



Digital supplementary material to

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Supplementary Material

for

Kinematic study of six mangrove ant species (Hymenoptera: Formicidae) reveals different swimming styles and abilities

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Contains: Figure S1, Figure S2, Figure S3, Figure S4, Table S1, Table S2, Table S3

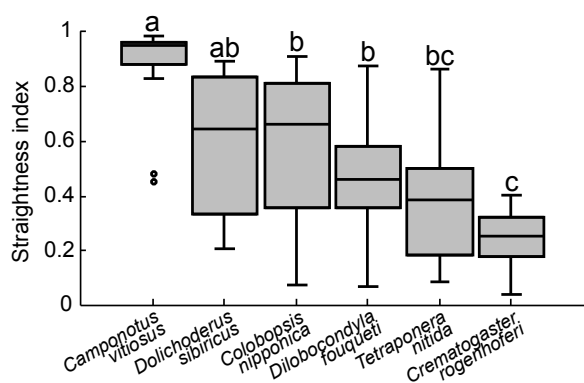


Figure S1. Straightness indices of swimming ants shown in Figure 1, with higher values indicating straighter paths. Large differences are evident between species (overall effect: Wald $\chi^2 = 70.62$, $p < 0.001$; $df = 5, 88$). Full statistical results are compiled in Table S1.

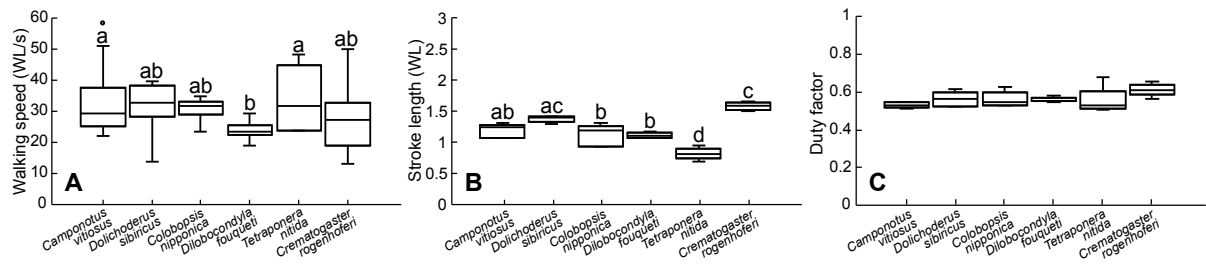


Figure S2. Kinematic parameters of walking ants. Distance measures are normalised to thorax length (Weber's length, WL), as body size varies between species and individuals. **(A)** Walking speed is different among species (overall effect: Wald $\chi^2 = 19.01$, $p < 0.01$; df 5,69) but not for many species comparisons, it is always higher than swimming speed (Fig. 2a). **(B)** Power stroke length (overall effect: Wald $\chi^2 = 222.32$, $p < 0.001$; df 5,30) varies between species and differs from swimming stroke length in most species (Fig. 2b). **(C)** Duty factors show only slight differences (overall effect: Wald $\chi^2 = 13.51$, $p < 0.05$; df 5,30), but not for any species comparisons; they are always higher than in swimming ants (Fig. 2c). Panels (B) and (C) are based on the movements of all six legs over three full strides (5 individuals per species). Full statistical results are compiled in Table S2.

