

Figure 1: Called strike zones for the 12 Ball-Strike combinations for RHP-RHB-Home.

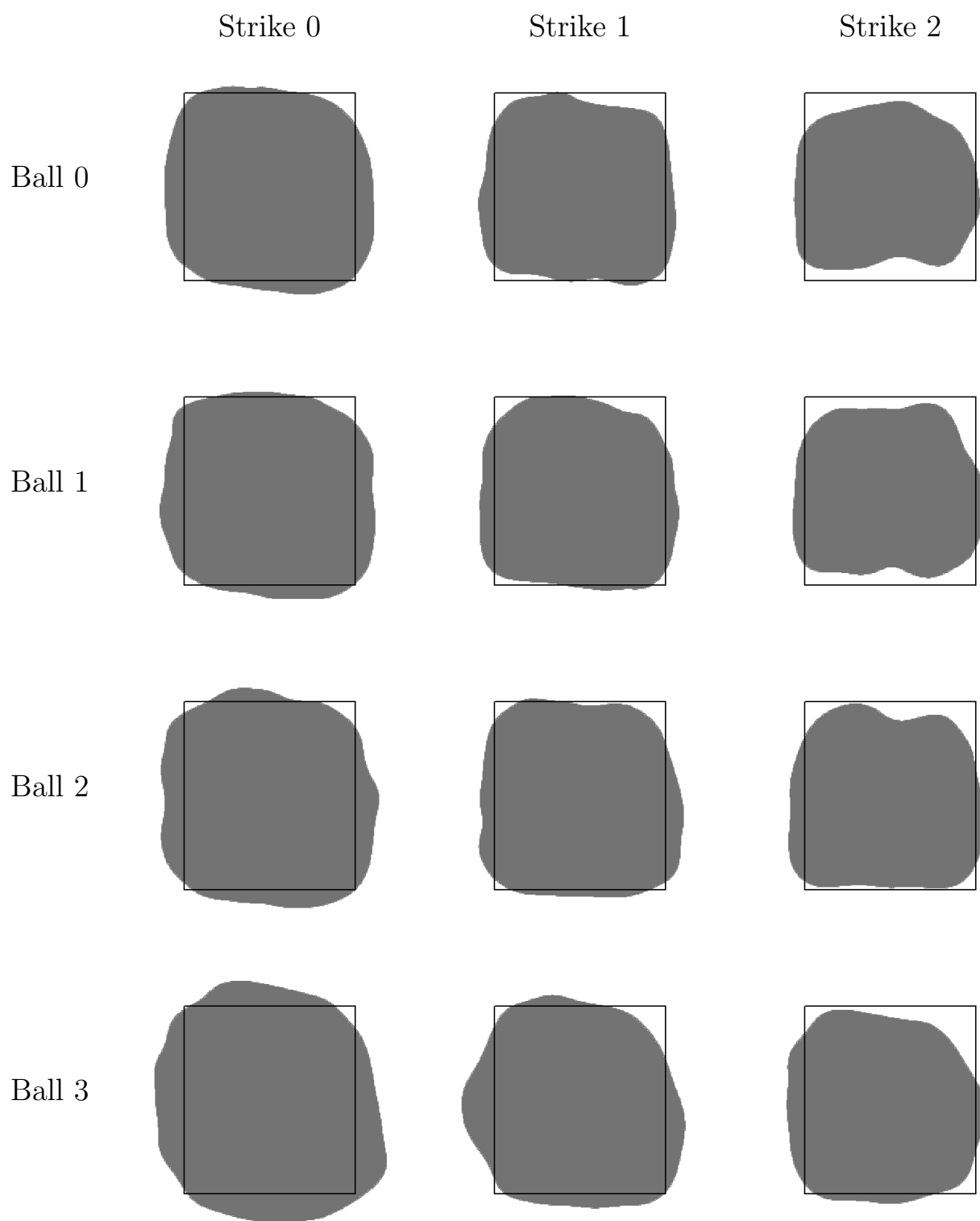


Figure 2: Called strike zones for the 12 Ball-Strike combinations for LHP-RHB-Home.

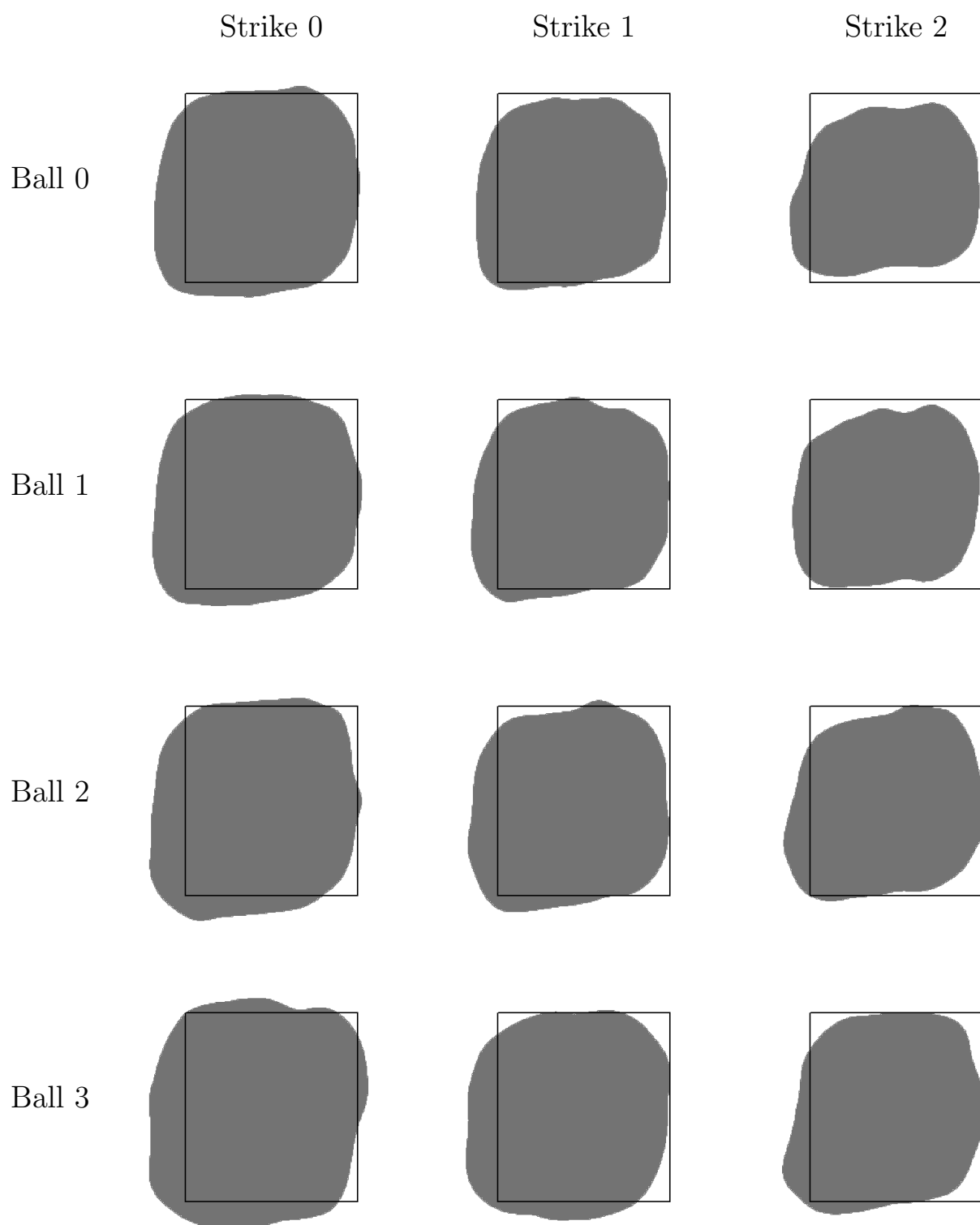


Figure 3: Called strike zones for the 12 Ball-Strike combinations for RHP-LHB-Home.

