Games-Howell Post Hoc Test

Purpose: compare all pairs of group means without assuming equal variances.
H0 for each pair: the two group means are equal.
H1 for each pair: the two group means are different.

Group summary:

group	n	mean	standard_deviation	variance	standard_error	minimum	maximum	mean_ci95_lower	mean_ci95_upper
1	212	10.844340	3.218624	10.359541	0.221056	0	18	10.411070	11.277609
2	305	12.091803	3.243125	10.517860	0.185701	0	19	11.727830	12.455777
3	97	13.226804	2.502104	6.260524	0.254050	8	18	12.728866	13.724742
4	35	13.057143	3.038410	9.231933	0.513585	6	19	12.050516	14.063769

Welch ANOVA context:

test	f_value	df_between	df_error_welch	p_value	note
Welch ANOVA context	18.182877	3	139.100569	5.188109e-10	Included because Games-Howell is designed for unequal variances and/or unequal group sizes.

Standard one-way ANOVA context:

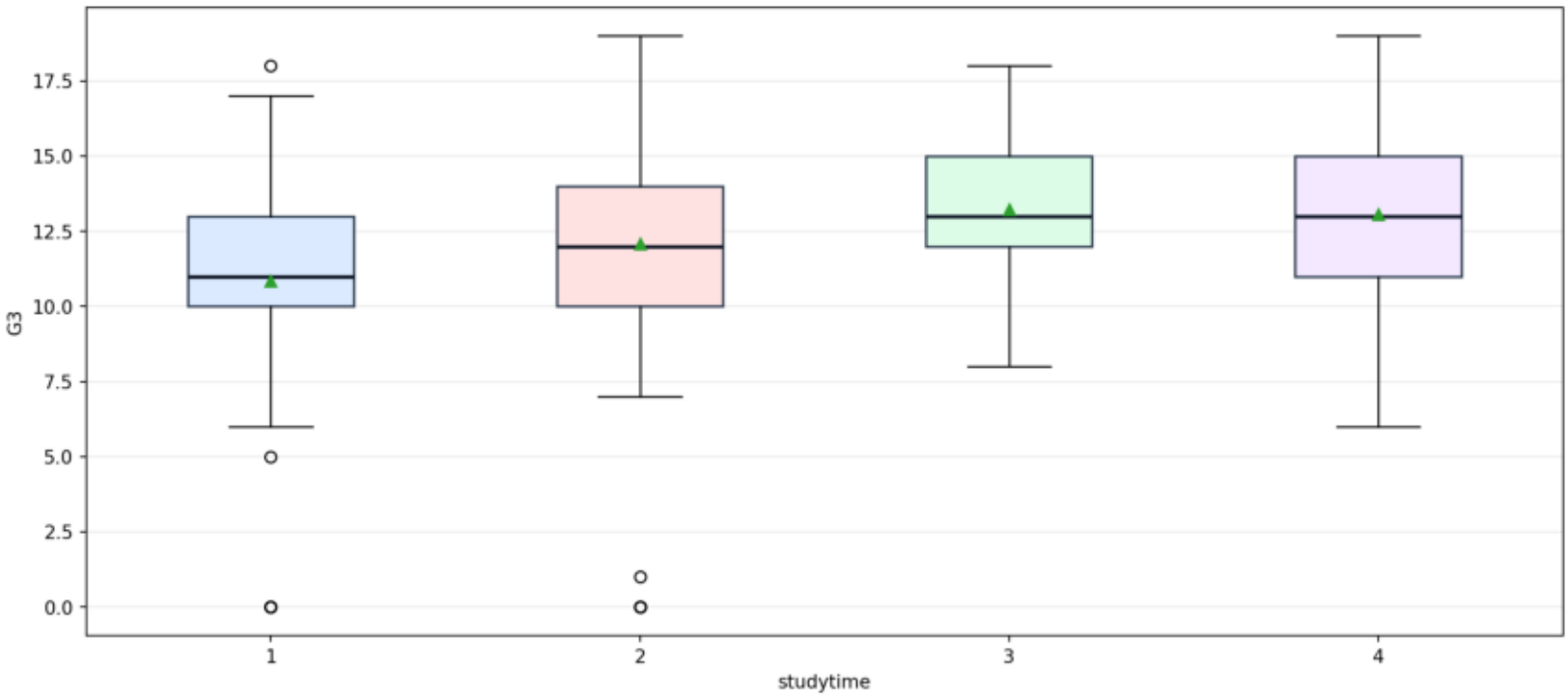
source	sum_of_squares	df	mean_square	f_value	p_value
Between groups	465.077825	3	155.025942	15.876268	5.705728e-10
Within groups	6298.188739	645	9.764634	NaN	NaN
Total	6763.266564	648	NaN	NaN	NaN