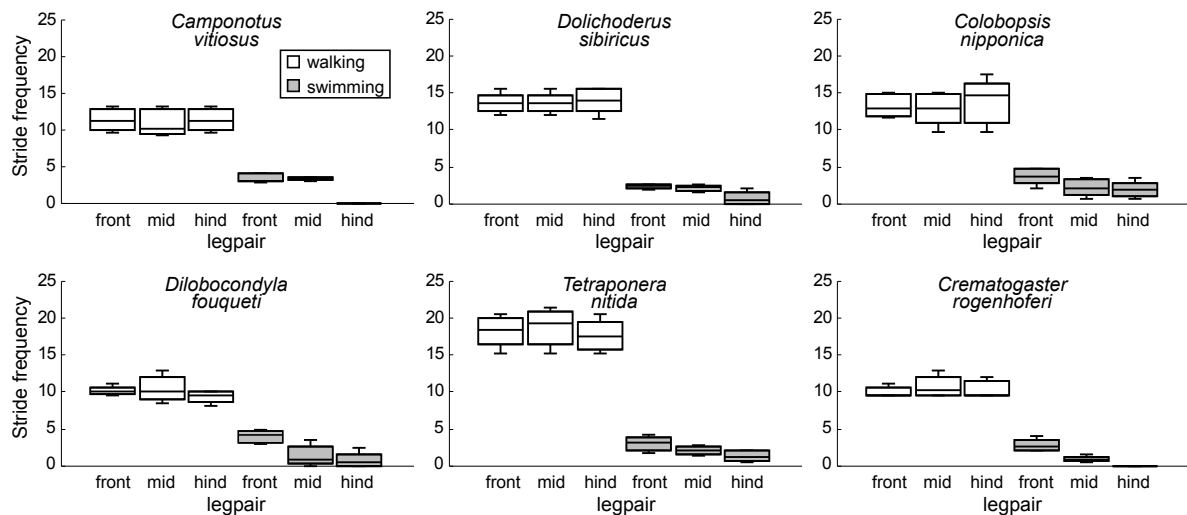


Figure S3. Stride frequency during walking and swimming locomotion for each leg pair separately (front/mid/hind). Frequency is generally much reduced in swimming ants, and legpairs are used asymmetrically for propulsion. The different swimming speeds between species are not caused by differences in average stride frequency, as all species (except *Crematogaster rogenhoferi*) swim with very similar, low stride frequencies. Overall effects (not separated by leg pair): swimming: Wald $\chi^2 = 27.39$, $p < 0.001$; df 5,30; walking: Wald $\chi^2 = 129.79$, $p < 0.001$; df 5,30. Full statistical results are compiled in Tables S1, S2 and S3.

