

# Supporting Information for: From Smartphone Images to Musculoskeletal Models: Personalized Inertial Parameter Estimation

In this supporting document, we provide additional results and details that support the findings presented in the main text. This includes participant and trial metadata, additional results for joint moments, and a detailed analysis the influence of gender on personalization and gait analysis outcomes.

## Participant and Trial Metadata

Participant and trial information are summarized in Table A.1 and Table A.2, respectively. Body height, age and gender are self-reported, while body mass was measured using force plates. The excluded trials are: P01, trials 3-6 and P06, trial 5.

Table A.1: **Participant Information.**

<b>ID</b>	<b>Age (years)</b>	<b>Mass (kg)</b>	<b>Height (cm)</b>	<b>Sex</b>
P01	26	72.31	167	F
P02	28	73.35	177	M
P03	26	64.49	165	F
P04	27	89.36	177	M
P05	30	87.63	179	M
P06	26	44.91	147	F

Table A.2: **Trial Information.**

<b>Trial Number</b>	<b>Speed (m/s)</b>	<b>Incline (%)</b>
1	1.3	0
2	0.8	0
3	1.3	8
4	0.8	8
5	1.3	-8
6	0.8	-8

## Additional Results

Similar to Fig. 4 in the main text, we present the joint moments for all models for lumbar rotation A.1, lumbar bending A.2, lumbar extension A.3, hip flexion A.4, hip rotation A.5, hip adduction A.6, and ankle angle A.7. Next, in Table A.3, we present the residual forces for each model.

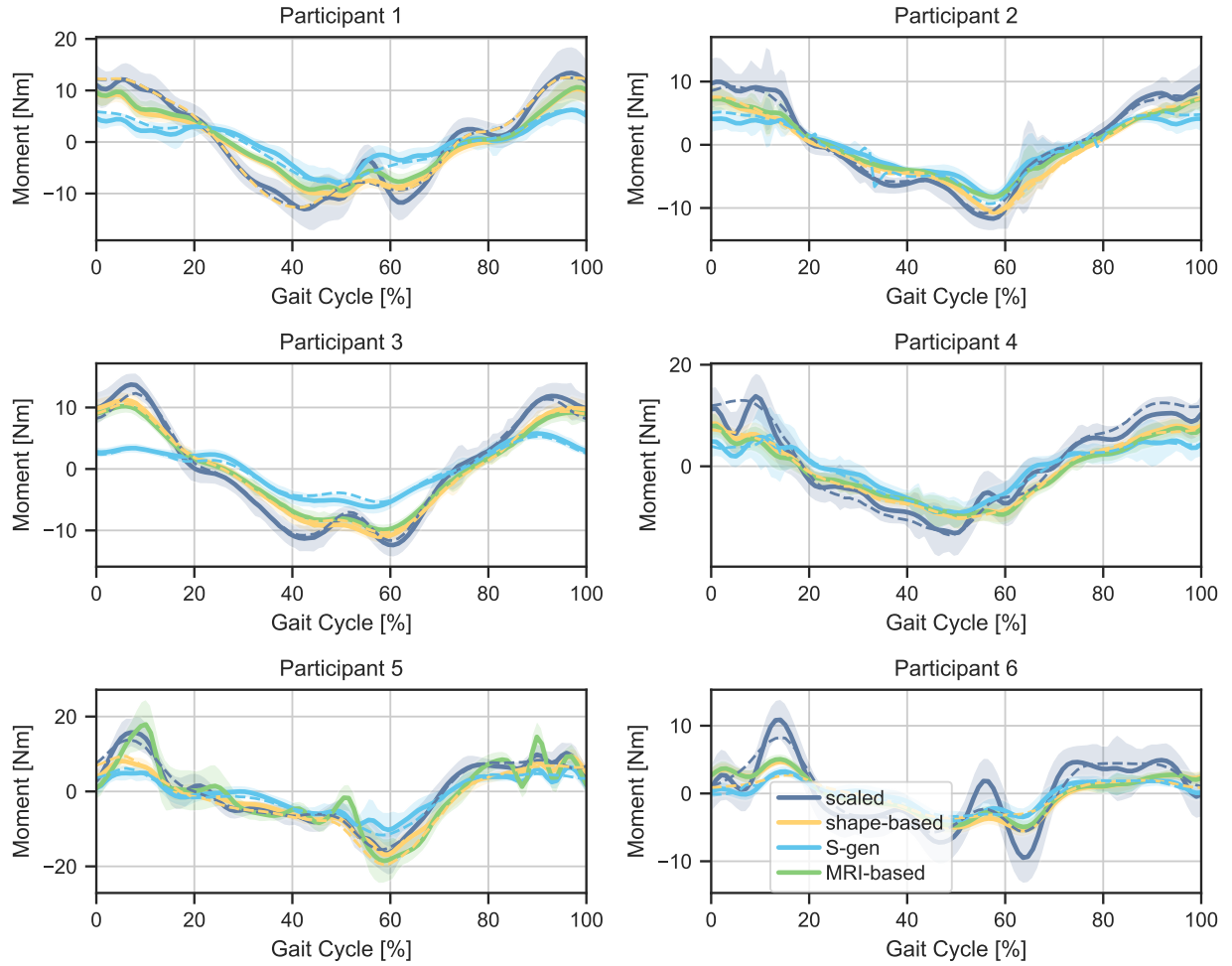


Figure A.1: **Lumbar rotation moments for all participants during level walking at  $1.3 \text{ m s}^{-1}$ .** Moments resulting from inverse dynamics are shown for the scaled, SIPP, SIPP-generic (S-gen), and MRI-personalized models. Shaded areas indicate standard deviation. We also show models that are optimized with addBiomechanics' physics optimization as dashed lines.