Games-Howell pairwise results:

group_1	group_2	mean_group_1	mean_group_2	mean_difference_group_1_minus_group_2	absolute_mean_difference	n_group_1	n_group_2	variance_group_1	variance_group_2	welch_standard_error	games_howell_standard_error	q_statistic	welch_degrees_of_freedom	adjusted_p_value_games_howell	q_critical_alpha_0_05	ci95_lower_difference	ci95_upper_difference	decision_alpha_0_05	interpretation
1	2	10.844340	12.091803	-1.247464	1.247464	212	305	10.359541	10.517860	0.288705	0.204145	6.110668	456.197905	1.120671e-04	3.646585	-1.991897	-0.503031	Significant	Group means differ after Games-Howell adjustment.
1	3	10.844340	13.226804	-2.382465	2.382465	212	97	10.359541	6.260524	0.336760	0.238125	10.005091	235.085651	1.023623e-10	3.659279	-3.253831	-1.511098	Significant	Group means differ after Games-Howell adjustment.
1	4	10.844340	13.057143	-2.212803	2.212803	212	35	10.359541	9.231933	0.559138	0.395370	5.596787	47.501844	1.395448e-03	3.765154	-3.701433	-0.724173	Significant	Group means differ after Games-Howell adjustment.
2	3	12.091803	13.226804	-1.135001	1.135001	305	97	10.517860	6.260524	0.314684	0.222515	5.100773	207.303759	2.183915e-03	3.662801	-1.950031	-0.319971	Significant	Group means differ after Games-Howell adjustment.
2	4	12.091803	13.057143	-0.965340	0.965340	305	35	10.517860	9.231933	0.546127	0.386170	2.499780	43.388409	3.025455e-01	3.778029	-2.424300	0.493621	Not significant	No statistically significant adjusted difference.
3	4	13.226804	13.057143	0.169661	0.169661	97	35	6.260524	9.231933	0.572984	0.405161	0.418750	51.580755	9.908627e-01	3.754464	-1.351501	1.690824	Not significant	No statistically significant adjusted difference.

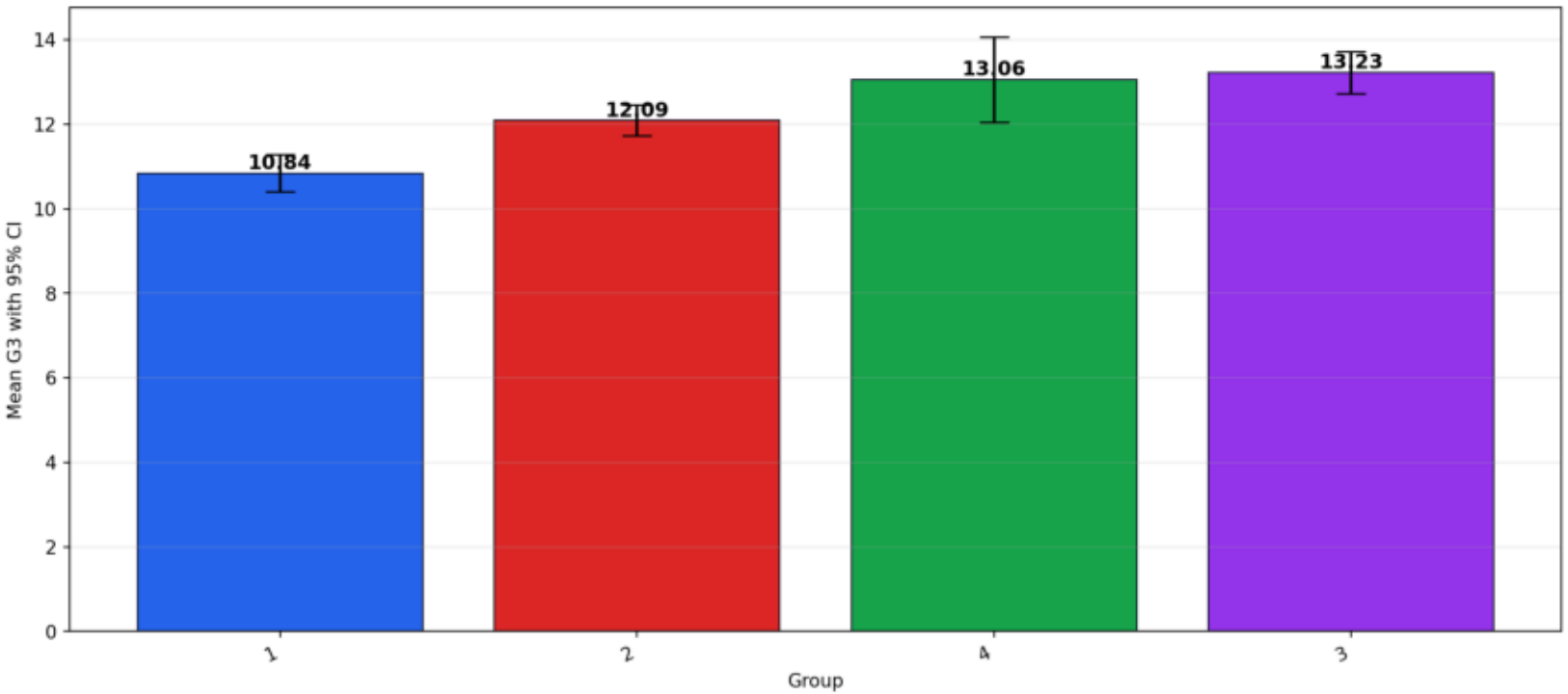
Games-Howell Test: Colorful Group Spread Boxplots