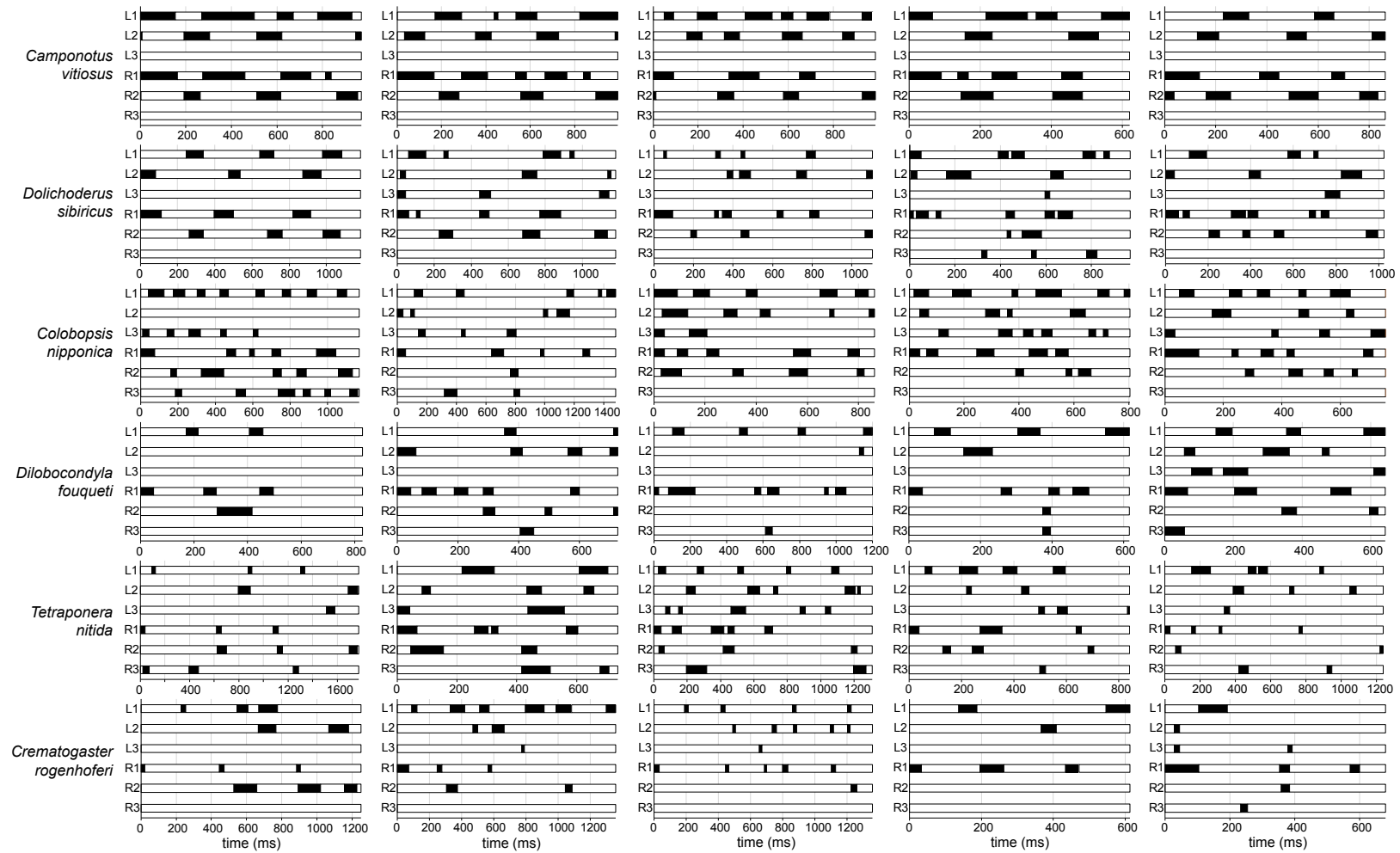


Figure S4. Gait patterns of swimming ants. Each panel shows the gait pattern of a different individual over three full strides of the right front leg (R1). Black bars show backward leg movement, and white bars show forward or no movement. The legs are named according to body side (L for left, R for right) and numbered front to back (1 to 3). The individuals in the first column are the same individuals shown in Figure 3. Despite large inter-individual differences, species-specific patterns in leg usage are visible. Note differences in scale on the time axis.

Table S1: Summary of generalised linear mixed modelling (GLMM) for five swimming kinematic parameters (A) speed, (B) straightness index, (C) stroke length, (D) duty factor and (E) stride frequency. Shown are the model coefficient (Estimate), standard error (SE), *t*-ratio, partial *P* (*p*-value) of the *F*-statistic. Bold values indicate statistical significance. Note: number of observations for speed & straightness index (*n* = 88), for stroke length, duty factor & stride frequency (*n* = 30).