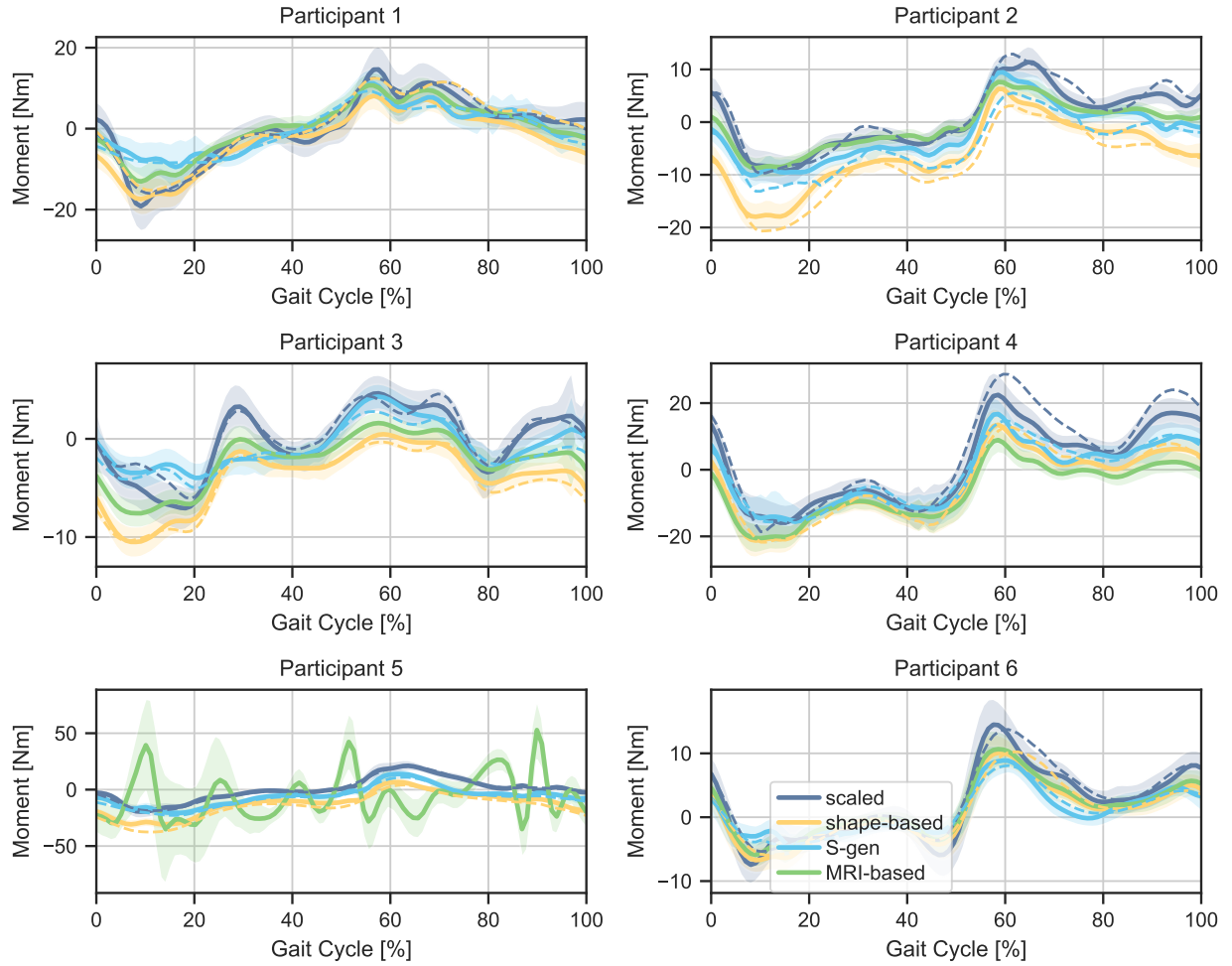


Figure A.2: **Lumbar bending moments for all participants during level walking at  $1.3 \text{ m s}^{-1}$ .** Moments resulting from inverse dynamics are shown for the scaled, SIPP, SIPP-generic (S-gen), and MRI-personalized models. Shaded areas indicate standard deviation. We also show models that are optimized with addBiomechanics' physics optimization as dashed lines.