Unequal spreads are important because Games-Howell does not require equal variances.



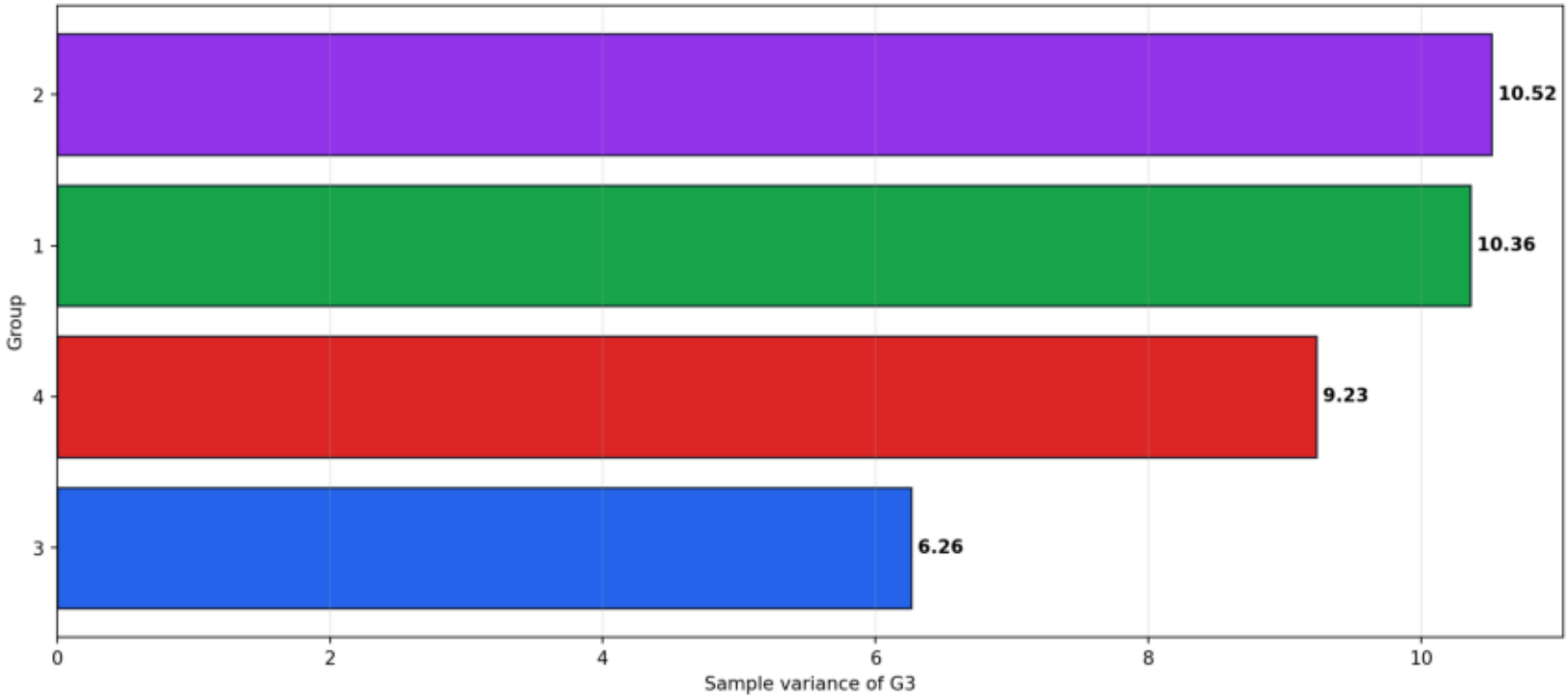
Games-Howell Test: Colorful Group Mean Comparison

