Appendix

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1 Introduction

The diagram in Fig. 1 shows where our contributions fit into the past literature survey.

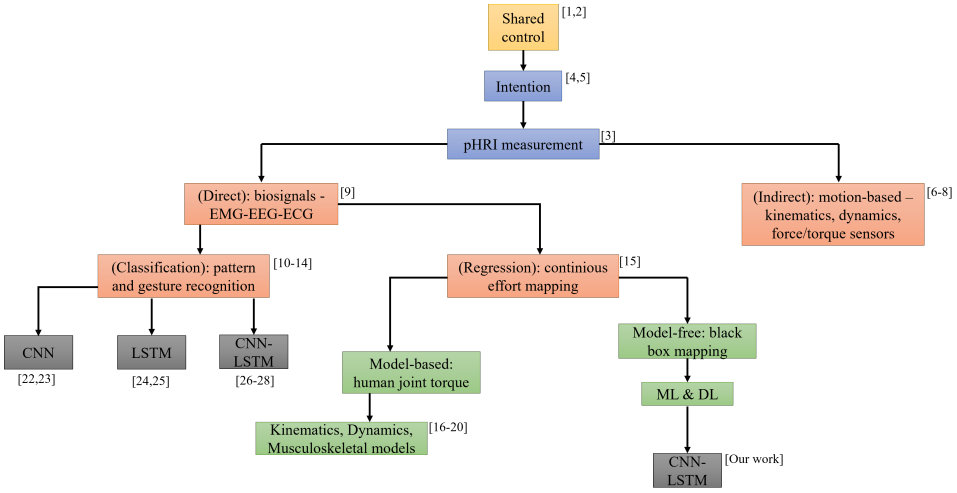

Figure 1: The diagram of the literature review is based on the references mentioned in the introduction.

2 IBPA

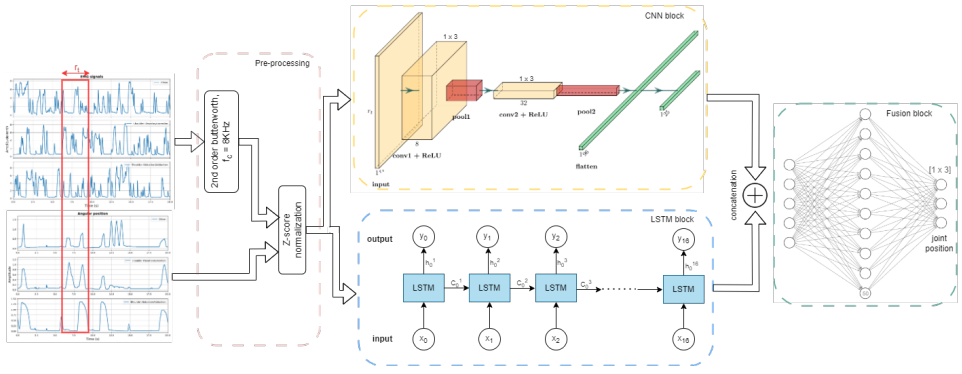

Figure 2: The architecture of the hybrid regression model comprises a CNN block, an LSTM block, and FC layers at the end.

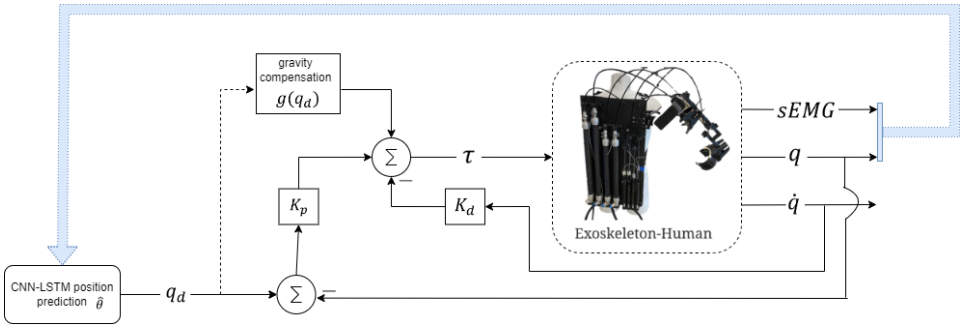

Figure 3: The overview of the controller. Proportional-derivative (PD) with feed-forward gravity compensation.