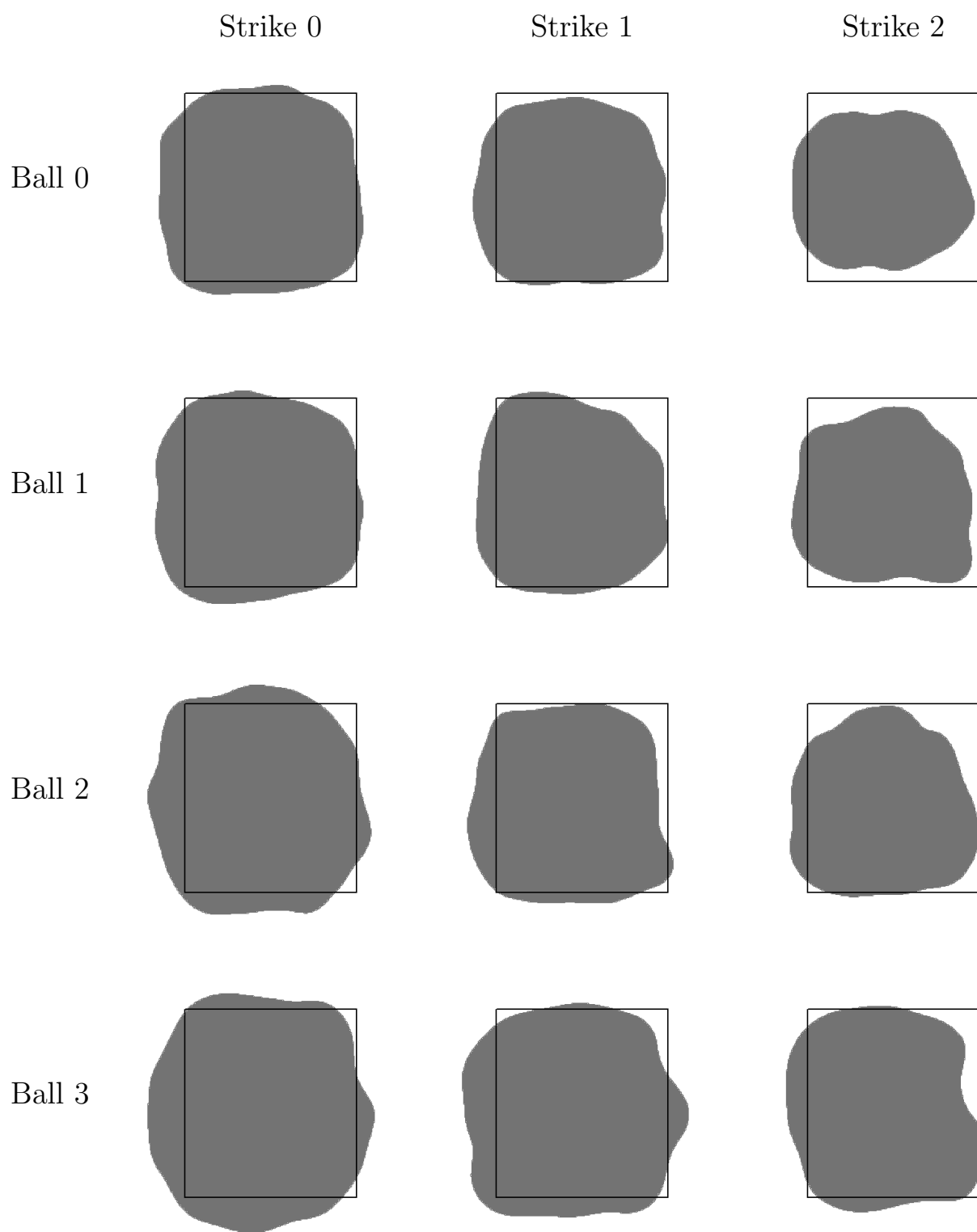


Figure 4: Called strike zones for the 12 Ball-Strike combinations for LHP-LHB-Home.

