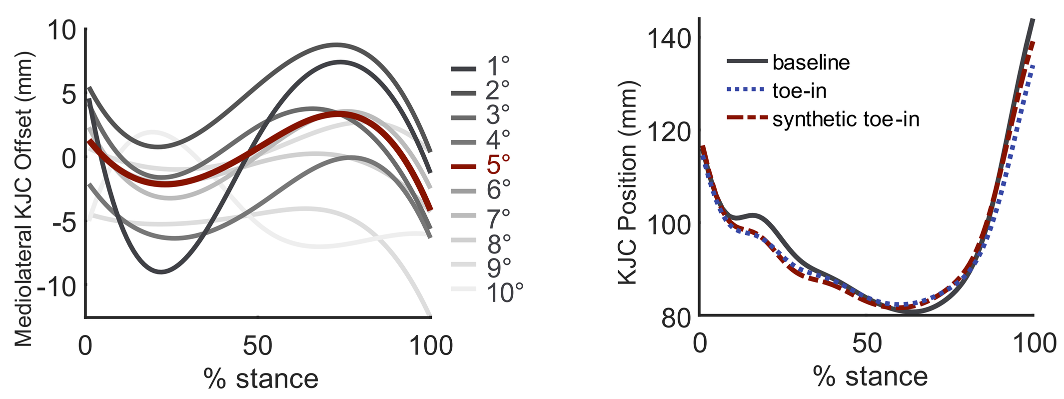
- The KAM is the cross-product of the ground reaction force and lever arm from the knee joint center.
- Toe-in gait shifts the knee joint center medially and the foot center of pressure laterally.
- Ground reaction force magnitude (not shown) does not change.



Synthetic data generation can help overcome paucity of patient data



Center of pressure and knee joint center gait patterns are used to create synthetic gait



- Gait patterns were learned by LOOCV from optical motion capture data of 12 subjects walking at baseline and with toe-in gait
- Trajectories were smoothed with fitted splines

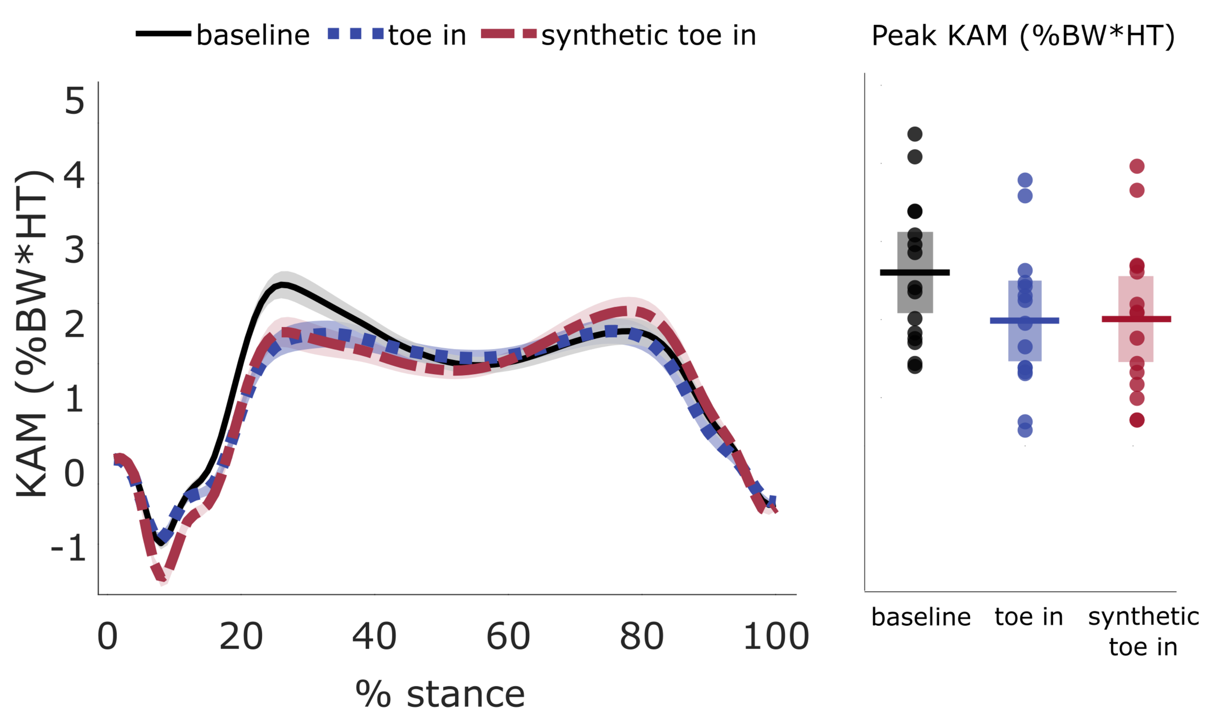
How accurate is the synthetic gait?

	LOOCV on Stanford dataset	Validation on CMU dataset
	RMSE (±STD)	RMSE (±STD)
Knee Joint Center (Anterior-Posterior)	12.7 (±7.8) mm	13.3 (±8.2) mm
Knee Joint Center (Mediolateral)	5.6 (±2.4) mm	4.5 (±2.7) mm
Center of Pressure (Anterior-Posterior)	13.4 (±4.8) mm	15.4 (±8.8) mm
Center of Pressure (Mediolateral)	8.1 (±5.4) mm	9.0 (±6.8) mm

- The accuracy of the knee joint center and center of pressure predictions were **within the error range** of joint center location estimates obtained with **optical motion capture.**
- Estimates of the knee joint center position can vary from 14 mm to 40 mm due to soft tissue artifacts [4].

How well do the models generalize to out-of-domain subjects?

