Additional File 1

1.1 Participant Details

Individual participant details and corresponding experiment parameters (as described in Methods) are included in Table 1.1. The average magnitude of the desired exoskeleton assistance torque trajectory was 33.07 +/- 5.63 Nm, with an average desired duration of 466 +/- 10.7 ms (including rate-limited portion).

Table 1.1. Participant details. Leg length was measured from greater trochanter to lateral malleolus. Push height was measured from the height of the pusher attachment on the pelvis brace to the lateral malleolus. Note that for two cases, a slightly lower torque value was used in the experiment compared to the calculated value (leg length was erroneously included in calculation instead of push height).

Participant	Height [m]	Leg Length [m]	Mass [kg]	Shoe Size [EUR]	Push Height [m]	Calculated 8%BW Push Impulse [Nm-s]	Calculated Exoskeleton Torque Magnitude (value used) [Nm]
PC03	1.80	0.86	64	40	0.96	12.05	30.14 (30)
PC05	1.85	0.84	66	46	0.94	12.17	30.43 (30)
PC07	1.86	0.84	74	44	0.94	13.65	34.12 (34)
PC08	1.88	0.87	74	44	0.97	14.08	35.21 (35)
PC09	1.69	0.77	71	38	0.87	12.12	30.30 (30)
PC10	1.81	0.93	60	40	0.85	10.01	25.02 (25)
PC11	1.86	0.87	90	44	0.94	16.60	41.50 (38)
PC12	1.85	0.92	70	40	0.99	13.60	33.99 (30)
PC13	1.90	0.90	81	42	1.00	15.89	39.73 (40)
PC14	1.85	0.88	80	42	0.97	15.23	38.06 (38)
PC15	1.81	0.89	75	44	0.94	13.83	34.58 (34.5)
PC16	1.89	0.86	77	42	0.94	14.20	35.50 (35.5)
PC17	1.71	0.79	50	40	0.87	8.53	21.34 (21.5)
group mean	1.83	0.86	71.69	42	0.94	13.23	33.07
group std	0.07	0.05	10.18	2.31	0.05	2.25	5.63

1.2 Experiment Validation, Expanded

In post-processing we computed a robust set of metrics to evaluate the extent to which the experiment was conducted as intended in order to report and address any inconsistencies.

We first computed the accuracy of the push trigger at left heel-strike. Due to the live filtering of the GRF signals used in the online gait phase detection algorithm, in practice the perturbation was triggered when the left GRF reached 14 +/- 2% bodyweight (BW), rather than the desired 10%. In post-processing, it was determined that 10% BW was reached on average 8 +/- 4 ms sooner than the actual trigger. Despite being a few milliseconds later than intended, the pushes were still triggered in line with our aims: consistently at left heel-strike.

We then computed a few metrics to verify robot performance. Robotic pusher accuracy was defined as the percentage of the desired push profile that was actually delivered, computed as the integral of the actual force delivered (measured by the load cell in line with the pusher rod) divided by the integral of the desired push profile, multiplied by 100. Robotic pusher onset was defined as the time delay between the desired pusher force and actual push force reaching 5N. Likewise, ankle exoskeleton accuracy was defined as the percentage of the desired torque profile that was actually delivered, computed as the integral of the actual torque profile (measured from the exoskeleton load cell multiplied by the perpendicular moment arm), divided by the integral of the desired torque profile, multiplied by 100. Ankle exoskeleton onset was defined as the time delay between the desired exoskeleton torque and actual exoskeleton torque reaching 5Nm. These values are tabulated in Table 1.2 below. Recall that the percentage of disturbance torque that was cancelled by the exoskeleton torque as well as the exoskeleton assistance delay (which combine these individual robot performances) were reported in the main text.

Table 1.2. Robotic device performance. Percentages were calculated for each participant, and then averaged across participants for the final value tabulated here.

Push Magnitude [%BW]	Pusher Accuracy [%]	Pusher Onset [ms]	Exoskeleton Accuracy [%]	Exoskeleton Onset [ms]
8	95.98 +/- 1.90	21.69 +/- 1.78	91.98 +/- 1.86	56.84 +/- 6.98
12	94.51 +/- 1.84	19.25 +/- 1.30	91.98 +/- 2.58	57.18 +/- 6.92
16	93.92 +/- 2.02	17.86 +/- 1.12	91.92 +/- 5.60	57.33 +/- 7.25

Data from a push was excluded from the analysis if pusher performance or exoskeleton performance was less than 75%. Three pushes (0.09% of all pushes) were excluded from the analysis for being below the pusher performance criteria. All pushes met the exoskeleton performance criteria.

Kinetic and spatiotemporal data from a push was removed from analysis if the participant crossed over on the treadmill force plates (i.e., right foot stepped on left treadmill belt, or vice-versa) in the step immediately preceding or following the push. Thirty pushes (0.85% of all pushes) were excluded from the kinetics/spatiotemporal analysis due to the crossover criteria.

We analyzed metrics at 500ms after the push, as this time stamp was (in theory) after the desired exoskeleton assistance would end but before the next heel-strike. However, this was not precisely the case for all pushes for two reasons: (1) After collecting the first seven participants, we noticed an error in the controller that sometimes caused the plantarflexion to hold longer than desired (this glitch was corrected for the remaining six participants); (2) the onset delay of ~50ms added to the desired exoskeleton assistance (~466ms) extend beyond 500ms after push trigger in some cases. Despite this, the exoskeleton torque was below 10Nm and decreasing at 500ms after push trigger for 95% of the assisted pushes. Furthermore, the average exoskeleton torque magnitude at 500ms after perturbation trigger was 7.12Nm and decreasing. Therefore, we deemed 500ms still the best time stamp to analyze, as any longer would encroach on potential heel-strikes for some participants.

Finally, in post-processing we noticed the pusher's range of motion was reached (i.e., hit endstop) within 500ms after the push in 23 cases (0.66% of all pushes). Due to the low number of instances this was not addressed in this work.

Note that the data for this experiment and processing scripts have been included with this work, which tags each push with the aforementioned information (e.g., crossover step, pusher range of motion reached, exoskeleton performance, etc.).

1.3 Additional Statistics

The results from all model fits and statistical tests are stored in the dataset included with this paper for further reference.