3 Experimental Protocol

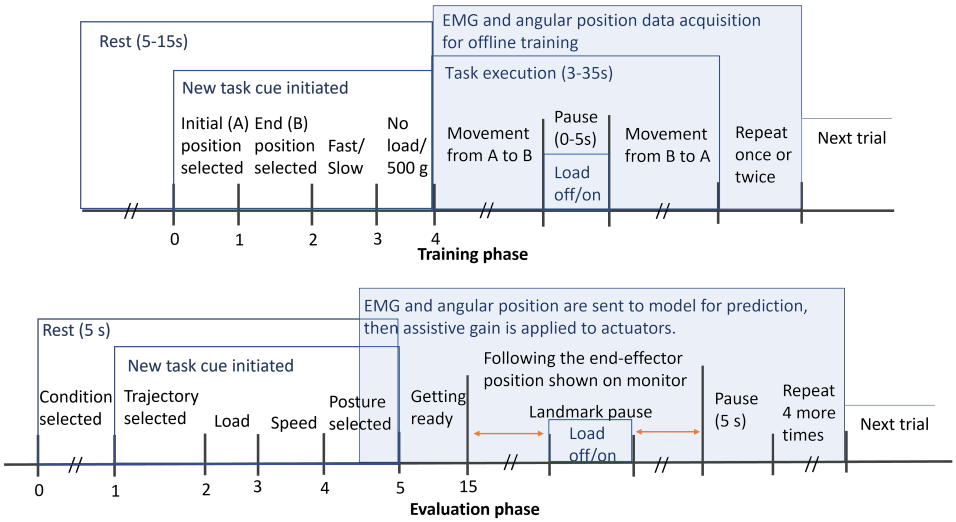

Figure 4: The timing diagram for the training and evaluation phase. The load off/on refers to being handed a load or handing the load back. The load off/on for the evaluation phase only happens in a few tasks and the majority are without it. The orange arrows are used for calculating the travel time and movement speed.

Fig. 6 shows the data collected during the evaluation phase. It includes the EMG data, position data, and actuation gain. Each of the highlighted segments represents a particular task as an example. The orange box rep-

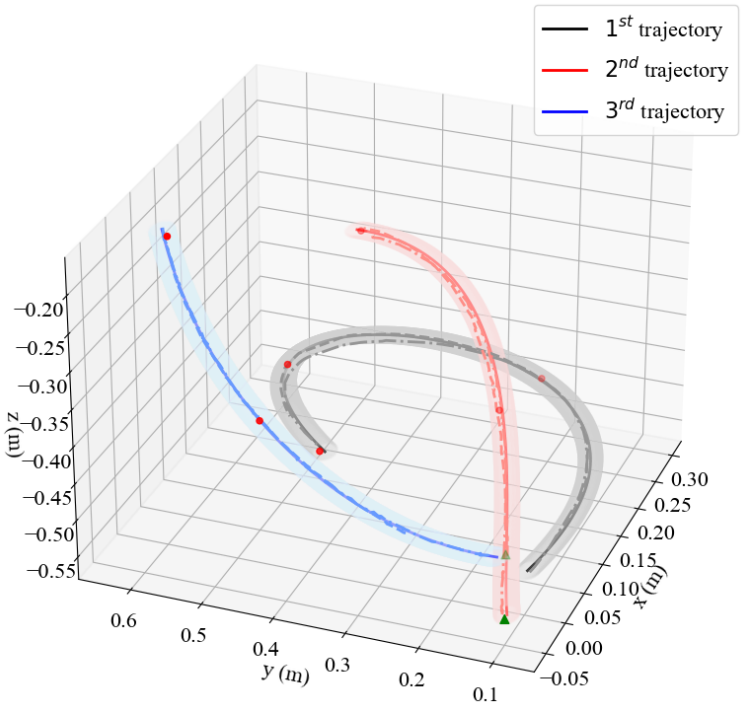

Figure 5: The predefined reference trajectories and error bounds of diameter 3 cm. The dashed lines represent the mean trajectories traveled by the participants.

resents the existence of a load, the green box shows a faster speed, the blue represents a load off/on, and the purple shows a difference in posture. It must be mentioned that the segments of data are attached together later and they are not continuous in time.

**The appendix is subject to ongoing refinement and augmentation to ensure its continual relevance and applicability in the evolving research context. Please refer to the above for the last date of update.