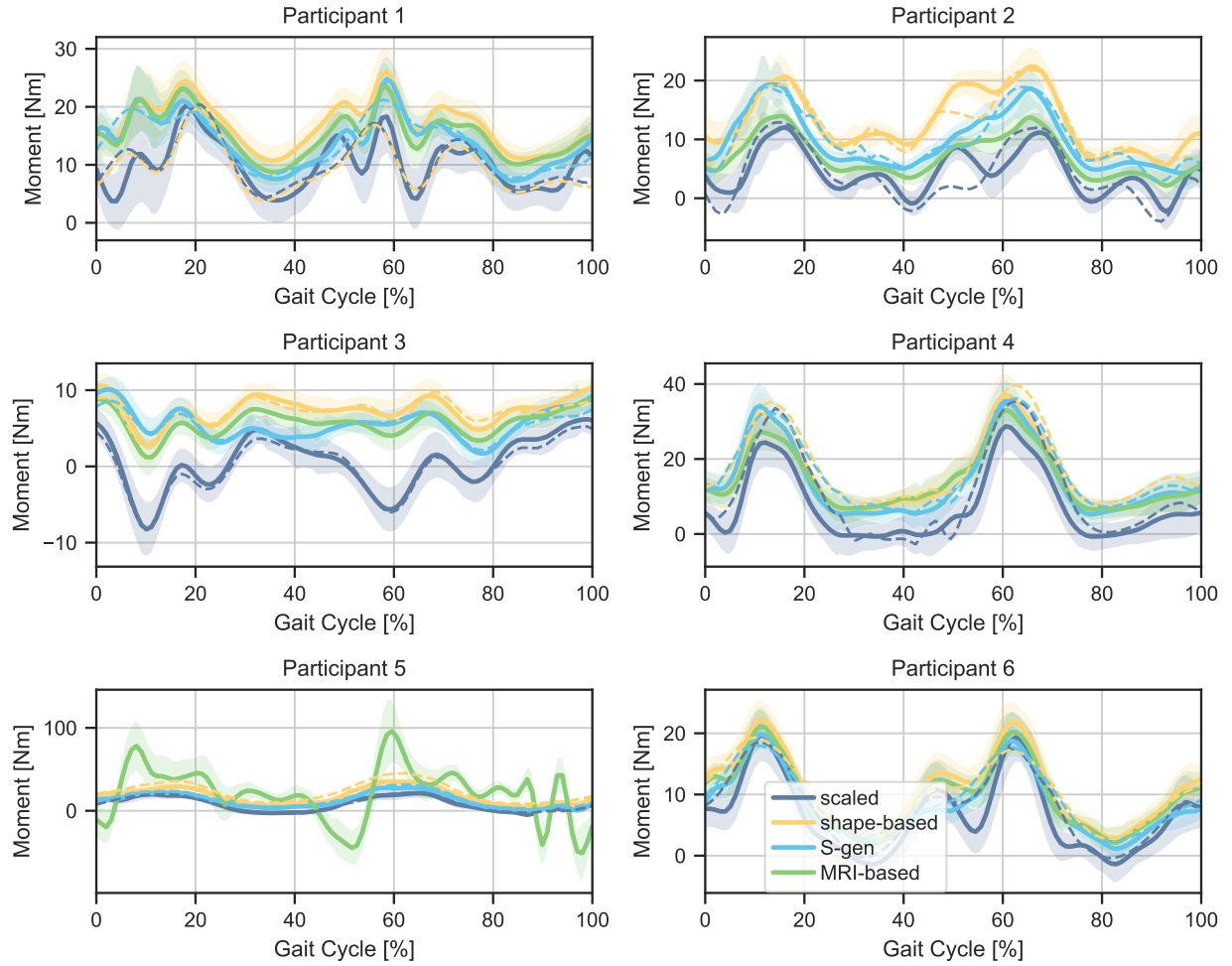


Figure A.3: **Lumbar extension moments for all participants during level walking at  $1.3 \text{ m s}^{-1}$ .** Moments resulting from inverse dynamics are shown for the scaled, SIPP, SIPP-generic (S-gen), and MRI-personalized models. Shaded areas indicate standard deviation. We also show models that are optimized with addBiomechanics' physics optimization as dashed lines.

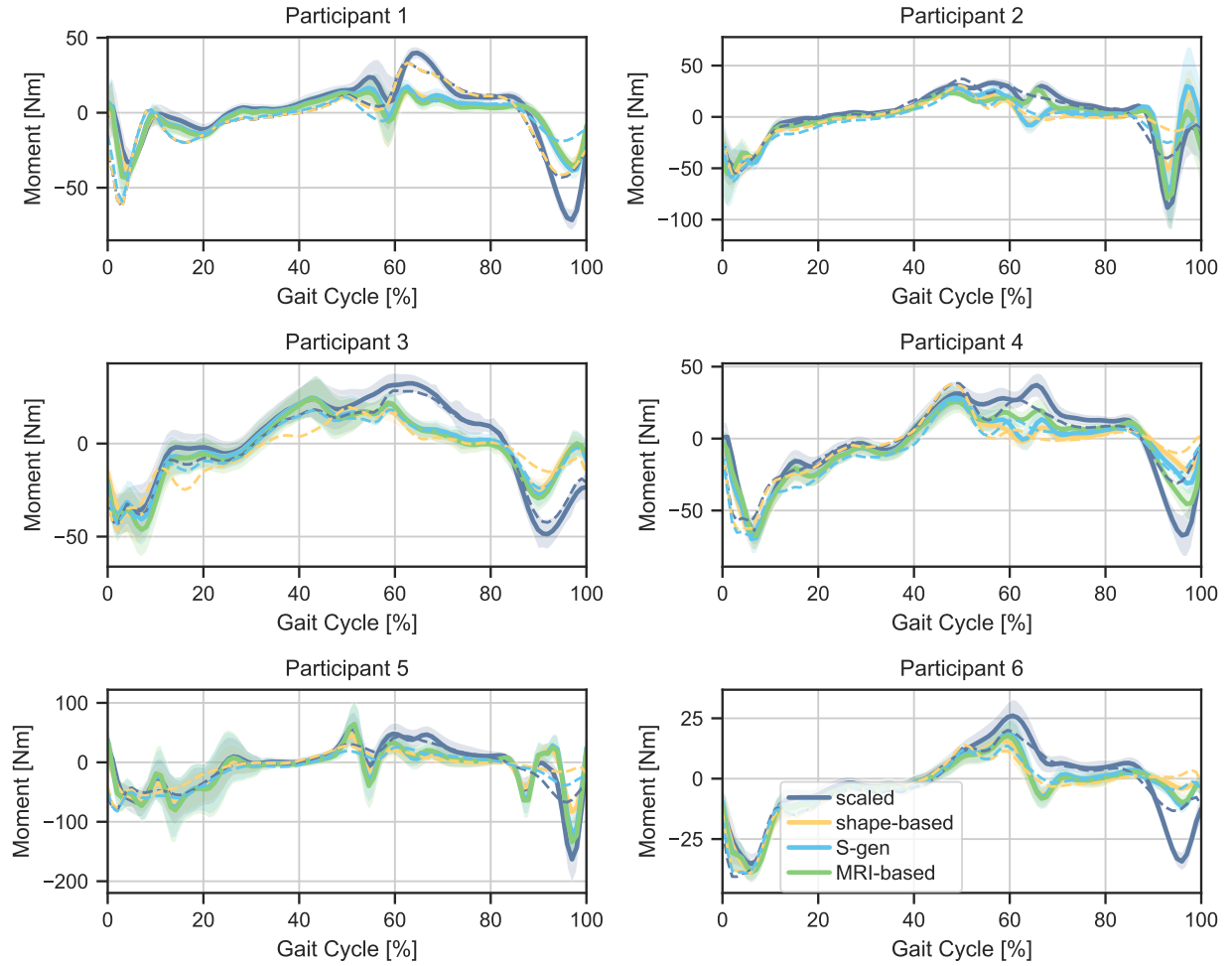


Figure A.4: **Hip flexion moments for all participants during level walking at  $1.3 \text{ m s}^{-1}$ .** Moments resulting from inverse dynamics are shown for the scaled, SIPP, SIPP-generic (S-gen), and MRI-personalized models. Shaded areas indicate standard deviation. We also show models that are optimized with addBiomechanics' physics optimization as dashed lines.

