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Biomechanical Gait Analysis According to Foot Type and Arm Swing

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ABSTRACT

The purpose of this study is to analyze kinetic and kinematic gait variables according to foot type and arm swing. Nine female college students were selected via RCSP for this study (pes rectus, pes planus, pes cavus). Subjects utilized three different types of arm swinging methods while walking: normal, forward arm swing (typically associated with power walking) and backward arm swing. Gait variables were measured using a force platform (Kistler,9287BA) and motion capture (Vicon, Motion Analysis, USA). There were no consistent patterns between arm swing and ground reaction force variables or kinematic variables. Although no single type of arm swinging method consistently yielded higher kinetic or kinematic values, the different types of arm swing patterns affected hip and pelvic angular velocity at both heel off and toe off.

1. PURPOSE

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2. METHODS

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3. RESULTS

3.A. Ground Reaction Force

3.1 According to Foot Type

Eleven ground reaction variables were significantly different according to foot type. In five cases, pes planus had significantly higher values for ground reaction force variables than pes rectus and pes cavus (trough time(Z), first peak value(Z), active loading rate(Z), Max. propulsive force(Y), propulsive Integral(Y)). In contrast, for the total time, pes planus was significantly lower than pes rectus and pes cavus. For the remaining five ground reaction force variables for pas rectus were significantly larger than for pes planus and pes cavus.

3.2. According to Arm Swing

Out of a all ground reaction variables, only nine were significantly different. Among these nine variables, four vertical variables had significant differences for arm swing. The time to first active peak, the magnitude of the 1st peak, the active loading rate, and

the active decay rate were all higher for both the forward and backward arm swing than the normal arm swing. Backward arm swing values within these four variables were higher than forward values, but these differences were not statistically significant.

Table 1. Ground Reaction Force variables according to foot type and arm swing

source		Type III sum of square	df	mean square	F	p	post-hoc
foot type A:normal, B:planus, C:cavus	total_time(s)	.005	2	.003	8.190	.001	B<A,C
	first peak time(s)	.001	2	.000	5.011	.009	A>B,C
	trough time(s)	.002	2	.001	3.283	.043	B<A,C
	second peak time(s)	.002	2	.001	10.324	.000	A>B>C
	first peak value(Z)	.377	2	.188	23.358	.000	A<C<B
	trough value(Z)	.097	2	.048	7.853	.001	A>B,C
	active loading rate	.372	2	.186	23.299	.000	A<C<B
	active decay rate	.593	2	.297	12.842	.000	A>B,C
	Max. propulsive force(Y)	.054	2	.027	5.536	.006	A<B,C
	breaking Integral(Y)	.078	2	.039	9.403	.000	A>B>C
	propulsive Integral(Y)	.018	2	.009	4.190	.019	B>A,C
arm swing A:barefoot, normal B:barefoot_forward, C:barefoot_backward	first active1loading time(s)	.008	2	.004	10.347	.000	A<B,C
	second loading time(s)	.010	2	.005	16.795	.000	A>C>B
	first active peak value	.201	2	.101	12.494	.000	A<B,C
	second active peak value	.090	2	.045	6.776	.002	A>B,C
	active loading rate	.200	2	.100	12.548	.000	A<B,C
	first active decay rate	.319	2	.159	6.904	.002	A>B,C
	second active decay rate	.089	2	.044	6.772	.002	A<B,C
	max. propulsive force	.058	2	.029	5.977	.004	A>B,C
	propulsive integral	.022	2	.011	5.137	.008	A>B,C

Table 2. Angle and Angular Velocity for X Direction According to Foot and Arm Swing Type

source		type III sum of square	df	mean square	F	p	post-hoc
foot_type A:normal, B:planus, C:cavus	pelvic_ang_RHC	212.621	2	106.311	5.146	.008	A<B,C
	pelvic_ang_RMS	135.020	2	67.510	3.686	.030	A<C
	pelvic_ang_RHO	133.575	2	66.788	3.158	.048	A<C
	hip_ang_RHC	1096.864	2	548.432	25.526	.000	B>A,C
	hip_ang_RMS	821.575	2	410.788	12.836	.000	B>A,C