Table 1: The differences between features and their combinations used in training and evaluation phase

	Experimental phase	
Features	Training	Evaluation
Conditions	GC	GC,IBPA,unassisted
Speed	slow/fast	$0.18m/s, 0.1m/s, 0.07m/s$
Load	No load, $0.5kg$	$0.5Kg, 1Kg, 1.5Kg$
Landmarks	6	9
Repetitions	2 or 3	5
Posture	Seated	Seated, Standing
Electrode placement	7	3
Pause	0-5 seconds on a random landmark	0-5 seconds only on end positions
Rest	Up to 15 seconds	5 seconds
Break	hourly or less	No breaks

Table 2: The mean and standard deviation for the speed of each trajectory traveled by the two participants during the evaluation phase. The values in the table present the mean and std across all three conditions and repetitions of the tasks.

		Trajectory 1		Trajectory 2		Trajectory 3	
		Mean	std	Mean	std	Mean	std
Participant 1	Fast	0.1801 m/s	0.0234	0.1790 m/s	0.013	0.1803 m/s	0.0181
	Medium	0.1005 m/s	0.0096	0.0945 m/s	0.0074	0.1020 m/s	0.0039
	Slow	0.0721 m/s	0.0088	0.0668 m/s	0.0023	0.0653 m/s	0.0067
Participant 2	Fast	0.1833 m/s	0.011	0.1845 m/s	0.0092	0.1800 m/s	0.0069
	Medium	0.0989 m/s	0.007	0.1010 m/s	0.0001	0.1016 m/s	0.0101
	Slow	0.0709 m/s	0.0104	0.0691 m/s	0.0037	0.0750 m/s	0.0012