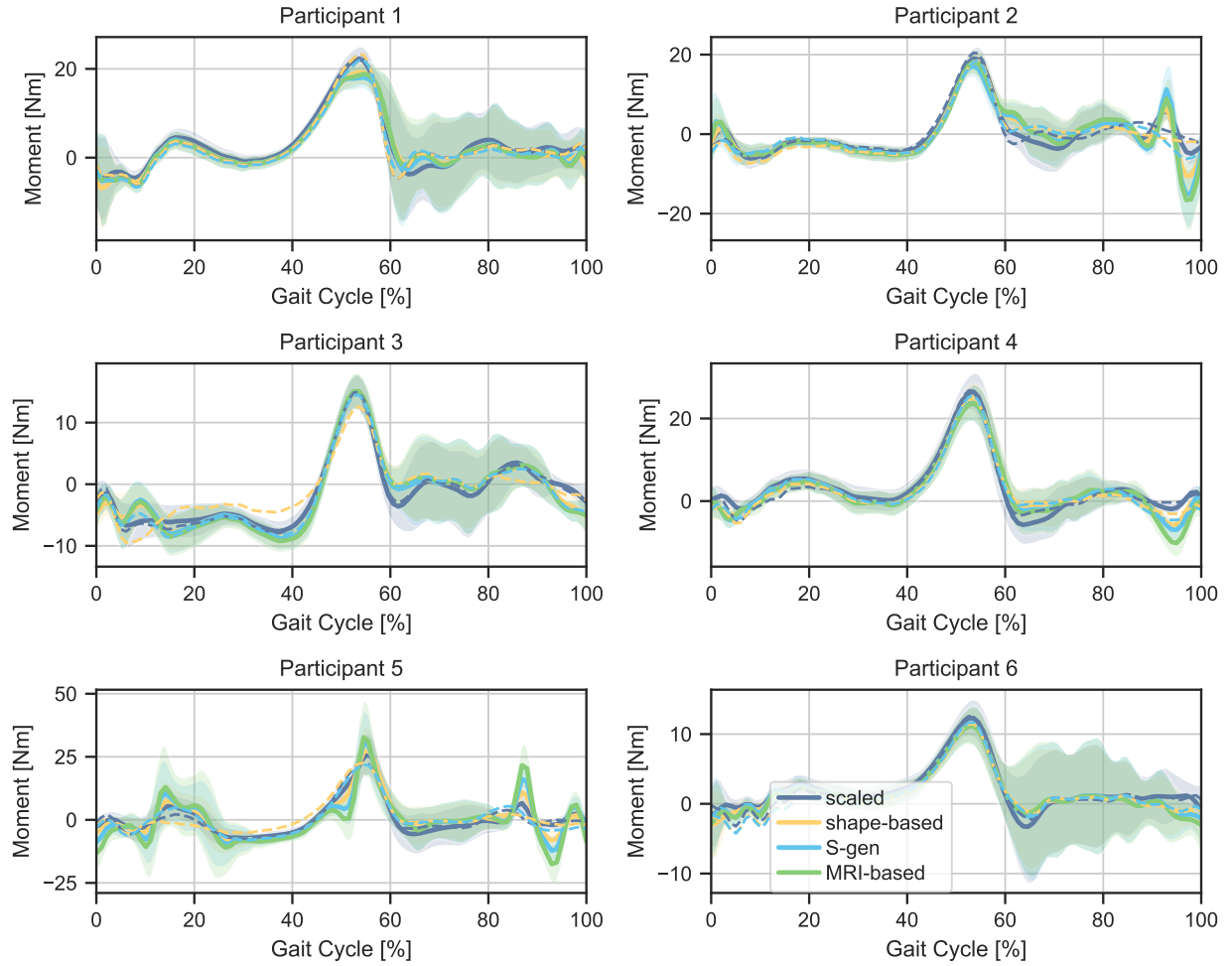


Figure A.5: **Hip rotation moments for all participants during level walking at  $1.3 \text{ m s}^{-1}$ .** Moments resulting from inverse dynamics are shown for the scaled, SIPP, SIPP-generic (S-gen), and MRI-personalized models. Shaded areas indicate standard deviation. We also show models that are optimized with addBiomechanics' physics optimization as dashed lines.