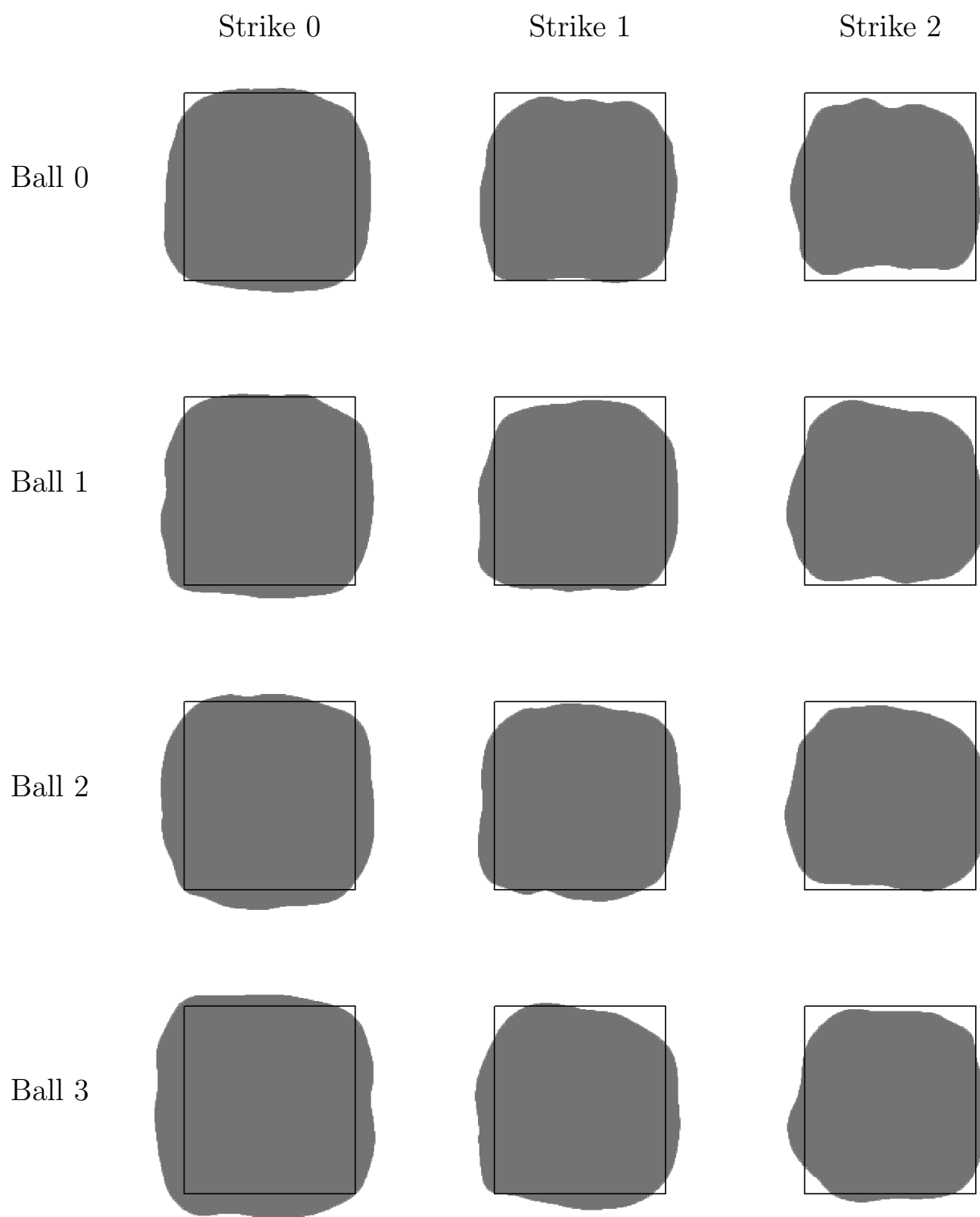


Figure 5: Called strike zones for the 12 Ball-Strike combinations for RHP-RHB-Away.

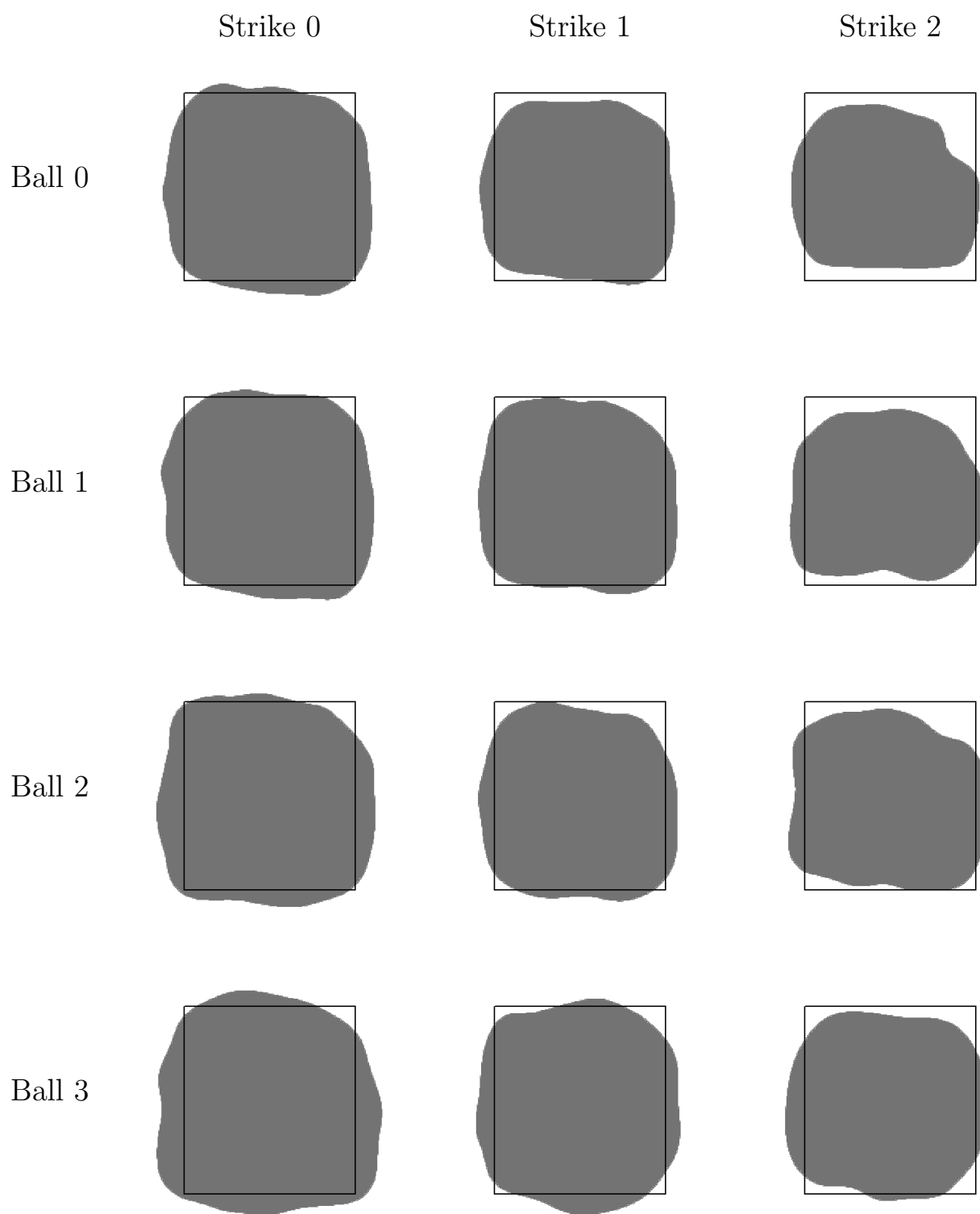


Figure 6: Called strike zones for the 12 Ball-Strike combinations for LHP-RHB-Away.