	hip_ang_RHO	480.663	2	240.331	9.938	.000	B>A,C
	hip_ang_RTO	547.777	2	273.888	7.294	.001	B>A
	hip_angvelo_RHC	12824.291	2	6412.145	7.561	.001	A<B,C
	hip_angvelo_RMS	4199.972	2	2099.986	7.235	.001	C>A,B
	hip_angvelo_RHO	5523.781	2	2761.891	4.399	.016	C>A,B
	hip_angvelo_RTO	8945.471	2	4472.735	7.320	.001	C>A,B
	knee_ang_RHC	1384.389	2	692.194	39.045	.000	C<A<B
	knee_ang_RMS	850.801	2	425.401	10.976	.000	B>A,C
	knee_ang_RHO	601.819	2	300.910	13.987	.000	C<A<B
	knee_ang_RTO	516.640	2	258.320	5.304	.007	B>A,C
	knee_angvelo_RHC	24472.935	2	12236.468	5.133	.008	A>B
	knee_angvelo_RMS	5217.944	2	2608.972	4.846	.011	C<A,B
	knee_angvelo_RTO	37475.782	2	18737.891	10.665	.000	A>B,C
	ankle_ang_RHC	163.193	2	81.597	20.498	.000	A>B>C
	ankle_ang_RMS	347.345	2	173.672	6.829	.002	A>B
	ankle_ang_RHO	1965.897	2	982.948	13.052	.000	B<A,C
	ankle_ang_RTO	2536.849	2	1268.424	20.430	.000	A>B,C
	ankle_angvelo_RHC	7211.810	2	3605.905	3.148	.049	A<B
	ankle_angvelo_RMS	20870.930	2	10435.465	4.536	.014	B<A,C
	ankle_angvelo_RHO	462008.457	2	231004.229	15.111	.000	C<A,B
arm swing type A:normal swing B:forward swing, C:backward swing	pelvic_angvelo_RTO	4889.110	2	2444.555	5.749	.005	**B<A,C**
	hip_angvelo_RTO	4200.150	2	2100.075	3.437	.038	**A<B,C**
	knee_angvelo_RTO	16777.242	2	8388.621	4.775	.011	A>B,C
	ankle_angvelo_RTO	104579.050	2	52289.525	3.169	.048	A<B

Table 3. Angle and Angular Velocity for Y Direction According to Foot and Arm Swing Type

source		type III sum of square	df	mean square	F	p	post-hoc
foot_type A:normal, B:planus, C:cavus	pelvic_ang_RHO	224.155	2	112.077	4.633	.013	B>A,C
	pelvic_ang_RTO	201.892	2	100.946	6.408	.003	B>A,C
	pelvic_angvelo_RMS	6342.778	2	3171.389	6.191	.003	A<B
	hip_ang_RHC	98.292	2	49.146	3.691	.030	B>A,C
	hip_ang_RMS	174.411	2	87.205	43.956	.000	C<A<B
	hip_ang_RHO	92.002	2	46.001	10.872	.000	C<A<B
	hip_ang_RTO	241.842	2	120.921	37.832	.000	C<A,B
	hip_angvelo_RMS	2531.027	2	1265.514	4.060	.021	A<C
	hip_angvelo_RHO	11668.766	2	5834.383	9.741	.000	A>B,C

	hip_angvelo_RTO	12163.317	2	6081.659	8.480	.000	C<A,B
	knee_ang_RMS	76.061	2	38.030	3.423	.038	B<C
	knee_angvelo_RMS	7868.356	2	3934.178	9.131	.000	B>A,C
	knee_angvelo_RTO	103799.915	2	51899.958	9.765	.000	A<B,C
	ankle_ang_RHC	743.470	2	371.735	4.135	.020	B>A,C
	ankle_ang_RMS	1757.036	2	878.518	9.449	.000	B>A,C
	ankle_ang_RHO	865.695	2	432.847	6.034	.004	A<B
	ankle_ang_RTO	434.715	2	217.357	3.193	.047	A<B
	ankle_angvelo_RHC	55546.837	2	27773.418	11.483	.000	C<A,B
	ankle_angvelo_RMS	4137.870	2	2068.935	5.076	.009	A<C
	ankle_angvelo_RHO	64107.629	2	32053.815	3.764	.028	B<C
	ankle_angvelo_RTO	157705.208	2	78852.604	11.831	.000	C<A,B
shoe_type A:barefoot, B:barefoot_F, C:barefoot_R	knee_ang_RMS	340.354	2	170.177	15.315	.000	A>B,C
	knee_ang_RHO	1736.608	2	868.304	25.302	.000	A>B,C
	knee_ang_RTO	2288.972	2	1144.486	17.414	.000	A>B,C
foot_type * shoe_type	knee_ang_RHC	324.489	4	81.122	3.010	.024	
	knee_ang_RMS	288.685	4	72.171	6.495	.000	
	knee_ang_RHO	373.044	4	93.261	2.718	.036	