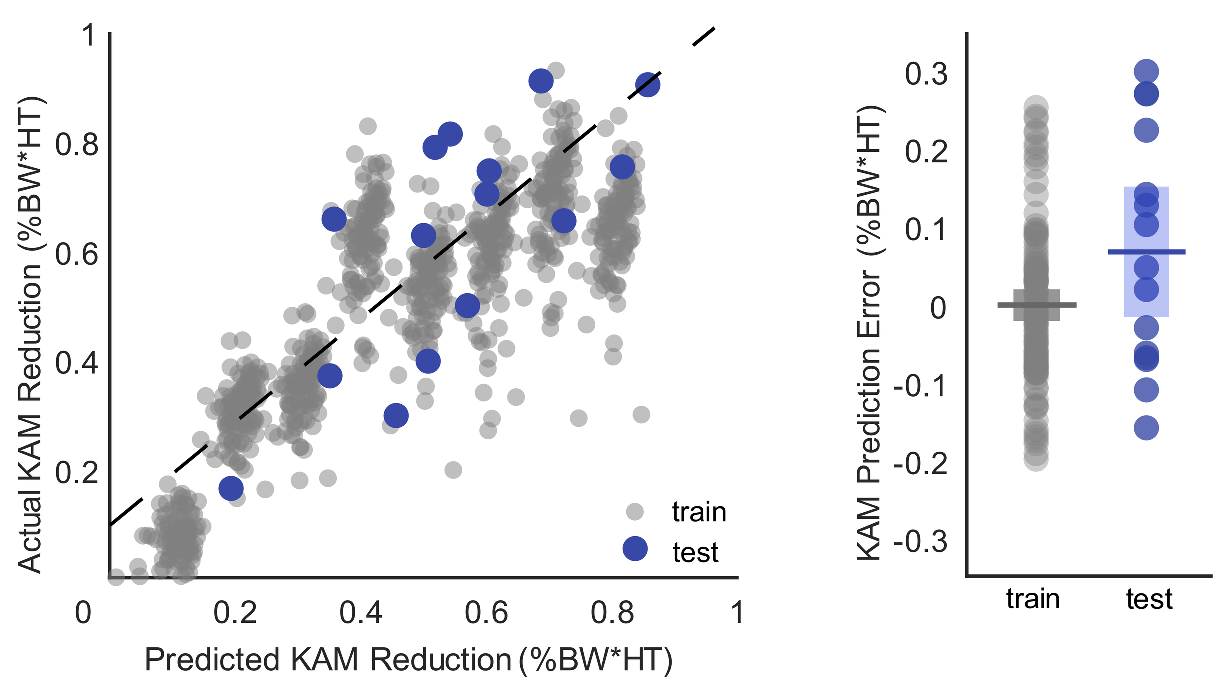
Synthetic KAM validation



- The synthetic toe-in KAM correctly captured that all subjects reduced the first KAM peak.
- While the synthetic KAM falsely predicted an increase in the second KAM peak, the overall KAM impulse was reduced, which would lead to therapeutic benefit [3]

The mean absolute error of **0.170% BW*HT** (±0.135) is significantly less than the ground truth first KAM peak reduction (0.620%BW*HT)

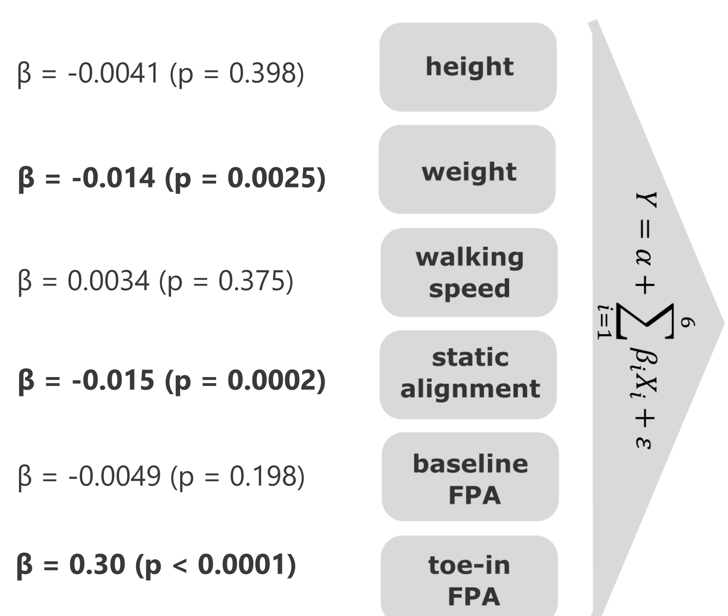
Predicted KAM reduction



- The R^2 between predicted and actual KAM reduction was 0.55.
- Using only the toe-in angle, the strongest predictor, as a feature, KAM reduction was estimated with an MAE of 0.187%BW*HT (±0.151%BW*HT).
- Holding all other inputs constant, increasing valgus angle by 12° or weight by 40 kg resulted in mean peak KAM reduction of less than 0.50%BW*HT.

The mean absolute error of **0.134 % BW*HT** (±0.0932) Is less than the average standard deviation of the first KAM peak during baseline gait (0.306%BW*HT)

Model sensitivity to changing inputs is physiologically feasible



- More investigation is warranted to understand why a higher weight is predictive of a smaller KAM reduction
- Static alignment (bow-legged or knock-kneed posture) has been previously found to correlate with KAM reduction [5]
- Increased toe-in foot progression angle is a strong predictor of a greater KAM reduction [3]

Rokhmanova et al. PLOS Comp Bio (2022)

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This work was supported in part by the U.S. National Science Foundation Graduate Research Fellowship Program under Grant DGE1745016 and DGE2140739.

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