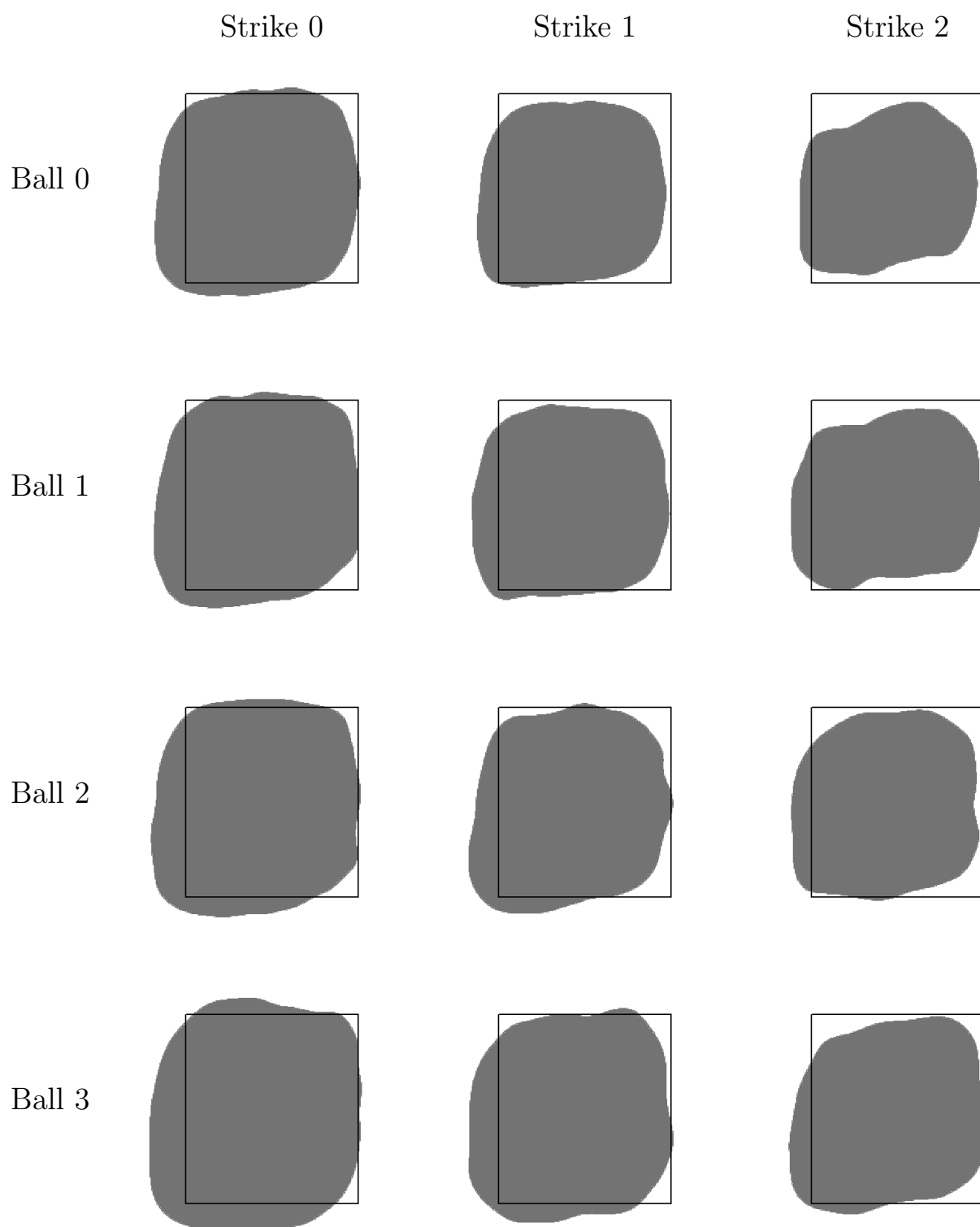


Figure 7: Called strike zones for the 12 Ball-Strike combinations for RHP-LHB-Away.

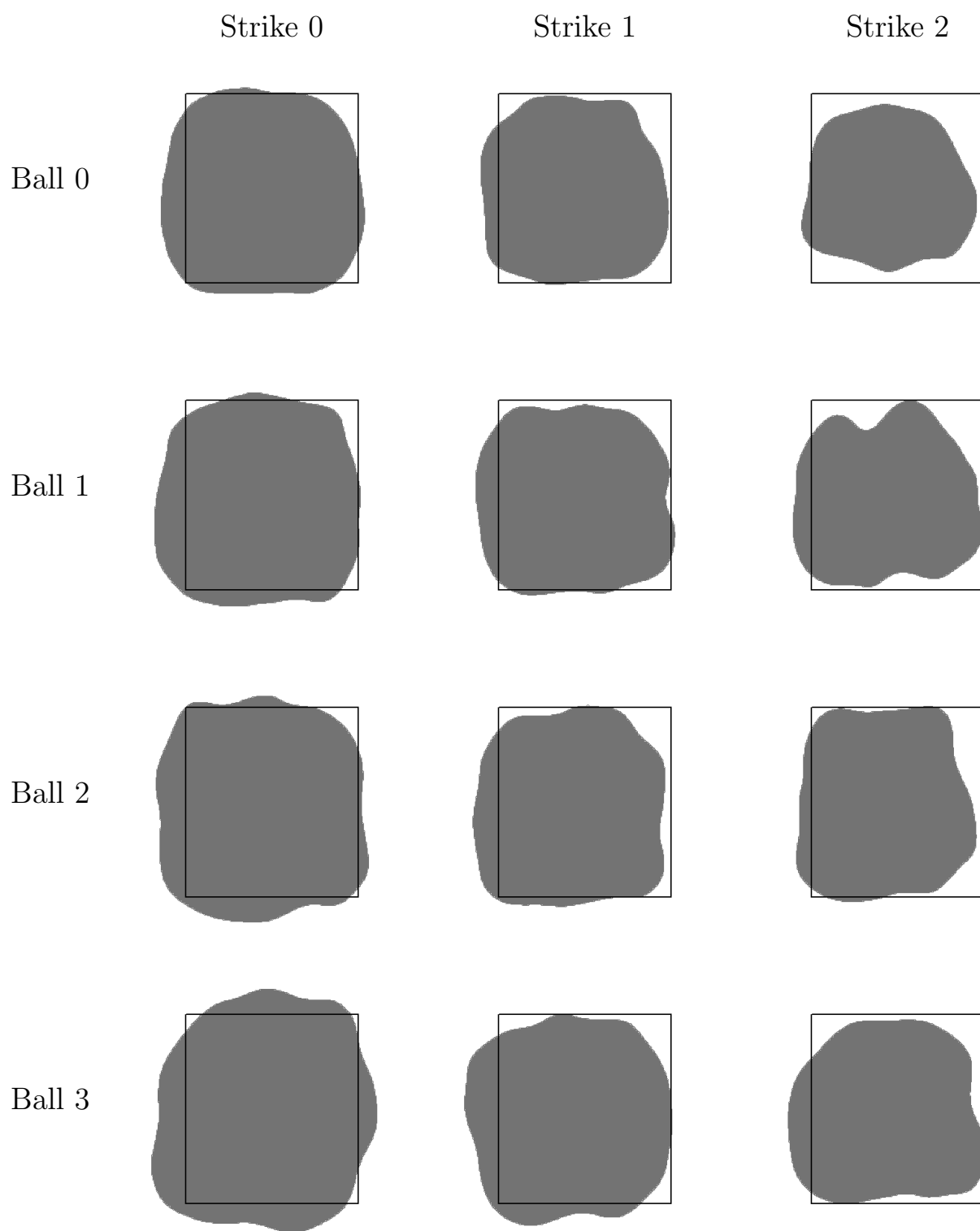


Figure 8: Called strike zones for the 12 Ball-Strike combinations for LHP-LHB-Away.