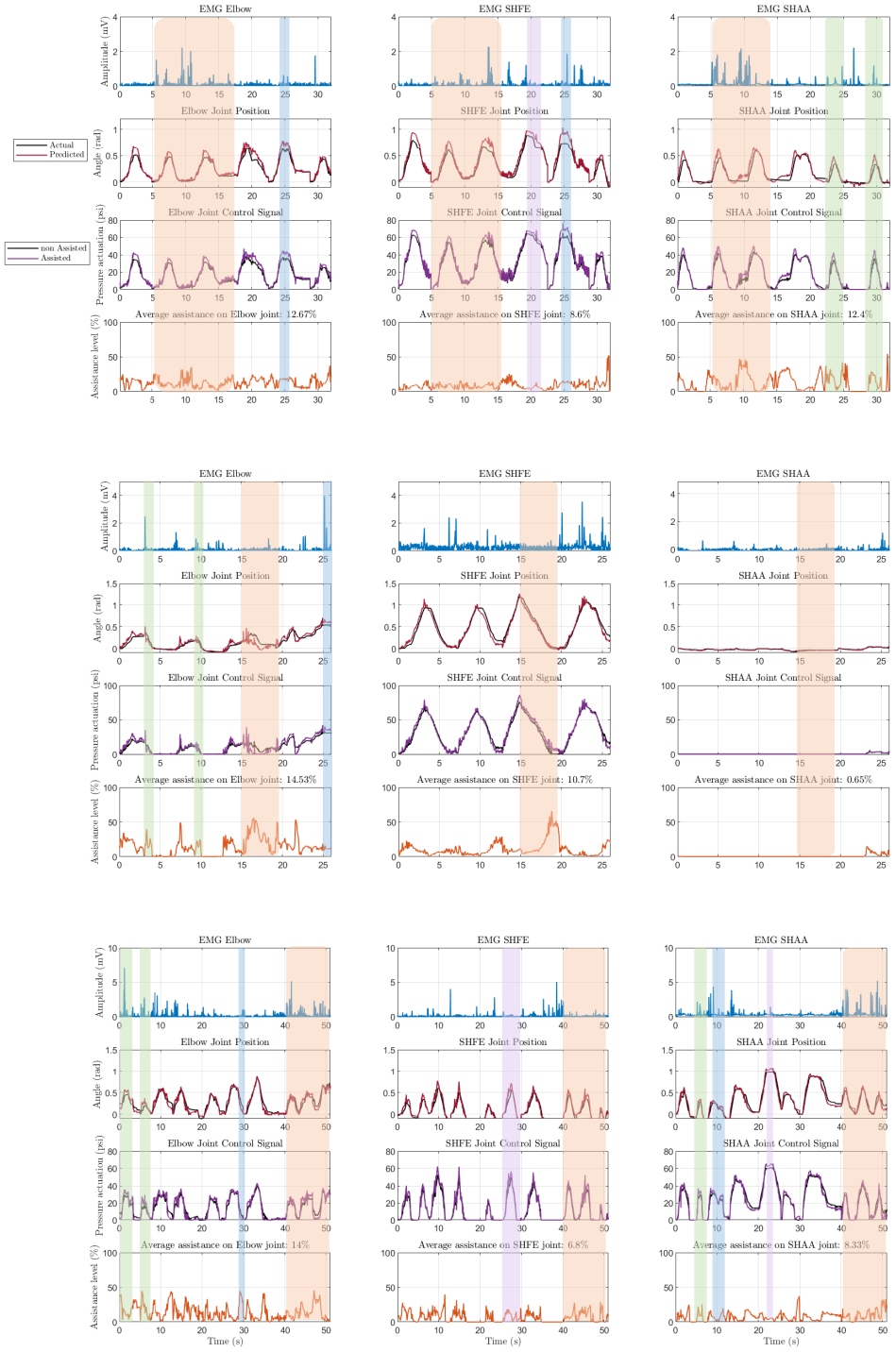

Figure 6: Some samples of tasks conducted during the evaluation phase by the female participant. The top row is for the first trajectory, the bottom row is for the second trajectory and the middle row shows data for the third trajectory.

Table 3: Descriptive statistics of average Total RMS EMG across both participants for the IBPA condition. The total EMG is calculated by adding up the RMS EMG of each joint individually.

				Count	Mean	Standard Deviation	Coefficient of Variation
IBPA	traj 1	fast	0.5	2	0.6832	0.15189	22.2%
			1	2	0.9438	0.30835	32.7%
			1.5	2	1.0652	0.36084	33.9%
			Total	6	0.8974	0.28309	31.5%
		medium	0.5	2	0.7078	0.08174	11.5%
			1	2	1.0036	0.27006	26.9%
			1.5	2	1.4157	0.42858	30.3%
			Total	6	1.0423	0.39214	37.6%
		slow	0.5	2	0.9378	0.16287	17.4%
			1	2	0.9871	0.23267	23.6%
			1.5	2	1.6093	0.61759	38.4%
			Total	6	1.1781	0.45220	38.4%
		Total	0.5	6	0.7763	0.16440	21.2%
			1	6	0.9782	0.21258	21.7%
			1.5	6	1.3634	0.44712	32.8%
			Total	18	1.0393	0.37795	36.4%
	traj 2	fast	0.5	2	0.8933	0.39700	44.4%
			1	2	0.9375	0.38870	41.5%
			1.5	2	0.8927	0.19350	21.7%
			Total	6	0.9078	0.26411	29.1%
		medium	0.5	2	1.1803	0.59066	50.0%
			1	2	1.3828	0.59422	43.0%
			1.5	2	0.9512	0.08690	9.1%
			Total	6	1.1714	0.42333	36.1%
		slow	0.5	2	0.7342	0.26053	35.5%
			1	2	0.7773	0.24699	31.8%
			1.5	2	1.2158	0.82782	68.1%
			Total	6	0.9091	0.46865	51.6%
		Total	0.5	6	0.9359	0.39465	42.2%
			1	6	1.0325	0.43794	42.4%
			1.5	6	1.0199	0.41202	40.4%
			Total	18	0.9961	0.39255	39.4%
	traj 3	fast	0.5	2	0.8143	0.32812	40.3%
			1	2	0.9091	0.28242	31.1%
			1.5	2	0.7560	0.05091	6.7%
			Total	6	0.8265	0.20683	25.0%
		medium	0.5	2	0.8385	0.42218	50.3%
			1	2	1.0388	0.37519	36.1%
			1.5	2	0.8602	0.07102	8.3%
			Total	6	0.9125	0.27290	29.9%
		slow	0.5	2	0.7899	0.31883	40.4%
			1	2	1.1281	0.67612	59.9%
			1.5	2	1.0600	0.20844	19.7%
			Total	6	0.9926	0.38217	38.5%
		Total	0.5	6	0.8142	0.27926	34.3%
			1	6	1.0253	0.38110	37.2%
			1.5	6	0.8921	0.17119	19.2%
			Total	18	0.9105	0.28691	31.5%
	Total	fast	0.5	6	0.7969	0.25822	32.4%
			1	6	0.9301	0.25585	27.5%
			1.5	6	0.9046	0.23075	25.5%
			Total	18	0.8772	0.24094	27.5%
		medium	0.5	6	0.9089	0.39290	43.2%
			1	6	1.1417	0.38532	33.7%
			1.5	6	1.0757	0.33205	30.9%
			Total	18	1.0421	0.36286	34.8%
		slow	0.5	6	0.8206	0.21924	26.7%
			1	6	0.9642	0.37335	38.7%
			1.5	6	1.2950	0.53493	41.3%
			Total	18	1.0266	0.42553	41.5%
		Total	0.5	18	0.8421	0.28567	33.9%
			1	18	1.0120	0.33620	33.2%
			1.5	18	1.0946	0.39910	36.6%
			Total	54	0.9820	0.35294	35.9%

Table 4: Descriptive statistics of average Total RMS EMG across both participants for the GC condition. The total EMG is calculated by adding up the RMS EMG of each joint individually.

