

Supplementary Information for

Title: Evolution of a high-performance and functionally robust musculoskeletal system in salamanders

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Table S1, part 1 of 5

Performance and thermal robustness data for salamander taxa included in this study, with sources.

Genus	Species	Ballistic	Projection Mechanism	Peak Projection Velocity (m/s)	Peak Projection Power (W/kg)	Peak Retraction Velocity (m/s)	Peak Retraction Power (W/kg)
<i>Ambystoma</i>	<i>maculatum</i>	Non	Muscle	0.62	36	0.54	35
<i>Aneides</i>	<i>flavipunctatus</i>	Non	Muscle	0.20	4	0.23	6
<i>Batrachoseps</i>	<i>attenuatus</i>	Ballistic	Spring	2.56	3160	0.39	13
<i>Bolitoglossa</i>	<i>franklini</i>	Ballistic	Spring	2.34	1800	0.99	130
<i>Chiropoterotriton</i>	<i>chondrostega</i>	Ballistic	Spring	2.83	5315	0.80	46
<i>Desmognathus</i>	<i>quadramaculatus</i>	Non	Muscle	0.47	22	0.74	78
<i>Ensatina</i>	<i>eschscholtzii</i>	Ballistic	Spring	1.73	958	0.49	23
<i>Eurycea</i>	<i>guttolineata</i>	Ballistic	Spring	1.87	1371	0.48	18
<i>Hemidactylium</i>	<i>scutatum</i>	Ballistic	Spring	2.34	3525	0.72	33
<i>Hydromantes</i>	<i>platycephalus</i>	Ballistic	Spring	3.47	2530	0.68	19
<i>Notophthalmus</i>	<i>viridescens</i>	Non	Muscle	0.05	0.08	0.01	0.03
<i>Plethodon</i>	<i>metcalfi</i>	Non	Muscle	0.26	6	0.31	9
<i>Pseudoeurycea</i>	<i>leprosa</i>	Ballistic	Spring	2.77	4166	0.82	82
<i>Pseudotriton</i>	<i>ruber</i>	Ballistic	Spring	2.76	2658	1.31	191
<i>Salamandra</i>	<i>salamandra</i>	Non	Muscle	0.34	9	0.56	39
<i>Thorius</i>	<i>macdougalli</i>	Ballistic	Spring	3.45	11973	0.48	12

Table S1, part 2 of 5

Genus	Temp. of Peak Projection Velocity (°C)	Temp. of Peak Projection Power (°C)	Projection Velocity Q₁₀ over 5-15°C	Projection Velocity Q₁₀ over 10-20°C	Projection Velocity Q₁₀ over 5-25°C	Projection Power Q₁₀ over 5-15°C	Projection Power Q₁₀ over 10-20°C	Projection Power Q₁₀ over 5-25°C
<i>Ambystoma</i>	25	25	2.0	1.8	1.8	7.8	5.3	4.4
<i>Aneides</i>	25	20	1.7	1.8	1.6	3.7	6.9	3.6
<i>Batrachoseps</i>	20	25	1.3	1.2	1.2	2.5	1.8	1.7
<i>Bolitoglossa</i>	25	25	0.9	1.3	1.1	0.8	1.9	1.3
<i>Chiropetrotriton</i>	10	10	1.0	0.9	0.9	0.9	0.7	0.8
<i>Desmognathus</i>	25	20	2.0	1.9	1.7	5.1	4.6	3.6
<i>Ensatina</i>	25	25	1.3	1.0	1.2	2.1	1.0	1.6
<i>Eurycea</i>	25	25	1.4	1.0	1.1	3.7	1.3	1.6
<i>Hemidactylium</i>	20	15	1.2	1.1	1.1	2.2	1.6	1.5
<i>Hydromantes</i>	15	25	1.0	0.9	1.0	0.9	0.7	1.1
<i>Notophthalmus</i> *	-	-	-	-	-	-	-	-
<i>Plethodon</i>	25	25	2.1	1.7	1.6	11.2	4.7	4.6
<i>Pseudoeurycea</i>	25	25	1.2	1.1	1.1	1.8	1.6	1.5
<i>Pseudotriton</i>	25	15	1.3	1.2	1.1	2.0	1.4	1.3
<i>Salamandra</i>	25	25	1.5	1.6	1.5	3.0	2.8	3.2
<i>Thorius</i>	15	15	-	1.1	-	-	1.2	-