	npts	nobs	$\hat{x}_0$	$\hat{y}_0$	$\hat{a}$	$\hat{b}$	$\hat{A}$	$\hat{E}$	$\hat{r}_1$	$\hat{r}_2$	$\hat{s}$
group1	510	76414	-0.027	2.486	0.993	0.974	3.474	1.019	1.391	1.999	-0.022
group2	492	28736	-0.028	2.484	0.932	0.877	3.015	1.063	1.545	2.668	-0.041
group3	437	14151	-0.035	2.500	0.880	0.831	2.592	1.059	1.327	1.811	-0.019
group4	515	22038	-0.023	2.474	1.015	0.982	3.536	1.033	1.316	1.868	-0.025
group5	507	18857	-0.022	2.493	0.966	0.935	3.280	1.033	1.358	2.608	-0.034
group6	468	16916	-0.043	2.499	0.923	0.819	2.766	1.127	1.443	2.597	-0.030
group7	507	6758	-0.018	2.463	1.023	1.014	3.683	1.009	1.346	1.796	0.007
group8	510	7878	-0.017	2.464	0.978	0.936	3.332	1.044	1.517	2.151	-0.007
group9	471	11108	-0.039	2.503	0.931	0.884	2.981	1.053	1.295	2.718	-0.029
group10	520	3091	-0.048	2.445	1.072	1.118	4.108	0.959	1.301	1.334	0.012
group11	464	3145	-0.016	2.466	0.960	1.007	3.364	0.953	1.282	1.548	-0.031
group12	482	4754	-0.039	2.454	0.932	0.905	3.056	1.031	1.644	1.795	-0.072
group13	475	37635	-0.013	2.492	0.998	0.982	3.456	1.017	1.355	1.654	0.075
group14	484	13426	-0.025	2.494	0.920	0.874	2.958	1.053	1.528	2.617	0.033
group15	417	6393	-0.055	2.540	0.871	0.774	2.425	1.125	1.195	2.935	-0.009
group16	510	11911	-0.009	2.478	1.011	0.981	3.539	1.030	1.477	1.695	0.060
group17	480	9305	-0.030	2.508	0.940	0.912	3.057	1.031	1.222	2.295	0.050
group18	429	7913	-0.032	2.532	0.901	0.803	2.617	1.123	1.300	2.632	0.014
group19	504	3961	-0.027	2.488	1.024	1.025	3.686	0.999	1.287	1.704	0.063
group20	502	4331	-0.007	2.487	0.953	0.935	3.255	1.020	1.511	2.305	0.049
group21	475	5549	-0.054	2.486	0.912	0.845	2.853	1.079	1.507	3.184	0.013
group22	525	1943	-0.018	2.500	1.080	1.146	4.191	0.943	1.090	1.494	0.101
group23	454	1850	-0.057	2.499	1.027	1.019	3.482	1.009	0.970	1.536	0.107
group24	448	2550	-0.087	2.445	0.926	0.911	2.927	1.017	1.239	1.569	0.072
group25	493	71827	-0.149	2.476	0.959	0.987	3.386	0.971	1.466	1.760	-0.094
group26	437	25285	-0.133	2.479	0.894	0.900	2.866	0.994	1.311	1.967	-0.081
group27	414	11461	-0.084	2.516	0.870	0.790	2.456	1.101	1.201	2.563	-0.147
group28	493	23687	-0.152	2.470	0.971	0.998	3.441	0.973	1.332	1.826	-0.087
group29	461	18133	-0.133	2.474	0.928	0.927	3.069	1.001	1.322	1.988	-0.090
group30	405	14706	-0.094	2.491	0.868	0.837	2.579	1.036	1.321	1.852	-0.128
group31	516	8008	-0.173	2.451	0.968	1.034	3.587	0.937	1.508	1.734	-0.100
group32	475	8448	-0.144	2.454	0.935	0.951	3.176	0.983	1.405	1.823	-0.092
group33	429	10414	-0.092	2.504	0.922	0.899	2.863	1.026	1.106	1.814	-0.164
group34	515	3956	-0.152	2.450	1.006	1.074	3.887	0.937	1.723	1.563	-0.094
group35	477	3908	-0.157	2.439	0.957	0.987	3.336	0.969	1.441	1.560	-0.085
group36	458	4934	-0.097	2.485	0.899	0.938	3.000	0.959	1.270	2.058	-0.140
group37	498	15914	-0.108	2.492	0.958	0.988	3.366	0.970	1.335	1.871	0.019
group38	436	5905	-0.122	2.481	0.897	0.887	2.826	1.012	1.264	2.029	0.021
group39	350	2877	-0.138	2.491	0.852	0.754	2.198	1.129	1.240	1.385	0.027
group40	484	4891	-0.132	2.471	0.979	0.988	3.421	0.990	1.369	1.691	0.006
group41	456	3987	-0.135	2.512	0.902	0.951	2.929	0.949	1.088	1.627	0.065
group42	427	3530	-0.108	2.494	0.839	0.817	2.435	1.027	1.085	3.146	0.048
group43	494	1544	-0.128	2.493	1.013	1.087	3.777	0.932	1.220	1.431	0.040
group44	488	1788	-0.138	2.463	0.905	0.941	3.123	0.962	1.488	2.596	0.033
group45	413	2330	-0.114	2.498	0.882	0.900	2.630	0.980	0.836	2.078	0.029
group46	488	710	-0.123	2.427	1.047	1.133	3.997	0.924	1.281	1.190	-0.001
group47	507	781	-0.110	2.446	1.021	1.020	3.635	1.001	1.214	1.727	0.008
group48	456	1081	-0.114	2.479	0.877	0.954	3.055	0.920	1.499	2.295	0.116