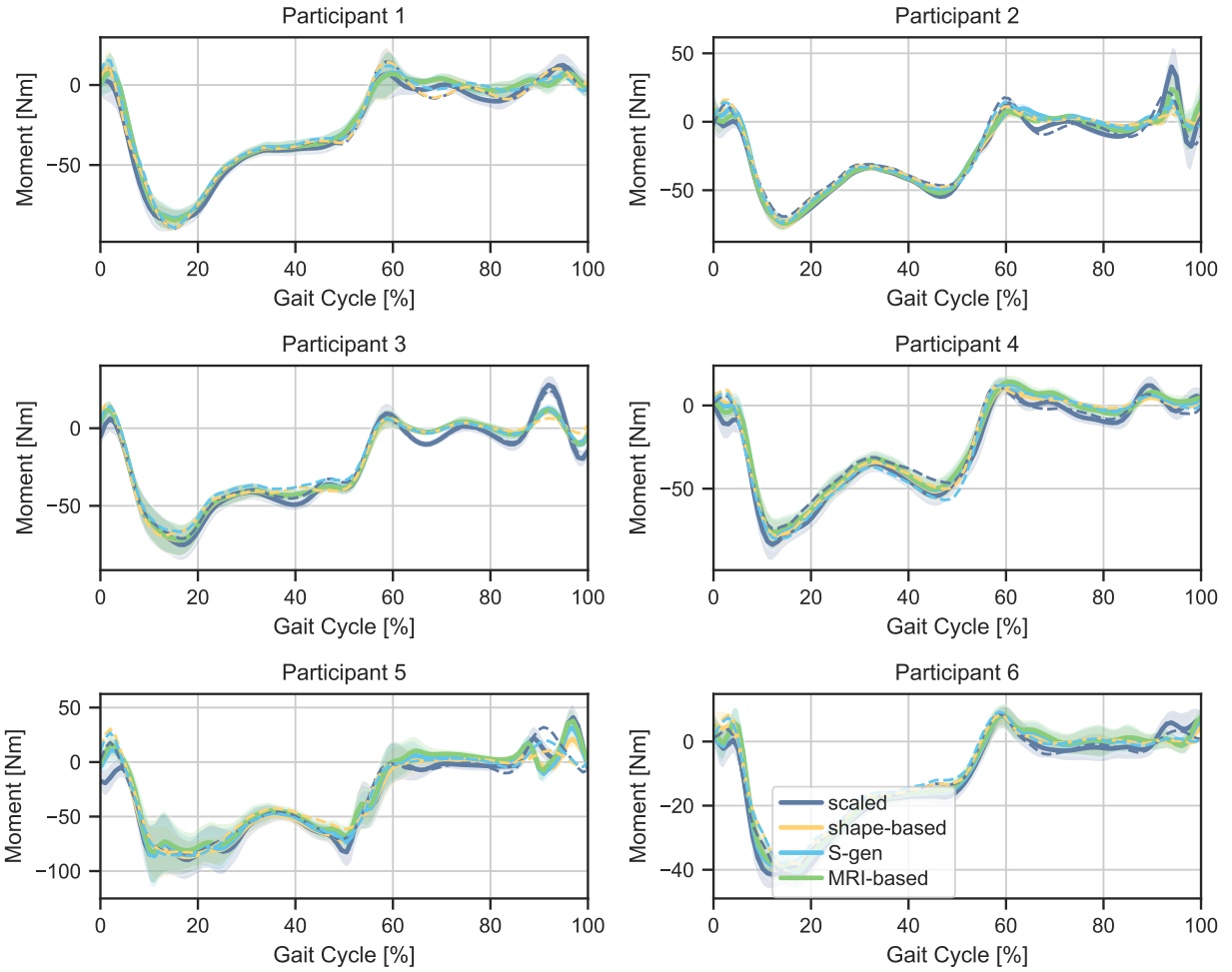


Figure A.6: **Hip adduction moments for all participants during level walking at  $1.3 \text{ m s}^{-1}$ .** Moments resulting from inverse dynamics are shown for the scaled, SIPP, SIPP-generic (S-gen), and MRI-personalized models. Shaded areas indicate standard deviation. We also show models that are optimized with addBiomechanics' physics optimization as dashed lines.

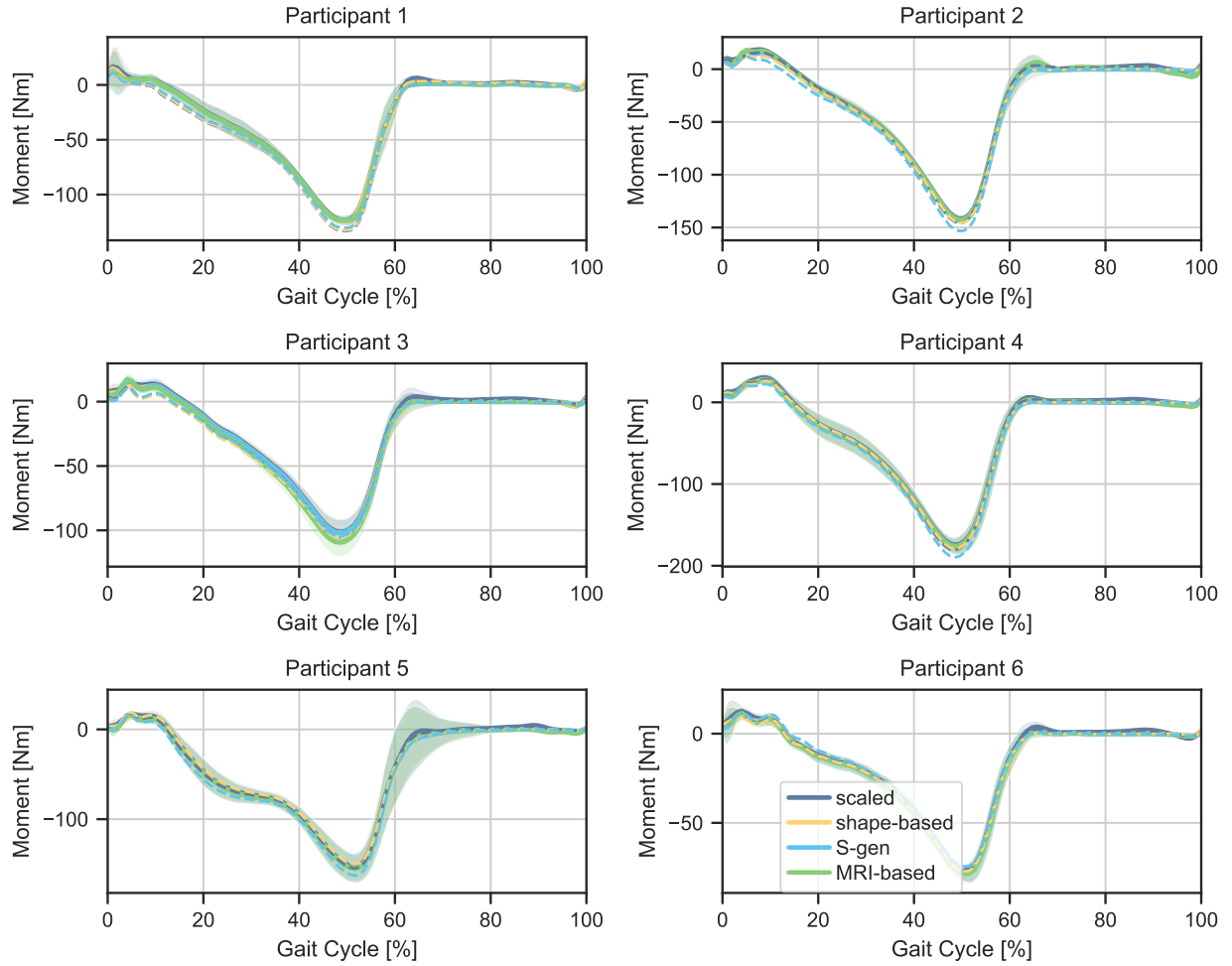


Figure A.7: **Ankle moments for all participants during level walking at  $1.3 \text{ m s}^{-1}$ .** Moments resulting from inverse dynamics are shown for the scaled, SIPP, SIPP-generic (S-gen), and MRI-personalized models. Shaded areas indicate standard deviation. We also show models that are optimized with addBiomechanics' physics optimization as dashed lines.