* Not tested at multiple temperatures

Table S1, part 3 of 5

Genus	Temp. of Peak Retraction Velocity (°C)	Temp. of Peak Retraction Power (°C)	Retraction Velocity Q_{10} over 5-15°C	Retraction Velocity Q_{10} over 10-20°C	Retraction Velocity Q_{10} over 5-25°C	Retraction Power Q_{10} over 5-15°C	Retraction Power Q_{10} over 10-20°C	Retraction Power Q_{10} over 5-25°C
	<i>Ambystoma</i>	25	25	1.9	2.1	1.8	6.17	5.00
<i>Aneides</i>	25	25	1.8	1.5	1.5	3.99	3.28	3.05
<i>Batrachoseps</i>	20	25	2.1	1.6	1.6	9.21	2.63	3.14
<i>Bolitoglossa</i>	25	25	1.9	1.7	1.6	7.46	6.75	5.18
<i>Chiropoterotriton</i>	20	20	1.4	1.5	1.5	2.65	3.05	2.77
<i>Desmognathus</i>	25	25	1.6	1.8	1.6	3.16	4.54	3.37
<i>Ensatina</i>	25	25	1.7	1.7	1.7	2.65	4.04	4.73
<i>Eurycea</i>	25	25	2.2	1.7	1.7	8.93	4.67	4.54
<i>Hemidactylium</i>	25	25	2.5	1.8	1.8	8.94	3.99	4.39
<i>Hydromantes</i>	25	25	1.6	1.4	1.7	3.78	3.60	4.59
<i>Notophthalmus</i>	-	-	-	-	-	-	-	-
<i>Plethodon</i>	25	25	2.4	2.0	1.8	10.90	7.56	6.06
<i>Pseudoeurycea</i>	25	25	1.8	1.4	1.5	7.66	3.89	3.78
<i>Pseudotriton</i>	25	25	1.8	1.3	1.5	11.70	2.88	4.35
<i>Salamandra</i>	25	25	1.5	1.3	1.6	3.38	2.50	3.82
<i>Thorius</i>	20	20	-	1.4	-	-	1.05	-

Table S1, part 4 of 5

Genus	Peak Projection Distance (mm)	Projection Distance Q₁₀ over 5-15°C	Projection Distance Q₁₀ over 10-20°C	Projection Distance Q₁₀ over 5-25°C	Peak Projection Accel. (m/s/s)	Projection Accel. Q₁₀ over 5-15°C	Projection Accel. Q₁₀ over 10-20°C	Projection Accel. Q₁₀ over 5-25°C
<i>Ambystoma</i>	3.8	1.35	1.07	1.09	90	3.53	2.79	2.37
<i>Aneides</i>	3.9	1.06	1.12	1.02	28	2.19	4.17	2.21
<i>Batrachoseps</i>	4.9	0.96	1.10	1.05	1802	2.04	1.55	1.48
<i>Bolitoglossa</i>	11.2	1.17	1.25	1.24	1100	0.93	1.51	1.23
<i>Chiropterotriton</i>	8.0	1.65	1.15	1.09	2819	0.72	0.75	0.92
<i>Desmognathus</i>	8.6	1.07	1.06	1.06	66	2.41	2.34	2.16
<i>Ensatina</i>	8.7	1.00	1.14	1.11	842	1.59	1.04	1.41
<i>Eurycea</i>	7.6	1.10	1.08	1.18	1018	2.59	1.26	1.49
<i>Hemidactylium</i>	4.7	1.12	1.03	1.04	2150	1.64	1.49	1.35
<i>Hydromantes</i>	28.0	1.09	0.95	0.94	997	0.96	0.81	1.03
<i>Notophthalmus</i>	2.8	-	-	-	2	-	-	-
<i>Plethodon</i>	5.5	1.08	0.94	0.97	35	4.98	3.03	2.78
<i>Pseudoeurycea</i>	8.5	1.23	1.31	1.21	2181	1.40	1.35	1.28
<i>Pseudotriton</i>	9.9	1.20	1.02	1.11	1462	1.76	1.38	1.25
<i>Salamandra</i>	7.2	1.09	0.94	1.03	46	1.86	1.76	2.01
<i>Thorius</i>	4.5	-	1.18	-	5276	-	1.08	-