	npts	nobs	$\hat{x}_0$	$\hat{y}_0$	$\hat{a}$	$\hat{b}$	$\hat{A}$	$\hat{E}$	$\hat{r}_1$	$\hat{r}_2$	$\hat{s}$
group49	502	73752	-0.021	2.491	0.983	0.972	3.412	1.011	1.372	1.906	-0.010
group50	468	27057	-0.019	2.487	0.920	0.872	2.950	1.055	1.554	2.471	-0.033
group51	427	13031	-0.043	2.525	0.875	0.799	2.579	1.095	1.429	3.240	0.020
group52	514	22322	-0.026	2.473	0.999	0.968	3.519	1.031	1.540	2.070	-0.024
group53	488	18143	-0.016	2.474	0.947	0.904	3.093	1.048	1.342	2.373	-0.038
group54	444	15805	-0.048	2.503	0.916	0.844	2.744	1.085	1.221	2.149	0.009
group55	512	7199	-0.021	2.458	1.016	1.022	3.683	0.994	1.554	1.504	0.011
group56	475	8022	-0.014	2.456	0.949	0.918	3.178	1.033	1.714	1.864	-0.045
group57	461	10564	-0.043	2.505	0.931	0.867	2.877	1.074	1.254	2.133	0.014
group58	564	3299	-0.057	2.455	1.039	1.068	4.080	0.973	1.910	1.859	0.010
group59	487	3386	-0.030	2.452	0.971	0.964	3.296	1.008	1.286	1.739	0.019
group60	469	4612	-0.008	2.467	0.907	0.916	2.942	0.990	1.404	1.651	-0.007
group61	502	36817	-0.012	2.488	0.982	0.993	3.483	0.990	1.461	1.740	0.061
group62	475	13372	-0.021	2.483	0.915	0.860	2.873	1.065	1.518	2.238	0.040
group63	406	6034	-0.086	2.529	0.887	0.794	2.380	1.118	0.907	2.126	0.135
group64	513	11570	-0.010	2.482	0.997	0.987	3.521	1.009	1.445	1.802	0.056
group65	481	9290	-0.027	2.485	0.941	0.915	3.094	1.028	1.347	2.151	0.063
group66	438	7652	-0.050	2.501	0.913	0.794	2.579	1.150	1.143	2.687	0.018
group67	537	4044	-0.044	2.482	1.031	1.006	3.680	1.024	1.327	1.831	0.040
group68	454	4257	-0.019	2.455	0.937	0.925	3.086	1.013	1.352	1.871	0.063
group69	455	5473	-0.038	2.485	0.935	0.847	2.802	1.104	1.201	2.122	0.083
group70	522	2045	-0.026	2.505	1.059	1.052	3.906	1.008	1.105	2.223	0.041
group71	465	1936	-0.016	2.445	0.972	1.008	3.347	0.964	1.370	1.236	0.012
group72	447	2558	-0.046	2.464	0.948	0.883	2.935	1.075	1.467	1.429	0.001
group73	485	68701	-0.150	2.483	0.950	0.978	3.310	0.971	1.409	1.775	-0.095
group74	446	23820	-0.138	2.474	0.875	0.868	2.737	1.008	1.439	1.976	-0.086
group75	384	10631	-0.101	2.522	0.849	0.793	2.250	1.071	1.000	1.512	-0.184
group76	512	23214	-0.146	2.478	0.957	1.007	3.444	0.950	1.451	1.763	-0.099
group77	470	17393	-0.144	2.459	0.913	0.902	2.987	1.012	1.524	2.019	-0.073
group78	430	13937	-0.101	2.502	0.890	0.805	2.559	1.105	1.284	2.128	-0.139
group79	521	8004	-0.159	2.472	0.971	1.026	3.565	0.947	1.491	1.715	-0.087
group80	454	8305	-0.154	2.462	0.920	0.957	3.116	0.962	1.317	1.798	-0.129
group81	445	10108	-0.121	2.502	0.876	0.881	2.737	0.994	1.304	1.874	-0.095
group82	539	4095	-0.160	2.456	0.995	1.087	3.878	0.915	1.489	1.761	-0.085
group83	505	3958	-0.145	2.446	0.946	0.986	3.334	0.959	1.473	1.714	-0.083
group84	459	4844	-0.088	2.475	0.896	0.903	2.875	0.993	1.264	2.028	-0.156
group85	475	15699	-0.099	2.485	0.946	0.978	3.271	0.967	1.287	1.845	0.012
group86	447	5661	-0.113	2.512	0.873	0.884	2.710	0.987	1.203	1.877	0.038
group87	351	2574	-0.096	2.553	0.798	0.763	2.058	1.046	0.969	1.818	0.029
group88	476	5006	-0.131	2.474	0.960	0.994	3.391	0.966	1.269	2.025	-0.013
group89	442	4045	-0.108	2.475	0.917	0.885	2.937	1.036	1.517	1.974	0.041
group90	421	3216	-0.117	2.501	0.875	0.802	2.500	1.092	1.213	2.326	-0.001
group91	509	1622	-0.108	2.457	0.984	1.034	3.674	0.951	1.539	1.853	0.030
group92	488	1849	-0.146	2.477	0.893	0.924	2.985	0.966	1.323	2.558	-0.015
group93	462	2282	-0.143	2.513	0.803	0.901	2.653	0.892	1.576	2.260	0.000
group94	503	781	-0.074	2.516	1.027	1.126	4.001	0.911	1.127	1.771	-0.087
group95	466	804	-0.153	2.417	0.962	0.965	3.256	0.996	1.439	1.468	0.008
group96	448	1073	-0.116	2.520	0.895	0.857	2.711	1.045	1.057	3.088	-0.008

Table 1: Number of points on the outline (npts), number of called pitches (nobs), and estimated ATLAS coefficients (plus area and eccentricity) for the 96 combinations of player attribute and game situation factors, for the combined 2014-2016 data.

## Weighted MANOVA of ATLAS coefficients plus eccentricity and area

```
manova <- manova(cbind(Xo, Yo, a, b, A, E, r1, r2, s) ~ batter + pitcher + ball + strike +
  inning + batter * pitcher + batter * ball + batter * strike +
  batter * inning + pitcher * ball + pitcher * strike + pitcher * inning +
  ball * strike + ball * inning + strike * inning, weights = nobs ^ (2 / 3),
  data = atlas_96)
summary(manova, test = "Wilks")
```

	Df	Wilks	approx F	num Df	den Df	Pr(>F)
batter	1	0.01688	356.02	9	55.00	< 2.2e-16 ***
pitcher	1	0.10118	54.29	9	55.00	< 2.2e-16 ***
ball	3	0.06146	9.55	27	161.27	< 2.2e-16 ***
strike	2	0.00325	101.13	18	110.00	< 2.2e-16 ***
inning	1	0.48488	6.49	9	55.00	3.081e-06 ***
batter:pitcher	1	0.50108	6.08	9	55.00	6.857e-06 ***
batter:ball	3	0.61692	1.07	27	161.27	0.3765
batter:strike	2	0.16673	8.86	18	110.00	2.596e-14 ***
batter:inning	1	0.86906	0.92	9	55.00	0.5144
pitcher:ball	3	0.60268	1.13	27	161.27	0.3111
pitcher:strike	2	0.34730	4.26	18	110.00	9.148e-07 ***
pitcher:inning	1	0.85442	1.04	9	55.00	0.4201
ball:strike	6	0.08411	3.30	54	285.04	5.119e-11 ***
ball:inning	3	0.70554	0.76	27	161.27	0.7994
strike:inning	2	0.65417	1.44	18	110.00	0.1253
Residuals	63					

```
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

## Weighted ANOVAs of each ATLAS coefficient plus eccentricity and area

```
## Xo-----
anova_Xo <- anova(lm(Xo ~ batter + pitcher + ball + strike + inning + batter * pitcher +
  batter * ball + batter * strike + batter * inning + pitcher * ball +
  pitcher * strike + pitcher * inning + ball * strike + ball * inning +
  strike * inning, weights = nobs ^ (2 / 3), data = atlas_96))
anova_Xo
```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
batter	1	113.105	113.105	2021.8609	< 2.2e-16 ***
pitcher	1	0.433	0.433	7.7423	0.0071093 **
ball	3	0.196	0.065	1.1696	0.3284491
strike	2	0.204	0.102	1.8223	0.1700771
inning	1	0.000	0.000	0.0000	0.9978622
batter:pitcher	1	0.676	0.676	12.0801	0.0009283 ***
batter:ball	3	0.217	0.072	1.2936	0.2844149
batter:strike	2	7.623	3.812	68.1367	< 2.2e-16 ***
batter:inning	1	0.010	0.010	0.1789	0.6737954
pitcher:ball	3	0.218	0.073	1.3013	0.2818665
pitcher:strike	2	2.269	1.135	20.2831	1.584e-07 ***
pitcher:inning	1	0.022	0.022	0.3853	0.5370298
ball:strike	6	0.301	0.050	0.8976	0.5023474
ball:inning	3	0.149	0.050	0.8905	0.4510283
strike:inning	2	0.100	0.050	0.8904	0.4155763
Residuals	63	3.524	0.056		

```
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
## Yo-----
anova_Yo <- anova(lm(Yo ~ batter + pitcher + ball + strike + inning + batter * pitcher +
  batter * ball + batter * strike + batter * inning + pitcher * ball +
```