Table A.3: **Overview of residual forces.** We show the mean and standard deviation of the absolute residuals for all dimensions ( $x, y, z$ ) and their norms. Forces are listed as a percentage of bodyweight [BW%] and the values for absolute residual moments are listed as a percentage of bodyweight times bodyweight [BWBH%]. We show the results for the MRI-personalized model, scaled model, SIPP model, and SIPP-generic (S-gen) model in the first four rows. In the last three rows, we show the results for the same models in combination with addBiomechanics’ physics optimization (addB, add+SIPP, add+S-gen). The best results per table section are highlighted in bold.

Model	Forces				Moments			
	$F_x$	$F_y$	$F_z$	$\ F\ $	$M_x$	$M_y$	$M_z$	$\ M\ $
	[BW%]	[BW%]	[BW%]	[BW%]	[BWBH%]	[BWBH%]	[BWBH%]	[BWBH%]
MRI	$4.75 \pm 7.0$	$3.50 \pm 3.9$	$3.04 \pm 3.2$	$7.70 \pm 7.7$	$1.75 \pm 1.8$	$0.92 \pm 0.8$	$1.91 \pm 4.8$	$3.12 \pm 5.0$
scaled	$5.14 \pm 5.1$	$3.57 \pm 3.2$	<b><math>2.67 \pm 2.7</math></b>	$7.71 \pm 5.5$	$2.06 \pm 1.8$	$0.96 \pm 0.8$	<b><math>1.30 \pm 4.3</math></b>	$2.94 \pm 4.5$
SIPP	<b><math>3.90 \pm 4.8</math></b>	<b><math>3.07 \pm 3.2</math></b>	$2.73 \pm 2.7$	<b><math>6.56 \pm 5.5</math></b>	<b><math>1.43 \pm 1.3</math></b>	<b><math>0.86 \pm 0.7</math></b>	$1.49 \pm 4.3$	<b><math>2.55 \pm 4.4</math></b>
S-gen	$4.66 \pm 6.8$	$3.56 \pm 4.0$	$3.19 \pm 3.4$	$7.77 \pm 7.6$	$1.64 \pm 1.7$	$0.92 \pm 0.8$	$1.83 \pm 4.8$	$3.00 \pm 4.9$
addB	$3.51 \pm 5.7$	$3.38 \pm 4.6$	<b><math>1.63 \pm 2.9</math></b>	$5.77 \pm 7.4$	$1.85 \pm 1.5$	$0.93 \pm 0.8$	<b><math>1.25 \pm 4.7</math></b>	$2.72 \pm 4.9$
addB+SIPP	<b><math>2.62 \pm 4.0</math></b>	<b><math>2.84 \pm 3.7</math></b>	$1.69 \pm 2.8$	<b><math>4.83 \pm 5.6</math></b>	<b><math>1.29 \pm 1.2</math></b>	<b><math>0.86 \pm 0.7</math></b>	$1.35 \pm 4.3$	<b><math>2.34 \pm 4.3</math></b>
addB+S-gen	$2.79 \pm 4.9$	$3.18 \pm 4.6$	$1.77 \pm 3.9$	$5.24 \pm 7.3$	$1.40 \pm 1.2$	$0.89 \pm 0.8$	$1.60 \pm 4.8$	$2.60 \pm 4.8$

## Effect of gender on SIPP-generic

### Results per gender

Female MSK models perform worse on all mean relative deviations in the MRIGait benchmark than scaled male MSK models, as shown in Table A.4. Both SIPP and SIPP-generic models outperform

Table A.4: **Results of the MRIGait benchmark for participants by gender.** The first two row show state-of-the-art methods of scaling (scaled) and addBiomechanics’ physics optimization (addB). The next two rows show the novel SIPP-personalized and scaled SIPP-generic (S-gen) models. In the final two rows, SIPP and SIPP-generic in combination with addBiomechanics’ physics optimization are shown (add+SIPP, add+S-gen). The columns show the mean and standard deviation of the mean absolute deviation (MAD) and mean relative deviation (MRD) for mass (M), center of mass (CoM), inertia (I), and kinetic energy (E). The best results are highlighted in bold. Inertia values only account for the diagonal elements of the inertia tensor, as generic OpenSim models assume off-diagonal elements to be zero.