Table S1, part 5 of 5

Genus	Peak Muscle Mass Specific Projection Power (W/kg)	Peak Muscle Mass Specific Retraction Power (W/kg)	Number of individuals	Number of feedings	Source
<i>Ambystoma</i>	228	-	6	129	This study
<i>Aneides</i>	10	6.18	4	126	This study
<i>Batrachoseps</i>	4200	9.93	8	145	This study
<i>Bolitoglossa</i>	1284	37.80	6	151	(1)
<i>Chiropterotriton</i>	5864	47.99	6	37	This study
<i>Desmognathus</i>	82	59.97	6	141	(1)
<i>Ensatina</i>	2134	29.70	7	179	(2)
<i>Eurycea</i>	2231	21.08	14	154	(3)
<i>Hemidactylium</i>	4336	30.42	5	107	This study
<i>Hydromantes</i>	2631	-	3	63	(4)
<i>Notophthalmus</i>	0.16	0.05	5	25	(5)
<i>Plethodon</i>	18	9.45	6	138	(2)
<i>Pseudoeurycea</i>	3033	39.19	12	194	This study
<i>Pseudotriton</i>	3310	64.56	8	176	This study
<i>Salamandra</i>	51	70.69	6	141	This study
<i>Thorius</i>	6765	51.53	4	46	(6)

Table S2, part 1 of 3

Morphological data for salamander taxa included in this study, with sources.

Genus	Species	Family	Body		N	Inner SAR Myofibers	Genioglossus muscle
			Mass (g)	SVL (mm)			
<i>Ambystoma</i>	<i>maculatum</i>	Ambystomatidae	11.8	86	3	Present	Stout
<i>Aneides</i>	<i>flavipunctatus</i>	Plethodontidae	1.4	40	4	Present	Stout
<i>Batrachoseps</i>	<i>attenuatus</i>	Plethodontidae	0.6	42	15	Absent	Elongated
<i>Bolitoglossa</i>	<i>franklini, dofleini</i>	Plethodontidae	3.6	60	5	Absent	Absent
<i>Chiropterotriton</i>	<i>chondrostega</i>	Plethodontidae	0.4	32	4	Absent	Absent
<i>Desmognathus</i>	<i>marmoratus,</i> <i>ocoee,</i> <i>quadramaculatus</i>	Plethodontidae	11.2	84	11	Present	Stout
<i>Ensatina</i>	<i>eschscholtzii</i>	Plethodontidae	4.3	59	10	Absent	Elongated
<i>Eurycea</i>	<i>guttolineata</i>	Plethodontidae	1.7	53	6	Absent	Absent
<i>Gyrinophilus</i>	<i>porphyriticus</i>	Plethodontidae	5.4	80	4	Absent	Absent
<i>Hemidactylum</i>	<i>scutatum</i>	Plethodontidae	0.7	37	8	Absent	Elongated
<i>Hydromantes</i>	<i>imperialis,</i> <i>platycephalus,</i> <i>supramontis</i>	Plethodontidae	3.1	60	5	Absent	Absent
<i>Notophthalmus</i>	<i>viridescens</i>	Salamandridae	2.0	44	5	Present	Stout
<i>Plethodon</i>	<i>metcalfi</i>	Plethodontidae	2.4	56	18	Present	Stout
<i>Pseudoeurycea</i>	<i>leprosa</i>	Plethodontidae	1.7	48	8	Absent	Absent
<i>Pseudotriton</i>	<i>ruber</i>	Plethodontidae	7.5	75	18	Absent	Absent
<i>Salamandra</i>	<i>salamandra</i>	Salamandridae	24.2	97	5	Present	Stout
<i>Stereochilus</i>	<i>marginatus</i>	Plethodontidae	1.1	48	5	Absent	Elongated
<i>Thorius</i>	<i>macdougalli</i>	Plethodontidae	0.1	21	8	Absent	Absent