```

pitcher * strike + pitcher * inning + ball * strike + ball * inning +
strike * inning, weights = nobs ^ (2 / 3), data = atlas_96))

anova_Yo

```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
batter	1	0.3463	0.3463	5.9044	0.0179643	*
pitcher	1	0.7005	0.7005	11.9429	0.0009874	***
ball	3	3.2119	1.0706	18.2532	1.233e-08	***
strike	2	6.4068	3.2034	54.6153	1.745e-14	***
inning	1	0.0014	0.0014	0.0242	0.8768151	
batter:pitcher	1	0.0058	0.0058	0.0983	0.7549609	
batter:ball	3	0.1053	0.0351	0.5984	0.6184404	
batter:strike	2	0.1974	0.0987	1.6825	0.1941460	
batter:inning	1	0.1601	0.1601	2.7301	0.1034474	
pitcher:ball	3	0.0650	0.0217	0.3696	0.7752177	
pitcher:strike	2	0.0677	0.0338	0.5767	0.5646680	
pitcher:inning	1	0.0769	0.0769	1.3110	0.2565476	
ball:strike	6	0.7883	0.1314	2.2401	0.0505946	.
ball:inning	3	0.2093	0.0698	1.1897	0.3208998	
strike:inning	2	0.4280	0.2140	3.6483	0.0316821	*
Residuals	63	3.6952	0.0587			

```

---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

## a-----
anova_a <- anova(lm(a ~ batter + pitcher + ball + strike + inning + batter * pitcher +
batter * ball + batter * strike + batter * inning + pitcher * ball +
pitcher * strike + pitcher * inning + ball * strike + ball * inning +
strike * inning, weights = nobs ^ (2 / 3), data = atlas_96))

anova_a

```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
batter	1	13.721	13.721	218.7018	< 2.2e-16	***
pitcher	1	0.146	0.146	2.3202	0.132707	
ball	3	4.300	1.433	22.8447	3.987e-10	***
strike	2	75.599	37.799	602.5111	< 2.2e-16	***
inning	1	1.261	1.261	20.1073	3.165e-05	***
batter:pitcher	1	0.057	0.057	0.9039	0.345384	
batter:ball	3	0.097	0.032	0.5138	0.674281	
batter:strike	2	0.071	0.036	0.5690	0.568984	
batter:inning	1	0.039	0.039	0.6178	0.434809	
pitcher:ball	3	0.815	0.272	4.3321	0.007708	**
pitcher:strike	2	0.626	0.313	4.9921	0.009716	**
pitcher:inning	1	0.015	0.015	0.2438	0.623191	
ball:strike	6	1.059	0.176	2.8124	0.017286	*
ball:inning	3	0.128	0.043	0.6800	0.567540	
strike:inning	2	0.163	0.081	1.2964	0.280717	
Residuals	63	3.952	0.063			

```

---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

## b-----
anova_b <- anova(lm(b ~ batter + pitcher + ball + strike + inning + batter * pitcher +
batter * ball + batter * strike + batter * inning + pitcher * ball +
pitcher * strike + pitcher * inning + ball * strike + ball * inning +
strike * inning, weights = nobs ^ (2 / 3), data = atlas_96))

anova_b

```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
batter	1	1.022	1.022	11.7530	0.0010757	**
pitcher	1	0.068	0.068	0.7800	0.3805060	

ball	3	23.625	7.875	90.5910	< 2.2e-16	***
strike	2	210.562	105.281	1211.1239	< 2.2e-16	***
inning	1	1.146	1.146	13.1825	0.0005684	***
batter:pitcher	1	0.007	0.007	0.0855	0.7709712	
batter:ball	3	0.618	0.206	2.3694	0.0789849	.
batter:strike	2	0.184	0.092	1.0589	0.3529111	
batter:inning	1	0.104	0.104	1.1925	0.2789899	
pitcher:ball	3	0.187	0.062	0.7158	0.5462030	
pitcher:strike	2	1.557	0.779	8.9582	0.0003768	***
pitcher:inning	1	0.003	0.003	0.0389	0.8442119	
ball:strike	6	2.656	0.443	5.0932	0.0002564	***
ball:inning	3	0.378	0.126	1.4484	0.2372055	
strike:inning	2	0.295	0.148	1.6971	0.1914748	
Residuals	63	5.476	0.087			

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

```
## A-----
anova_A <- anova(lm(A ~ batter + pitcher + ball + strike + inning + batter * pitcher +
  batter * ball + batter * strike + batter * inning + pitcher * ball +
  pitcher * strike + pitcher * inning + ball * strike + ball * inning +
  strike * inning, weights = nobs ^ (2 / 3), data = atlas_96))
```

anova_A	Df	Sum Sq	Mean Sq	F value	Pr(>F)
batter	1	138.6	138.56	137.3724	< 2.2e-16 ***
pitcher	1	24.5	24.48	24.2668	6.383e-06 ***
ball	3	405.5	135.15	133.9920	< 2.2e-16 ***
strike	2	5907.5	2953.77	2928.3977	< 2.2e-16 ***
inning	1	46.2	46.16	45.7627	5.127e-09 ***
batter:pitcher	1	0.0	0.00	0.0002	0.98902
batter:ball	3	6.0	2.00	1.9844	0.12534
batter:strike	2	5.9	2.96	2.9369	0.06033 .
batter:inning	1	1.1	1.11	1.1032	0.29757
pitcher:ball	3	6.4	2.14	2.1193	0.10664
pitcher:strike	2	37.3	18.67	18.5125	4.740e-07 ***
pitcher:inning	1	0.7	0.67	0.6684	0.41669
ball:strike	6	61.4	10.24	10.1496	7.840e-08 ***
ball:inning	3	4.6	1.52	1.5038	0.22218
strike:inning	2	6.8	3.42	3.3912	0.03993 *
Residuals	63	63.5	1.01		

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

```
## E-----
anova_E <- anova(lm(E ~ batter + pitcher + ball + strike + inning + batter * pitcher +
  batter * ball + batter * strike + batter * inning + pitcher * ball +
  pitcher * strike + pitcher * inning + ball * strike + ball * inning +
  strike * inning, weights = nobs ^ (2 / 3), data = atlas_96))
```

anova_E	Df	Sum Sq	Mean Sq	F value	Pr(>F)
batter	1	25.425	25.4254	111.0077	1.569e-15 ***
pitcher	1	0.000	0.0002	0.0008	0.97729
ball	3	11.224	3.7414	16.3348	5.806e-08 ***
strike	2	48.174	24.0872	105.1649	< 2.2e-16 ***
inning	1	0.000	0.0002	0.0009	0.97636
batter:pitcher	1	0.183	0.1833	0.8001	0.37445
batter:ball	3	1.418	0.4727	2.0638	0.11397
batter:strike	2	0.102	0.0511	0.2231	0.80067

batter:inning	1	0.019	0.0190	0.0828	0.77453
pitcher:ball	3	0.347	0.1156	0.5046	0.68050
pitcher:strike	2	0.565	0.2823	1.2324	0.29854
pitcher:inning	1	0.003	0.0029	0.0127	0.91071
ball:strike	6	3.231	0.5385	2.3511	0.04113 *
ball:inning	3	0.557	0.1856	0.8103	0.49293
strike:inning	2	0.338	0.1688	0.7370	0.48261
Residuals	63	14.430	0.2290		

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