Contrast	Estimate	SE	<i>t</i> -ratio	<i>p</i> -value
(A) Swimming speed				
Intercept	2.084	0.064	32.357	<0.001
<i>Camponotus</i> - <i>Colobopsis</i>	1.283	0.113	11.388	<0.001
<i>Camponotus</i> - <i>Crematogaster</i>	2.347	0.177	13.294	<0.001
<i>Camponotus</i> - <i>Dilobocondyla</i>	2.468	0.187	13.231	<0.001
<i>Camponotus</i> - <i>Dolichoderus</i>	1.193	0.109	10.958	<0.001
<i>Camponotus</i> - <i>Tetraponera</i>	2.189	0.169	12.919	<0.001
<i>Colobopsis</i> - <i>Crematogaster</i>	1.064	0.195	5.463	<0.001
<i>Colobopsis</i> - <i>Dilobocondyla</i>	1.185	0.204	5.813	<0.001
<i>Colobopsis</i> - <i>Dolichoderus</i>	-0.090	0.136	-0.658	0.986
<i>Colobopsis</i> - <i>Tetraponera</i>	0.906	0.189	4.800	0.001
<i>Crematogaster</i> - <i>Dilobocondyla</i>	0.121	0.245	0.494	0.996
<i>Crematogaster</i> - <i>Dolichoderus</i>	-1.154	0.193	-5.991	<0.001
<i>Crematogaster</i> - <i>Tetraponera</i>	-0.158	0.233	-0.681	0.984
<i>Dilobocondyla</i> - <i>Dolichoderus</i>	-1.275	0.202	-6.318	<0.001
<i>Dilobocondyla</i> - <i>Tetraponera</i>	-0.280	0.240	-1.164	0.852
<i>Dolichoderus</i> - <i>Tetraponera</i>	0.996	0.186	5.339	<0.001
(B) Swimming straightness index				
Intercept	-0.140	0.086	-1.635	0.107
<i>Camponotus</i> - <i>Colobopsis</i>	0.426	0.134	3.190	0.025
<i>Camponotus</i> - <i>Crematogaster</i>	1.284	0.179	7.165	<0.001
<i>Camponotus</i> - <i>Dilobocondyla</i>	0.587	0.140	4.185	0.01
<i>Camponotus</i> - <i>Dolichoderus</i>	0.356	0.131	2.721	0.084
<i>Camponotus</i> - <i>Tetraponera</i>	0.808	0.154	5.234	<0.001
<i>Colobopsis</i> - <i>Crematogaster</i>	0.858	0.188	4.567	<0.001
<i>Colobopsis</i> - <i>Dilobocondyla</i>	0.161	0.151	1.065	0.893
<i>Colobopsis</i> - <i>Dolichoderus</i>	-0.070	0.142	-0.491	0.996
<i>Colobopsis</i> - <i>Tetraponera</i>	0.382	0.164	2.324	0.199
<i>Crematogaster</i> - <i>Dilobocondyla</i>	-0.697	0.193	-3.617	0.007
<i>Crematogaster</i> - <i>Dolichoderus</i>	-0.928	0.186	-4.990	<0.001
<i>Crematogaster</i> - <i>Tetraponera</i>	-0.476	0.203	-2.343	0.192
<i>Dilobocondyla</i> - <i>Dolichoderus</i>	-0.231	0.149	-1.552	0.632
<i>Dilobocondyla</i> - <i>Tetraponera</i>	0.221	0.170	1.301	0.784
<i>Dolichoderus</i> - <i>Tetraponera</i>	0.452	0.162	2.787	0.072
(C) Swimming stroke length				
Intercept	2.637	0.137	19.205	<0.001
<i>Camponotus</i> - <i>Colobopsis</i>	0.975	0.194	5.021	0.001
<i>Camponotus</i> - <i>Crematogaster</i>	1.286	0.194	6.624	<0.001
<i>Camponotus</i> - <i>Dilobocondyla</i>	1.410	0.194	7.260	<0.001
<i>Camponotus</i> - <i>Dolichoderus</i>	0.552	0.194	2.840	0.093
<i>Camponotus</i> - <i>Tetraponera</i>	1.511	0.194	7.781	<0.001
<i>Colobopsis</i> - <i>Crematogaster</i>	0.311	0.194	1.602	0.607
<i>Colobopsis</i> - <i>Dilobocondyla</i>	0.435	0.194	2.239	0.266
<i>Colobopsis</i> - <i>Dolichoderus</i>	-0.424	0.194	-2.181	0.291

<i>Colobopsis - Tetraponera</i>	0.536	0.194	2.760	0.109
<i>Crematogaster - Dilobocondyla</i>	0.124	0.194	0.637	0.987
<i>Crematogaster - Dolichoderus</i>	-0.735	0.194	-3.783	0.014
<i>Crematogaster - Tetraponera</i>	0.225	0.194	1.157	0.851
<i>Dilobocondyla - Dolichoderus</i>	-0.858	0.194	-4.420	0.003
<i>Dilobocondyla - Tetraponera</i>	0.101	0.194	0.520	0.995
<i>Dolichoderus - Tetraponera</i>	0.959	0.194	4.941	0.001

(D) Swimming duty factor

Intercept	0.231	0.018	12.944	<0.001
<i>Camponotus - Colobopsis</i>	0.046	0.025	1.850	0.460
<i>Camponotus - Crematogaster</i>	0.148	0.025	5.966	<0.001
<i>Camponotus - Dilobocondyla</i>	0.105	0.025	4.234	0.005
<i>Camponotus - Dolichoderus</i>	0.097	0.025	3.911	0.010
<i>Camponotus - Tetraponera</i>	0.105	0.025	4.256	0.005
<i>Colobopsis - Crematogaster</i>	0.102	0.025	4.131	0.006
<i>Colobopsis - Dilobocondyla</i>	0.059	0.025	2.393	0.208
<i>Colobopsis - Dolichoderus</i>	0.051	0.025	2.069	0.343
<i>Colobopsis - Tetraponera</i>	0.059	0.025	2.390	0.209
<i>Crematogaster - Dilobocondyla</i>	-0.043	0.025	-1.738	0.525
<i>Crematogaster - Dolichoderus</i>	-0.051	0.025	-2.063	0.346
<i>Crematogaster - Tetraponera</i>	-0.043	0.025	-1.726	0.533
<i>Dilobocondyla - Dolichoderus</i>	-0.008	0.025	-0.324	0.999
<i>Dilobocondyla - Tetraponera</i>	0.000	0.025	0.006	1.000
<i>Dolichoderus - Tetraponera</i>	0.008	0.025	0.329	0.999