Table 4. Angle and Angular Velocity for Z Direction According to Foot and Arm Swing Type

source		type III sum of square	df	mean square	F	p	post -hoc
foot_type A:normal, B:planus, C:cavus	pelvic_angvelo_RMS	12001.029	2	6000.514	5.417	.006	C>A,B
	pelvic_angvelo_RHO	6215.794	2	3107.897	5.251	.007	A>B
	hip_ang_RHC	906.740	2	453.370	3.467	.037	A<B,C
	hip_angvelo_RHC	70669.686	2	35334.843	7.513	.001	B>A,C
	knee_angvelo_RMS	8172.561	2	4086.281	3.598	.032	B>C
	knee_angvelo_RHO	303424.034	2	151712.017	18.686	.000	A>C
	knee_angvelo_RTO	100666.595	2	50333.297	6.042	.004	C>A,B
	ankle_ang_RHC	1044.146	2	522.073	7.031	.002	B<A,C
	ankle_ang_RMS	467.543	2	233.771	5.781	.005	A>B
	ankle_ang_RHO	898.772	2	449.386	10.791	.000	A>B,C
	ankle_ang_RTO	823.198	2	411.599	9.668	.000	A>B,C
	ankle_angvelo_RHO	212401.657	2	106200.829	12.062	.000	C>A,B
	ankle_angvelo_RTO	22108.684	2	11054.342	5.819	.005	A>B,C
shoe_type A:barefoot,	pelvic_ang_RMS	340.049	2	170.024	7.768	.001	A>B,C
	pelvic_angvelo_RHC	32705.508	2	16352.754	17.000	.000	A>B,C

B:barefoot F, C:barefoot R	pelvic_angvelo_RHO	19799.921	2	9899.961	16.728	.000	A<B,C
	pelvic_angvelo_RTO	20007.584	2	10003.792	18.197	.000	A<B,C
	knee_ang_RHC	4143.477	2	2071.739	14.574	.000	A>B,C
	knee_ang_RMS	6521.223	2	3260.611	20.544	.000	A<B,C
	knee_ang_RHO	873.495	2	436.748	3.342	.041	A>B,C
	knee_ang_RTO	6267.409	2	3133.704	28.115	.000	A>B,C
	knee_angvelo_RMS	13059.595	2	6529.797	5.749	.005	A>B,C
foot type * shoe_type	pelvic_angvelo_RTO	7706.788	4	1926.697	3.505	.011	
	knee_ang_RHC	2461.247	4	615.312	4.328	.003	
	knee_ang_RMS	3156.835	4	789.209	4.972	.001	
	knee_ang_RHO	2308.791	4	577.198	4.417	.003	
	knee_ang_RTO	2414.684	4	603.671	5.416	.001	

3.B. Angular Velocity

There are no significant differences between arm swing kinematic variables in the anterior / posterior plane. In the medial / lateral plane, pelvic angular velocity at right toe off was highest for the backward and normal arm swing. At the hip, angular velocity was highest for the backward and ford arm swing arm swing during right toe off. Vertical angle was higher for the rear **arm swing** in the knee at mid swing. In the pelvis at both right heel off and right toe off angular velocity was highest for both forward and rear arm swings.

4. CONCLUSIONS

In conclusion, there were no consistent patterns between arm swing and ground reaction force variables or kinematic variables. Although no single type of arm swinging method consistently yielded higher kinetic or kinematic values, the different types of arm swing patterns affected hip and pelvic angular velocity at both heel off and toe off. Future studies will include upper body kinematics to create a more comprehensive analysis. In addition, since subjects did not regularly practice either the forward or backward arm swing form, future studies will increase the reliability of this research by using subjects more familiar with these movements.

5. References

Brian R. Umberger(2008), “Effects of suppressing arm swing on kinematics, kinetics, and energetics of human walking*.” Journal of Biomechanics*, Volume **41**, Issue 11, 7 Pages 2575–2580.

ST Eke-Okoro, M Gregoric, LE Larsson(1997),“Alterations in gait resulting from deliberate changes of arm-swing amplitude and phase.” *Clinical Biomechanics*. Volume **12**, Issues 7–8, Pages 516–521.

Michael D. Lewek, Roxanne Poole, Julia Johnson, Omar Halawa, Xuemei Huang, (2010),“Arm swing magnitude and asymmetry during gait in the early stages of Parkinson's disease.” *Gait & Posture*, Volume **31**, Issue 2, Pages 256–260.