				Count	Mean	Standard Deviation	Coefficient of Variation
GC	traj 1	fast	0.5	2	1.5295	0.39527	25.8%
			1	2	2.1525	0.56922	26.4%
			1.5	2	2.2200	0.84846	38.2%
			Total	6	1.9673	0.59661	30.3%
		medium	0.5	2	1.6770	0.33517	20.0%
			1	2	2.4212	0.75455	31.2%
			1.5	2	2.3345	0.66026	28.3%
			Total	6	2.1442	0.59666	27.8%
		slow	0.5	2	1.6845	0.29254	17.4%
			1	2	2.3010	0.74536	32.4%
			1.5	2	2.5469	0.77687	30.5%
			Total	6	2.1774	0.63785	29.3%
		Total	0.5	6	1.6303	0.27738	17.0%
			1	6	2.2915	0.55161	24.1%
			1.5	6	2.3671	0.61147	25.8%
			Total	18	2.0963	0.58143	27.7%
	traj 2	fast	0.5	2	1.7336	0.63078	36.4%
			1	2	1.9018	0.42370	22.3%
			1.5	2	1.7923	0.45925	25.6%
			Total	6	1.8093	0.40434	22.3%
		medium	0.5	2	2.3094	1.11981	48.5%
			1	2	2.5778	1.15994	45.0%
			1.5	2	2.1207	0.32962	15.5%
			Total	6	2.3360	0.76409	32.7%
		slow	0.5	2	2.0664	0.53573	25.9%
			1	2	2.1151	0.55597	26.3%
			1.5	2	1.6149	0.01799	1.1%
			Total	6	1.9322	0.42443	22.0%
		Total	0.5	6	2.0365	0.67425	33.1%
			1	6	2.1982	0.67997	30.9%
			1.5	6	1.8426	0.34154	18.5%
			Total	18	2.0258	0.57130	28.2%
	traj 3	fast	0.5	2	1.2818	0.51294	40.0%
			1	2	1.4929	0.65464	43.9%
			1.5	2	1.3840	0.10461	7.6%
			Total	6	1.3862	0.38657	27.9%
		medium	0.5	2	1.6548	0.77817	47.0%
			1	2	1.8420	0.58266	31.6%
			1.5	2	1.5910	0.27011	17.0%
			Total	6	1.6959	0.46607	27.5%
		slow	0.5	2	1.5818	0.69544	44.0%
			1	2	2.0328	1.00805	49.6%
			1.5	2	1.6725	0.35715	21.4%
			Total	6	1.7624	0.60910	34.6%
		Total	0.5	6	1.5061	0.54928	36.5%
			1	6	1.7892	0.64561	36.1%
			1.5	6	1.5492	0.24494	15.8%
			Total	18	1.6148	0.49538	30.7%
	Total	fast	0.5	6	1.5150	0.45211	29.8%
			1	6	1.8491	0.52450	28.4%
			1.5	6	1.7988	0.57284	31.8%
			Total	18	1.7209	0.51034	29.7%
		medium	0.5	6	1.8804	0.71057	37.8%
			1	6	2.2803	0.75567	33.1%
			1.5	6	2.0154	0.49063	24.3%
			Total	18	2.0587	0.64535	31.3%
		slow	0.5	6	1.7775	0.47268	26.6%
			1	6	2.1496	0.62551	29.1%
			1.5	6	1.9448	0.60372	31.0%
			Total	18	1.9573	0.55902	28.6%
		Total	0.5	18	1.7243	0.54717	31.7%
			1	18	2.0930	0.63124	30.2%
			1.5	18	1.9196	0.53210	27.7%
			Total	54	1.9123	0.58118	30.4%

Table 5: Descriptive statistics of average Total RMS EMG across both participants for the No Exoskeleton condition. The total EMG is calculated by adding up the RMS EMG of each joint individually.