(E) Swimming stride frequency

Intercept	2.262	0.228	9.918	<0.001
<i>Camponotus - Colobopsis</i>	-0.321	0.323	-0.994	0.914
<i>Camponotus - Crematogaster</i>	1.057	0.323	3.278	0.039
<i>Camponotus - Dilobocondyla</i>	0.253	0.323	0.783	0.967
<i>Camponotus - Dolichoderus</i>	0.571	0.323	1.772	0.505
<i>Camponotus - Tetraponera</i>	0.174	0.323	0.539	0.994
<i>Colobopsis - Crematogaster</i>	1.378	0.323	4.272	0.005
<i>Colobopsis - Dilobocondyla</i>	0.573	0.323	1.778	0.502
<i>Colobopsis - Dolichoderus</i>	0.892	0.323	2.766	0.107
<i>Colobopsis - Tetraponera</i>	0.495	0.323	1.534	0.648
<i>Crematogaster - Dilobocondyla</i>	-0.805	0.323	-2.495	0.175
<i>Crematogaster - Dolichoderus</i>	-0.486	0.323	-1.506	0.665
<i>Crematogaster - Tetraponera</i>	-0.883	0.323	-2.739	0.113
<i>Dilobocondyla - Dolichoderus</i>	0.319	0.323	0.988	0.916
<i>Dilobocondyla - Tetraponera</i>	-0.079	0.323	-0.244	1.000
<i>Dolichoderus - Tetraponera</i>	-0.397	0.323	-1.232	0.816

Table S2: Summary of generalised linear mixed modelling (GLMM) for four walking kinematic parameters (A) speed, (B) stroke length, (C) duty factor and (D) stride frequency. Shown are the model coefficient (Estimate), standard error (SE), *t*-ratio, partial *P* (*p*-value) of the *F*-statistic. Bold values indicate statistical significance. Note: number of observations for speed (*n* = 69), for stroke length, duty factor & stride frequency (*n* = 30).