The main post-hoc question is which group means differ after unequal-variance adjustment.



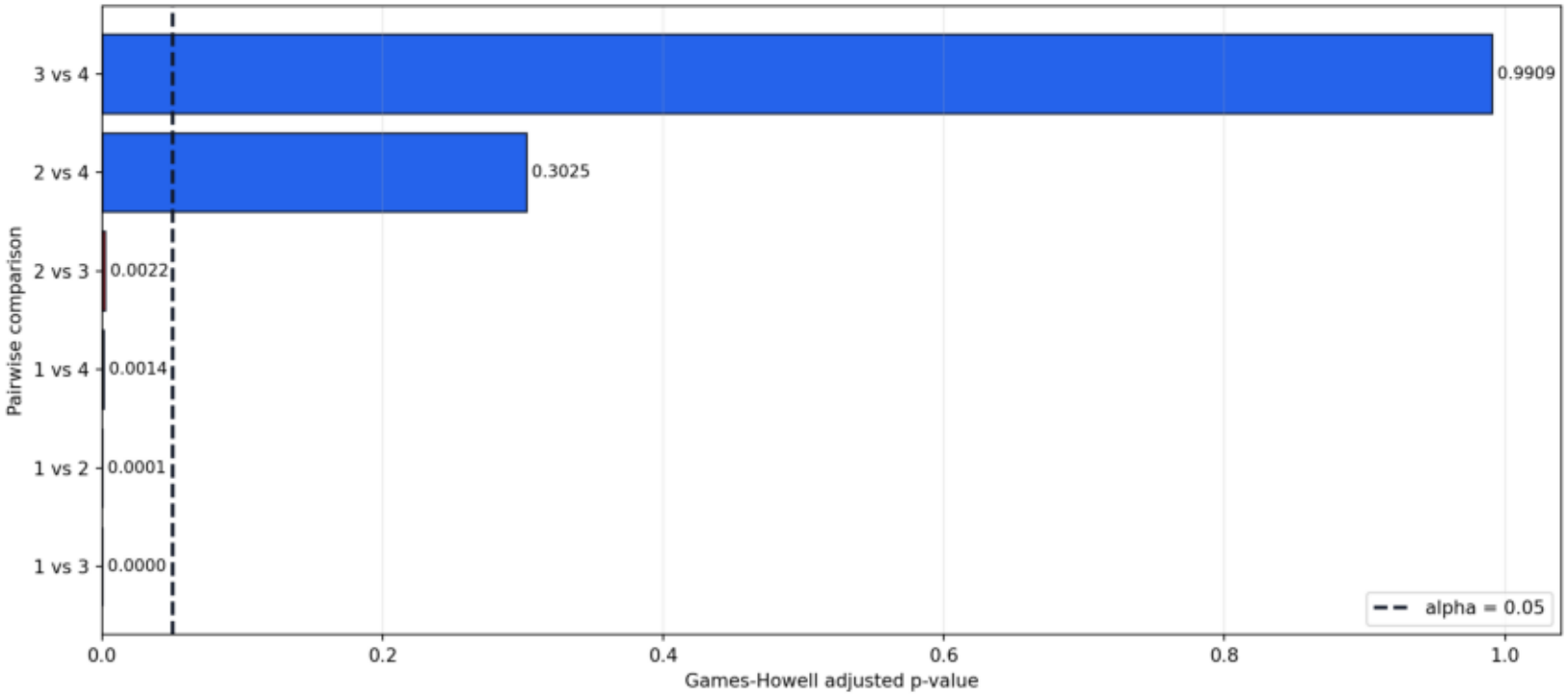
Games-Howell Test: Unequal Variance Context