				Count	Mean	Standard Deviation	Coefficient of Variation
NoExo	traj 1	fast	0.5	2	1.7199	0.35341	20.5%
			1	2	1.9726	0.55522	28.1%
			1.5	2	2.4459	0.82859	33.9%
			Total	6	2.0461	0.57672	28.2%
		medium	0.5	2	1.7052	0.33262	19.5%
			1	2	1.8653	0.52199	28.0%
			1.5	2	2.0516	0.58739	28.6%
			Total	6	1.8740	0.41190	22.0%
		slow	0.5	2	1.6178	0.15585	9.6%
			1	2	2.4007	0.56583	23.6%
			1.5	2	2.5196	0.76855	30.5%
			Total	6	2.1794	0.61569	28.3%
		Total	0.5	6	1.6810	0.23324	13.9%
			1	6	2.0795	0.49434	23.8%
			1.5	6	2.3390	0.61248	26.2%
			Total	18	2.0332	0.52513	25.8%
	traj 2	fast	0.5	2	1.5396	0.42904	27.9%
			1	2	1.7325	0.58845	34.0%
			1.5	2	1.9568	0.60892	31.1%
			Total	6	1.7430	0.46379	26.6%
		medium	0.5	2	2.3386	1.00754	43.1%
			1	2	2.4757	0.91035	36.8%
			1.5	2	2.1586	0.47007	21.8%
			Total	6	2.3243	0.65818	28.3%
		slow	0.5	2	2.1701	0.67022	30.9%
			1	2	2.4351	0.81049	33.3%
			1.5	2	1.2945	0.81083	62.6%
			Total	6	1.9666	0.79861	40.6%
		Total	0.5	6	2.0161	0.68674	34.1%
			1	6	2.2144	0.71139	32.1%
			1.5	6	1.8033	0.64290	35.7%
			Total	18	2.0113	0.66254	32.9%
	traj 3	fast	0.5	2	1.4462	0.40001	27.7%
			1	2	1.7618	0.44088	25.0%
			1.5	2	1.9008	0.66581	35.0%
			Total	6	1.7029	0.45051	26.5%
		medium	0.5	2	1.5636	0.51421	32.9%
			1	2	1.6179	0.43537	26.9%
			1.5	2	1.8401	0.60818	33.1%
			Total	6	1.6738	0.42654	25.5%
		slow	0.5	2	1.5143	0.35956	23.7%
			1	2	1.8797	0.53698	28.6%
			1.5	2	2.0398	0.74925	36.7%
			Total	6	1.8113	0.50384	27.8%
		Total	0.5	6	1.5080	0.33693	22.3%
			1	6	1.7531	0.38498	22.0%
			1.5	6	1.9269	0.53226	27.6%
			Total	18	1.7293	0.43768	25.3%
	Total	fast	0.5	6	1.5685	0.33059	21.1%
			1	6	1.8223	0.42838	23.5%
			1.5	6	2.1012	0.60997	29.0%
			Total	18	1.8307	0.49563	27.1%
		medium	0.5	6	1.8691	0.64366	34.4%
			1	6	1.9863	0.64352	32.4%
			1.5	6	2.0167	0.45629	22.6%
			Total	18	1.9574	0.55603	28.4%
		slow	0.5	6	1.7674	0.46906	26.5%
			1	6	2.2385	0.57494	25.7%
			1.5	6	1.9513	0.81658	41.8%
			Total	18	1.9857	0.63075	31.8%
		Total	0.5	18	1.7350	0.48498	28.0%
			1	18	2.0157	0.55139	27.4%
			1.5	18	2.0231	0.60891	30.1%
			Total	54	1.9286	0.55696	28.9%

Table 6: The inter condition analysis of Mixed Model Anova with 95% confidence level.

Estimates of Fixed Effects

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
IBPA	0.869115	0.089767	0.000	9.682	1.000	-2.205830	3.944060
GC	1.755466	0.100684	0.000	17.435	1.000	-2.795455	6.306387
No Exo	1.800917	0.100786	0.000	17.869	1.000	-2.481724	6.083557

Dependent Variable: Total_emg.

Table 7: The inter condition analysis of Mixed Model Anova with 95% confidence level.

Estimates of Fixed Effects

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
IBPA	76.584585	8.146362	4.250	9.401	0.001	54.482150	98.687021
GC	61.338501	8.121999	4.196	7.552	0.001	39.197780	83.479223

Dependent Variable: Total_torque.