Model	Mean Absolute Deviation				Mean Relative Deviation			
	M [g]	CoM [cm]	I [kg m <sup>2</sup> ]	E [J]	M [%]	CoM [%]	I [%]	E [%]
<b>Male Participants</b>								
scaled	$80.7 \pm 92.2$	$9.5 \pm 0.8$	$0.38 \pm 0.60$	$2.3 \pm 0.7$	$22.3 \pm 6.7$	$56.7 \pm 2.0$	$28.1 \pm 13.2$	$22.2 \pm 9.1$
addB	$45.3 \pm 144.8$	$9.5 \pm 0.6$	$0.40 \pm 0.59$	$1.7 \pm 0.5$	$15.7 \pm 9.8$	$56.8 \pm 2.5$	$25.1 \pm 9.9$	$16.9 \pm 7.8$
SIPP	$56.4 \pm 71.6$	$4.9 \pm 1.6$	$0.34 \pm 0.58$	$1.8 \pm 0.6$	$14.7 \pm 2.7$	$23.6 \pm 4.5$	$22.1 \pm 1.8$	$16.9 \pm 6.3$
S-gen	$35.8 \pm 261.5$	$5.0 \pm 1.7$	$0.35 \pm 0.56$	$1.5 \pm 0.5$	$6.5 \pm 3.7$	$23.5 \pm 5.3$	$4.9 \pm 3.5$	$13.7 \pm 6.0$
addB+SIPP	$44.4 \pm 80.9$	$4.9 \pm 1.7$	$0.36 \pm 0.59$	$2.3 \pm 0.5$	$22.1 \pm 0.6$	$23.2 \pm 5.3$	$26.7 \pm 7.0$	$21.5 \pm 4.0$
addB+S-gen	$76.2 \pm 323.6$	$5.7 \pm 1.7$	$0.35 \pm 0.58$	$1.1 \pm 0.4$	$7.6 \pm 3.7$	$27.2 \pm 4.5$	$2.8 \pm 2.8$	$9.8 \pm 3.7$
<b>Female Participants</b>								
scaled	$83.5 \pm 44.0$	$7.9 \pm 0.5$	$0.32 \pm 0.58$	$2.0 \pm 0.5$	$36.9 \pm 2.5$	$65.1 \pm 1.9$	$51.2 \pm 4.7$	$32.3 \pm 4.5$
addB	$20.5 \pm 13.2$	$8.0 \pm 0.6$	$0.37 \pm 0.70$	$1.5 \pm 0.4$	$30.9 \pm 4.6$	$66.3 \pm 2.0$	$43.8 \pm 7.9$	$23.9 \pm 2.9$
SIPP	$56.4 \pm 35.4$	$1.3 \pm 0.2$	$0.38 \pm 0.13$	$0.2 \pm 0.2$	$4.6 \pm 3.5$	$9.9 \pm 0.8$	$8.7 \pm 3.4$	$4.0 \pm 3.1$
S-gen	$89.7 \pm 18.1$	$1.9 \pm 0.2$	$0.24 \pm 0.12$	$0.4 \pm 0.4$	$2.2 \pm 1.0$	$12.8 \pm 1.6$	$7.1 \pm 5.8$	$4.9 \pm 4.5$
add+SIPP	$63.1 \pm 64.9$	$3.9 \pm 4.1$	$0.19 \pm 0.32$	$1.1 \pm 0.5$	$14.5 \pm 10.1$	$31.1 \pm 31.7$	$24.2 \pm 21.9$	$17.1 \pm 6.6$
add+S-gen	$107.7 \pm 63.6$	$1.7 \pm 0.3$	$0.15 \pm 0.55$	$0.6 \pm 0.4$	$2.6 \pm 1.2$	$12.3 \pm 2.6$	$3.3 \pm 1.5$	$7.6 \pm 3.6$

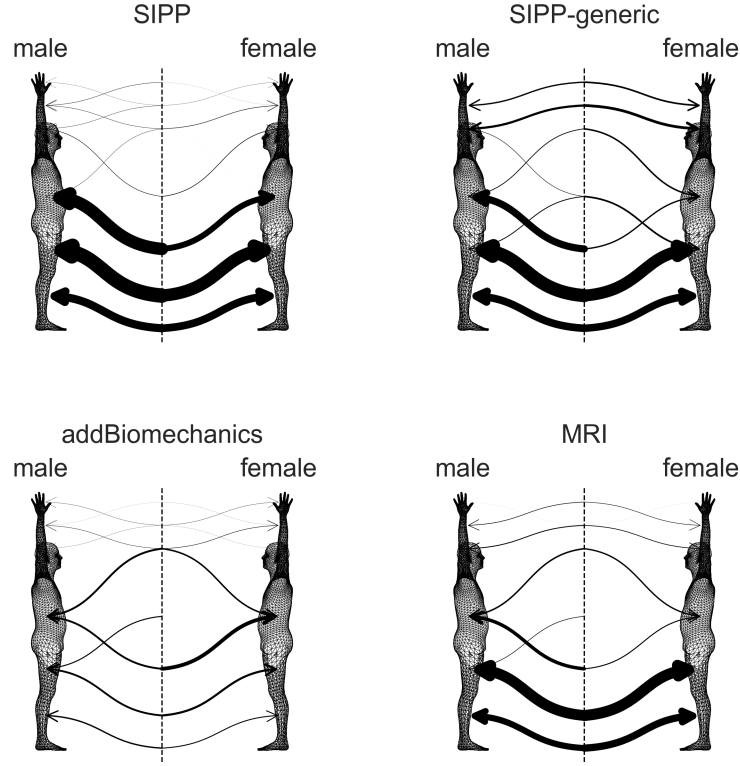


Figure A.8: **Average mass reallocation compared to scaled models.** The arrows depict the average transfer of mass from the scaled (dotted line in the middle) to the personalized (male: left, female: right) MSK models. We binned the body parts into 7 regions, which are (from top to bottom): hand, lower arm, upper arm, trunk, upper leg, lower leg and feet. The thickness of the arrows corresponds to the average amount of mass reallocated from one segment to another.

the scaled models for each gender. Mean absolute deviations should not be compared between genders, as the body mass and height greatly differ. In Figs A.8, we show the average mass reallocation when using SIPP, SIPP-generic, addBiomechanics’ physics optimization, and MRI-personalization. Compared to the main text, we show these results separately per gender. The averages differ slightly between genders. In Table A.5, we show the residual forces and moments for all models, separated by gender. Here, female participants show lower residual forces and moments accross all models, however, modelling errors are not the only gender-dependent factor. When comparing the effect of personalization on metabolics per gender, we found only slight differences between the two groups.

### Misgendered SIPP-generic

In the main text, we presented the results of the SIPP-generic model. To underline the importance of gender-specific BSIP parameterizations, we show the results of the SIPP-generic model when misgendered in Table A.6. The results show that the SIPP-generic model performs slightly worse than the scaled model when misgendered.

Table A.5: **Overview of residual forces.** We show the mean and standard deviation of the absolute residuals for all dimensions ( $x, y, z$ ) and their norms. Forces are listed as a percentage of bodyweight [BW%] and the values for absolute residual moments are listed as a percentage of bodyweight times bodyweight [BWBH%]. We show the results for the MRI-personalized model, scaled model, SIPP model, and SIPP-generic (S-gen) model, in the first four rows. In the last three rows, we show the results for the same models in combination with addBiomechanics’ physics optimization (addB, add+SIPP, add+S-gen). The best results per table section are highlighted in bold.