Table S2, part 2 of 3

Genus	Extended Tongue Length (mm)	Extended Tongue Length / SVL	Tongue Mass (g)	SAR Mass (g)	SAR Mass / Tongue Mass	Tongue Skeleton Length (mm)	Tongue Skeleton Length / SVL
<i>Ambystoma</i>	-	-	0.132	0.021	0.16	13.8	0.16
<i>Aneides</i>	7.5	0.19	0.014	0.006	0.39	9.2	0.23
<i>Batrachoseps</i>	8.2	0.20	0.003	0.002	0.75	7.4	0.18
<i>Bolitoglossa</i>	19.0	0.32	0.026	0.040	1.40	17.1	0.29
<i>Chiropterotriton</i>	12.5	0.39	0.004	0.003	0.91	8.4	0.26
<i>Desmognathus</i>	7.8	0.09	0.125	0.034	0.27	17.9	0.21
<i>Ensatina</i>	14.5	0.25	0.083	0.041	0.47	18.2	0.31
<i>Eurycea</i>	14.9	0.28	0.016	0.010	0.61	13.7	0.26
<i>Gyrinophilus</i>	10.2	0.13	0.053	0.023	0.43	12.7	0.16
<i>Hemidactylium</i>	5.5	0.16	0.005	0.004	0.81	7.9	0.22
<i>Hydromantes</i>	39.5	0.66	-	-	0.96	34.2	0.57
<i>Notophthalmus</i>	2.5	0.06	0.009	0.005	0.48	9.4	0.22
<i>Plethodon</i>	6.7	0.11	0.031	0.009	0.28	11.5	0.20
<i>Pseudoeurycea</i>	11.8	0.24	0.011	0.018	1.37	13.1	0.26
<i>Pseudotriton</i>	9.9	0.15	0.041	0.031	0.73	13.1	0.18
<i>Salamandra</i>	6.8	0.07	0.164	0.030	0.18	16.5	0.17
<i>Stereochilus</i>	2.3	0.05	0.004	0.001	0.39	5.8	0.12
<i>Thorius</i>	5.6	0.26	0.001	0.001	1.77	5.0	0.24

Table S2, part 3 of 3

Genus	Epibranchial Length (mm)	Aponeurosis Spirality Angle (°)	Aponeurosis Spirality Length (mm)	SAR Perimeter (mm)	Epibranchial Aspect Ratio	Source
<i>Ambystoma</i>	5.7	-	-	-	-	(7); this study
<i>Aneides</i>	3.3	28	0.32	3.8	2.0	(7)
<i>Batrachoseps</i>	4.0	130	0.50	1.9	1.2	(7)
<i>Bolitoglossa</i>	11.0	359	2.82	4.5	1.4	(7)
<i>Chiropterotriton</i>	4.9	383	1.22	1.7	1.3	(7)
<i>Desmognathus</i>	6.2	14	1.02	4.3	2.2	(7)
<i>Ensatina</i>	7.5	212	1.97	4.6	1.3	(7)
<i>Eurycea</i>	6.9	296	2.03	3.4	1.3	(7)
<i>Gyrinophilus</i>	5.3	145	1.59	5.2	1.4	(7)
<i>Hemidactylium</i>	3.1	116	0.65	2.7	1.2	(7)
<i>Hydromantes</i>	22.0	198	1.57	4.0	1.3	(4, 8)
<i>Notophthalmus</i>	3.6	6	0.19	2.8	1.8	This study
<i>Plethodon</i>	3.5	26	0.32	2.5	1.5	(7)
<i>Pseudoeurycea</i>	7.8	305	1.69	2.8	1.2	(7)
<i>Pseudotriton</i>	5.6	207	2.10	5.2	1.4	(7)
<i>Salamandra</i>	4.9	0	0.00	2.5	4.4	(7)
<i>Stereochilus</i>	2.0	73	0.27	2.0	1.1	(7)
<i>Thorius</i>	2.6	226	0.65	1.3	1.3	(6, 7)

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