Contrast	Estimate	SE	<i>t</i> -ratio	<i>p</i> -value
(A) Walking speed				
Intercept	32.889	2.443	13.465	<0.001
<i>Camponotus</i> - <i>Colobopsis</i>	2.840	3.400	0.835	0.959
<i>Camponotus</i> - <i>Crematogaster</i>	4.590	3.220	1.424	0.712
<i>Camponotus</i> - <i>Dilobocondyla</i>	9.280	2.890	3.207	0.029
<i>Camponotus</i> - <i>Dolichoderus</i>	1.120	3.160	0.353	0.999
<i>Camponotus</i> - <i>Tetraoponera</i>	-1.940	3.870	-0.502	0.996
<i>Colobopsis</i> - <i>Crematogaster</i>	1.750	3.400	0.516	0.995
<i>Colobopsis</i> - <i>Dilobocondyla</i>	6.440	3.090	2.082	0.316
<i>Colobopsis</i> - <i>Dolichoderus</i>	-1.720	3.340	-0.515	0.995
<i>Colobopsis</i> - <i>Tetraoponera</i>	-4.780	4.030	-1.185	0.841
<i>Crematogaster</i> - <i>Dilobocondyla</i>	4.690	2.880	1.627	0.586
<i>Crematogaster</i> - <i>Dolichoderus</i>	-3.470	3.150	-1.104	0.877
<i>Crematogaster</i> - <i>Tetraoponera</i>	-6.530	3.900	-1.675	0.555
<i>Dilobocondyla</i> - <i>Dolichoderus</i>	-8.160	2.800	-2.919	0.058
<i>Dilobocondyla</i> - <i>Tetraoponera</i>	-11.220	3.630	-3.094	0.038
<i>Dolichoderus</i> - <i>Tetraoponera</i>	-3.060	3.850	-0.795	0.967
(B) Walking stroke length				
Intercept	1.190	0.044	27.045	<0.001
<i>Camponotus</i> - <i>Colobopsis</i>	0.069	0.062	1.105	0.868
<i>Camponotus</i> - <i>Crematogaster</i>	-0.397	0.062	-6.387	0.001
<i>Camponotus</i> - <i>Dilobocondyla</i>	0.077	0.062	1.234	0.814
<i>Camponotus</i> - <i>Dolichoderus</i>	-0.193	0.062	-3.106	0.095
<i>Camponotus</i> - <i>Tetraoponera</i>	0.373	0.062	5.997	0.002
<i>Colobopsis</i> - <i>Crematogaster</i>	-0.466	0.062	-7.492	0.000
<i>Colobopsis</i> - <i>Dilobocondyla</i>	0.008	0.062	0.129	1.000
<i>Colobopsis</i> - <i>Dolichoderus</i>	-0.262	0.062	-4.211	0.020
<i>Colobopsis</i> - <i>Tetraoponera</i>	0.304	0.062	4.892	0.008
<i>Crematogaster</i> - <i>Dilobocondyla</i>	0.474	0.062	7.621	0.000
<i>Crematogaster</i> - <i>Dolichoderus</i>	0.204	0.062	3.281	0.074
<i>Crematogaster</i> - <i>Tetraoponera</i>	0.771	0.062	12.384	<0.001
<i>Dilobocondyla</i> - <i>Dolichoderus</i>	-0.270	0.062	-4.340	0.017
<i>Dilobocondyla</i> - <i>Tetraoponera</i>	0.296	0.062	4.763	0.009
<i>Dolichoderus</i> - <i>Tetraoponera</i>	0.567	0.062	9.103	0.000
(C) Walking duty factor				
Intercept	-0.633	0.032	-19.597	<0.001
<i>Camponotus</i> - <i>Colobopsis</i>	-0.058	0.045	-1.284	0.787
<i>Camponotus</i> - <i>Crematogaster</i>	-0.140	0.044	-3.158	0.088
<i>Camponotus</i> - <i>Dilobocondyla</i>	-0.050	0.045	-1.099	0.875
<i>Camponotus</i> - <i>Dolichoderus</i>	-0.058	0.045	-1.278	0.790
<i>Camponotus</i> - <i>Tetraoponera</i>	-0.043	0.045	-0.958	0.920
<i>Colobopsis</i> - <i>Crematogaster</i>	-0.082	0.044	-1.877	0.470
<i>Colobopsis</i> - <i>Dilobocondyla</i>	0.008	0.045	0.185	1.000
<i>Colobopsis</i> - <i>Dolichoderus</i>	0.000	0.044	0.005	1.000
<i>Colobopsis</i> - <i>Tetraoponera</i>	0.015	0.045	0.325	0.999
<i>Crematogaster</i> - <i>Dilobocondyla</i>	0.090	0.044	2.062	0.381

<i>Crematogaster</i> - <i>Dolichoderus</i>	0.082	0.044	1.882	0.467
<i>Crematogaster</i> - <i>Tetraoponera</i>	0.096	0.044	2.202	0.322
<i>Dilobocondyla</i> - <i>Dolichoderus</i>	-0.008	0.045	-0.180	1.000
<i>Dilobocondyla</i> - <i>Tetraoponera</i>	0.006	0.045	0.140	1.000
<i>Dolichoderus</i> - <i>Tetraoponera</i>	0.014	0.045	0.320	0.999
<hr/>				
(D) Walking stride frequency				
Intercept	11.278	0.676	16.683	<0.001
<i>Camponotus</i> - <i>Colobopsis</i>	-2.047	0.956	-2.142	0.347
<i>Camponotus</i> - <i>Crematogaster</i>	0.951	0.956	0.995	0.908
<i>Camponotus</i> - <i>Dilobocondyla</i>	1.282	0.956	1.341	0.759
<i>Camponotus</i> - <i>Dolichoderus</i>	-2.533	0.956	-2.650	0.179
<i>Camponotus</i> - <i>Tetraoponera</i>	-6.986	0.956	-7.308	0.000
<i>Colobopsis</i> - <i>Crematogaster</i>	2.999	0.956	3.137	0.091
<i>Colobopsis</i> - <i>Dilobocondyla</i>	3.330	0.956	3.483	0.055
<i>Colobopsis</i> - <i>Dolichoderus</i>	-0.486	0.956	-0.508	0.995
<i>Colobopsis</i> - <i>Tetraoponera</i>	-4.939	0.956	-5.166	0.006
<i>Crematogaster</i> - <i>Dilobocondyla</i>	0.331	0.956	0.346	0.999
<i>Crematogaster</i> - <i>Dolichoderus</i>	-3.485	0.956	-3.645	0.044
<i>Crematogaster</i> - <i>Tetraoponera</i>	-7.937	0.956	-8.303	0.000
<i>Dilobocondyla</i> - <i>Dolichoderus</i>	-3.816	0.956	-3.991	0.027
<i>Dilobocondyla</i> - <i>Tetraoponera</i>	-8.268	0.956	-8.649	0.000
<i>Dolichoderus</i> - <i>Tetraoponera</i>	-4.452	0.956	-4.658	0.011