```
## r1-----
anova_r1 <- anova(lm(r1 ~ batter + pitcher + ball + strike + inning + batter * pitcher +
  batter * ball + batter * strike + batter * inning + pitcher * ball +
  pitcher * strike + pitcher * inning + ball * strike + ball * inning +
  strike * inning, weights = nobs ^ (2 / 3), data = atlas_96))
```

anova_r1	Df	Sum Sq	Mean Sq	F value	Pr(>F)
batter	1	22.22	22.219	3.0538	0.08542 .
pitcher	1	67.44	67.436	9.2683	0.00340 **
ball	3	5.53	1.843	0.2533	0.85868
strike	2	186.40	93.201	12.8095	2.148e-05 ***
inning	1	4.83	4.825	0.6631	0.41852
batter:pitcher	1	1.75	1.746	0.2400	0.62590
batter:ball	3	12.63	4.209	0.5785	0.63126
batter:strike	2	31.47	15.737	2.1628	0.12346
batter:inning	1	0.07	0.070	0.0096	0.92224
pitcher:ball	3	21.45	7.149	0.9825	0.40678
pitcher:strike	2	0.46	0.229	0.0315	0.96903
pitcher:inning	1	0.49	0.491	0.0675	0.79583
ball:strike	6	70.36	11.727	1.6117	0.15866
ball:inning	3	11.25	3.748	0.5152	0.67332
strike:inning	2	35.23	17.614	2.4209	0.09706 .
Residuals	63	458.38	7.276		

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

```
## r2-----
anova_r2 <- anova(lm(r2 ~ batter + pitcher + ball + strike + inning + batter * pitcher +
  batter * ball + batter * strike + batter * inning + pitcher * ball +
  pitcher * strike + pitcher * inning + ball * strike + ball * inning +
  strike * inning, weights = nobs ^ (2 / 3), data = atlas_96))
```

anova_r2	Df	Sum Sq	Mean Sq	F value	Pr(>F)
batter	1	534.76	534.76	14.3733	0.0003381 ***
pitcher	1	0.68	0.68	0.0182	0.8931279
ball	3	478.97	159.66	4.2913	0.0080821 **
strike	2	1757.27	878.64	23.6161	2.221e-08 ***
inning	1	23.75	23.75	0.6384	0.4272796
batter:pitcher	1	94.57	94.57	2.5418	0.1158715
batter:ball	3	242.42	80.81	2.1720	0.1001053
batter:strike	2	276.21	138.11	3.7121	0.0299229 *
batter:inning	1	14.94	14.94	0.4016	0.5285675
pitcher:ball	3	145.43	48.48	1.3030	0.2813213
pitcher:strike	2	88.82	44.41	1.1937	0.3098550
pitcher:inning	1	2.17	2.17	0.0585	0.8097401
ball:strike	6	199.33	33.22	0.8930	0.5056415
ball:inning	3	101.99	34.00	0.9137	0.4394868

```
strike:inning 2 80.99 40.50 1.0884 0.3429900
Residuals 63 2343.91 37.20
```

```
---
```

```
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
## s-----
anova_s <- anova(lm(s ~ batter + pitcher + ball + strike + inning + batter * pitcher +
  batter * ball + batter * strike + batter * inning + pitcher * ball +
  pitcher * strike + pitcher * inning + ball * strike + ball * inning +
  strike * inning, weights = nobs ^ (2 / 3), data = atlas_96))
```

```
anova_s
      Df Sum Sq Mean Sq F value    Pr(>F)
batter    1 70.215  70.215 257.4879 < 2.2e-16 ***
pitcher    1 82.801  82.801 303.6427 < 2.2e-16 ***
ball       3  0.109   0.036   0.1332  0.939940
strike     2  2.271   1.136   4.1644  0.020016 *
inning     1  0.113   0.113   0.4140  0.522294
batter:pitcher 1  6.753   6.753 24.7637 5.302e-06 ***
batter:ball   3  0.659   0.220   0.8058  0.495336
batter:strike 2  3.730   1.865   6.8389  0.002052 **
batter:inning 1  0.839   0.839   3.0775  0.084243 .
pitcher:ball  3  0.102   0.034   0.1243  0.945415
pitcher:strike 2  0.342   0.171   0.6266  0.537687
pitcher:inning 1  0.450   0.450   1.6512  0.203504
ball:strike   6  0.944   0.157   0.5769  0.747248
ball:inning   3  0.459   0.153   0.5612  0.642584
strike:inning 2  1.345   0.673   2.4669  0.093006 .
Residuals   63 17.180   0.273
```

```
---
```

```
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Factor	Levels	$\hat{x}_0$	$\hat{y}_0$	$\hat{a}$	$\hat{b}$	$\hat{A}$	$\hat{E}$	$\hat{r}_1$	$\hat{r}_2$	$\hat{s}$
Pitcher	RHP	0.001	0.001	0.001	0.002	0.006	0.003	0.016	0.036	0.003
	LHP	0.002	0.002	0.002	0.002	0.008	0.004	0.022	0.050	0.004
Batter	RHB	0.002	0.002	0.002	0.002	0.006	0.003	0.017	0.039	0.003
	LHB	0.002	0.002	0.002	0.002	0.007	0.003	0.019	0.043	0.004
Venue	Home	0.002	0.002	0.002	0.002	0.007	0.003	0.018	0.041	0.004
	Away	0.002	0.002	0.002	0.002	0.007	0.003	0.018	0.041	0.004
Ball	0	0.002	0.002	0.002	0.002	0.007	0.003	0.020	0.044	0.004
	1	0.002	0.002	0.002	0.003	0.009	0.004	0.024	0.054	0.005
	2	0.003	0.003	0.003	0.003	0.011	0.005	0.031	0.070	0.006
	3	0.004	0.004	0.004	0.004	0.015	0.007	0.040	0.090	0.008
Strike	0	0.002	0.002	0.002	0.002	0.007	0.003	0.020	0.044	0.004
	1	0.002	0.002	0.002	0.003	0.009	0.004	0.023	0.053	0.005
	2	0.002	0.002	0.002	0.003	0.009	0.004	0.025	0.057	0.005
Batter×Strike:		Batter	Strike	$\hat{x}_0$	Batter×Pitcher:		Batter	Pitcher	$\hat{s}$	
		RHB	0	0.002			RHB	RHP	0.004	
		RHB	1	0.003			RHB	LHP	0.005	
		RHB	2	0.003			LHB	RHP	0.004	
		LHB	0	0.003			LHB	LHP	0.007	
		LHB	1	0.003						
		LHB	2	0.003						

Table 2: Standard errors associated with weighted level means of estimated ATLAS coefficients, plus area and eccentricity, corresponding to each player attribute and game situation factor and selected two-factor combinations, for the combined 2014–2016 data.