Model	Forces				Moments			
	$F_x$ [BW%]	$F_y$ [BW%]	$F_z$ [BW%]	$\ F\ $ [BW%]	$M_x$ [BWBH%]	$M_y$ [BWBH%]	$M_z$ [BWBH%]	$\ M\ $ [BWBH%]
<b>Male Participants</b>								
MRI	$6.51 \pm 10.1$	$3.95 \pm 4.6$	$3.41 \pm 3.5$	$9.58 \pm 10.6$	$2.53 \pm 2.8$	$1.04 \pm 1.0$	$2.38 \pm 8.3$	$4.09 \pm 8.6$
scaled	$6.25 \pm 6.6$	$4.05 \pm 3.8$	$2.98 \pm 2.9$	$9.05 \pm 6.9$	$2.66 \pm 2.5$	$1.10 \pm 0.9$	<b><math>1.56 \pm 7.3</math></b>	$3.67 \pm 7.6$
SIPP	<b><math>4.97 \pm 6.5</math></b>	<b><math>3.33 \pm 3.5</math></b>	<b><math>2.95 \pm 2.8</math></b>	<b><math>7.67 \pm 6.9</math></b>	<b><math>1.89 \pm 1.7</math></b>	<b><math>0.96 \pm 0.8</math></b>	$1.62 \pm 7.3$	<b><math>3.02 \pm 7.4</math></b>
S-gen	$6.21 \pm 9.6$	$3.94 \pm 4.6$	$3.46 \pm 3.6$	$9.40 \pm 10.2$	$2.26 \pm 2.5$	$1.01 \pm 1.0$	$2.04 \pm 8.2$	$3.66 \pm 8.4$
addB	$3.80 \pm 7.0$	$3.57 \pm 4.5$	<b><math>1.61 \pm 3.1</math></b>	$6.12 \pm 8.4$	$2.20 \pm 1.8$	$1.08 \pm 1.0$	$1.47 \pm 8.2$	$3.22 \pm 8.3$
addB+SIPP	<b><math>2.95 \pm 5.6</math></b>	<b><math>3.01 \pm 4.5</math></b>	$1.70 \pm 4.1$	<b><math>5.20 \pm 7.9</math></b>	<b><math>1.54 \pm 1.4</math></b>	<b><math>0.95 \pm 1.0</math></b>	<b><math>1.45 \pm 8.1</math></b>	<b><math>2.62 \pm 8.2</math></b>
addB+S-gen	$3.08 \pm 6.2$	$3.18 \pm 4.6$	$1.68 \pm 4.6$	$5.40 \pm 8.6$	$1.75 \pm 1.4$	$0.99 \pm 1.0$	$1.70 \pm 8.2$	$2.96 \pm 8.2$
<b>Female Participants</b>								
MRI	$3.23 \pm 3.8$	$3.21 \pm 3.7$	$2.75 \pm 3.0$	$6.14 \pm 5.2$	$1.08 \pm 1.0$	$0.79 \pm 0.6$	$1.50 \pm 1.5$	$2.28 \pm 1.6$
scaled	$4.25 \pm 3.9$	$3.24 \pm 3.1$	<b><math>2.42 \pm 2.6</math></b>	$6.66 \pm 4.6$	$1.52 \pm 1.3$	$0.82 \pm 0.7$	<b><math>1.04 \pm 1.3</math></b>	$2.27 \pm 1.6$
SIPP	<b><math>3.00 \pm 3.3</math></b>	<b><math>2.94 \pm 3.2</math></b>	$2.58 \pm 2.7$	<b><math>5.68 \pm 4.5</math></b>	<b><math>1.03 \pm 1.0</math></b>	<b><math>0.76 \pm 0.6</math></b>	$1.32 \pm 1.3$	<b><math>2.09 \pm 1.4</math></b>
S-gen	$3.30 \pm 3.8$	$3.34 \pm 3.8$	$2.99 \pm 3.2$	$6.42 \pm 5.4$	$1.10 \pm 1.0$	$0.82 \pm 0.7$	$1.60 \pm 1.5$	$2.38 \pm 1.6$
addB	$3.42 \pm 4.8$	$3.37 \pm 4.6$	<b><math>1.72 \pm 2.7</math></b>	$5.73 \pm 6.7$	$1.56 \pm 1.4$	$0.78 \pm 0.7$	<b><math>1.02 \pm 1.3</math></b>	$2.28 \pm 1.7$
addB+SIPP	<b><math>2.56 \pm 4.4</math></b>	<b><math>3.15 \pm 4.2</math></b>	$1.87 \pm 2.7$	<b><math>5.10 \pm 6.2</math></b>	$1.18 \pm 1.3$	<b><math>0.78 \pm 0.6</math></b>	$1.23 \pm 1.4$	<b><math>2.15 \pm 1.7</math></b>
addB+S-gen	$2.60 \pm 4.0$	$3.31 \pm 4.5$	$1.93 \pm 3.0$	$5.29 \pm 6.2$	<b><math>1.07 \pm 1.0</math></b>	$0.78 \pm 0.6$	$1.50 \pm 1.5$	$2.25 \pm 1.6$

Table A.6: **Overview of residual forces of SIPP-generic and SIPP-generic when the wrong gender is assigned.** We show the mean and standard deviation of the absolute residuals for all dimensions ( $x, y, z$ ) and their norms. Forces are listed as a percentage of bodyweight [BW%] and the values for absolute residual moments are listed as a percentage of bodyweight times bodyweight [BWBH%]. The best results are highlighted in bold.

Model	Forces				Moments			
	$F_x$ [BW%]	$F_y$ [BW%]	$F_z$ [BW%]	$\ F\ $ [BW%]	$M_x$ [BWBH%]	$M_y$ [BWBH%]	$M_z$ [BWBH%]	$\ M\ $ [BWBH%]
S-gen	<b><math>4.66 \pm 6.8</math></b>	<b><math>3.56 \pm 4.0</math></b>	<b><math>3.19 \pm 3.4</math></b>	<b><math>7.77 \pm 7.6</math></b>	$1.64 \pm 1.7$	$0.92 \pm 0.8$	<b><math>1.83 \pm 4.8</math></b>	<b><math>3.00 \pm 4.9</math></b>
S-gen, misgendered	$4.74 \pm 7.2$	$3.57 \pm 4.1$	$3.24 \pm 3.3$	$7.88 \pm 8.0$	<b><math>1.64 \pm 1.8</math></b>	<b><math>0.91 \pm 0.8</math></b>	$1.84 \pm 4.8$	$3.02 \pm 5.0$