Table S3: Summary of generalised linear mixed modelling (GLMM) for comparisons between modalities (walking vs. swimming) overall and among species for four kinematic parameters (A) speed, (B) stroke length, (C) duty factor and (D) stride frequency. Shown are the model coefficient (Estimate), standard error (SE), *t*-ratio, partial *P* (*p*-value) of the *F*-statistic. Bold values indicate statistical significance. Note: number of observations for speed (*n* = 157), for stroke length, duty factor & stride frequency (*n* = 60).

Contrast	Estimate	SE	<i>t</i> -ratio	<i>p</i> -value
(A) Speed				
Intercept	2.086	0.094	22.117	<0.001
swimming - walking (overall)	-2.890	0.103	-28.098	<0.001
<i>Camponotus</i> : swimming - walking	-1.393	0.112	-12.467	<0.001
<i>Colobopsis</i> : swimming - walking	-2.577	0.178	-14.465	<0.001
<i>Crematogaster</i> : swimming - walking	-3.594	0.285	-12.621	<0.001
<i>Dilobocondyla</i> : swimming - walking	-3.54	0.299	-11.826	<0.001
<i>Dolichoderus</i> : swimming - walking	-2.557	0.169	-15.165	<0.001
<i>Tetraoponera</i> : swimming - walking	-3.671	0.277	-13.266	<0.001
(B) Stroke length				
Intercept	0.970	0.048	20.079	<0.001
swimming - walking (overall)	0.309	0.040	7.843	<0.001
<i>Camponotus</i> : swimming - walking	0.796	0.087	9.187	<0.001
<i>Colobopsis</i> : swimming - walking	0.394	0.096	4.106	0.021
<i>Crematogaster</i> : swimming - walking	-0.161	0.092	-1.759	0.821
<i>Dilobocondyla</i> : swimming - walking	0.097	0.103	0.949	0.997
<i>Dolichoderus</i> : swimming - walking	0.410	0.086	4.774	0.005
<i>Tetraoponera</i> : swimming - walking	0.321	0.114	2.816	0.244
(C) Duty factor				
Intercept	-1.467	0.078	-18.751	<0.001
swimming - walking (overall)	-1.390	0.047	-29.738	<0.001
<i>Camponotus</i> : swimming - walking	-0.834	0.094	-8.897	<0.001
<i>Colobopsis</i> : swimming - walking	-1.111	0.101	-11.036	<0.001
<i>Crematogaster</i> : swimming - walking	-1.996	0.139	-14.354	<0.001
<i>Dilobocondyla</i> : swimming - walking	-1.488	0.117	-12.696	<0.001
<i>Dolichoderus</i> : swimming - walking	-1.434	0.114	-12.557	<0.001
<i>Tetraoponera</i> : swimming - walking	-1.487	0.118	-12.654	<0.001
(D) Stride frequency				
Intercept	0.816	0.113	7.196	<0.001
swimming - walking (overall)	-1.880	0.055	-34.276	<0.001
<i>Camponotus</i> : swimming - walking	-1.607	0.124	-12.929	<0.001
<i>Colobopsis</i> : swimming - walking	-1.641	0.116	-14.149	<0.001
<i>Crematogaster</i> : swimming - walking	-2.149	0.164	-13.083	<0.001
<i>Dilobocondyla</i> : swimming - walking	-1.604	0.132	-12.166	<0.001
<i>Dolichoderus</i> : swimming - walking	-2.101	0.139	-15.113	<0.001
<i>Tetraoponera</i> : swimming - walking	-2.169	0.125	-17.404	<0.001