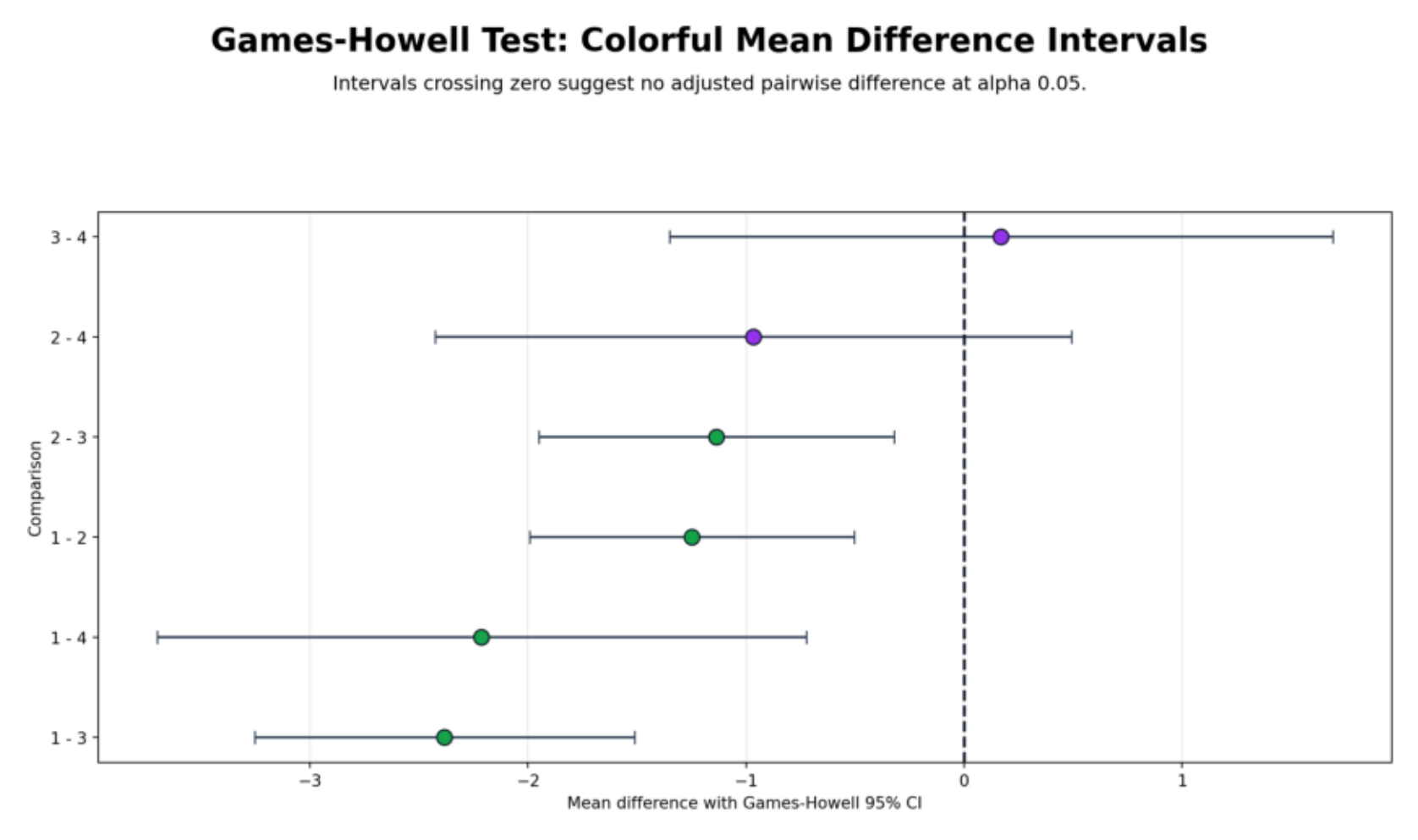
Games-Howell is commonly selected when equal-variance assumptions are doubtful.



Games-Howell Test: Colorful Adjusted p-value Ranking

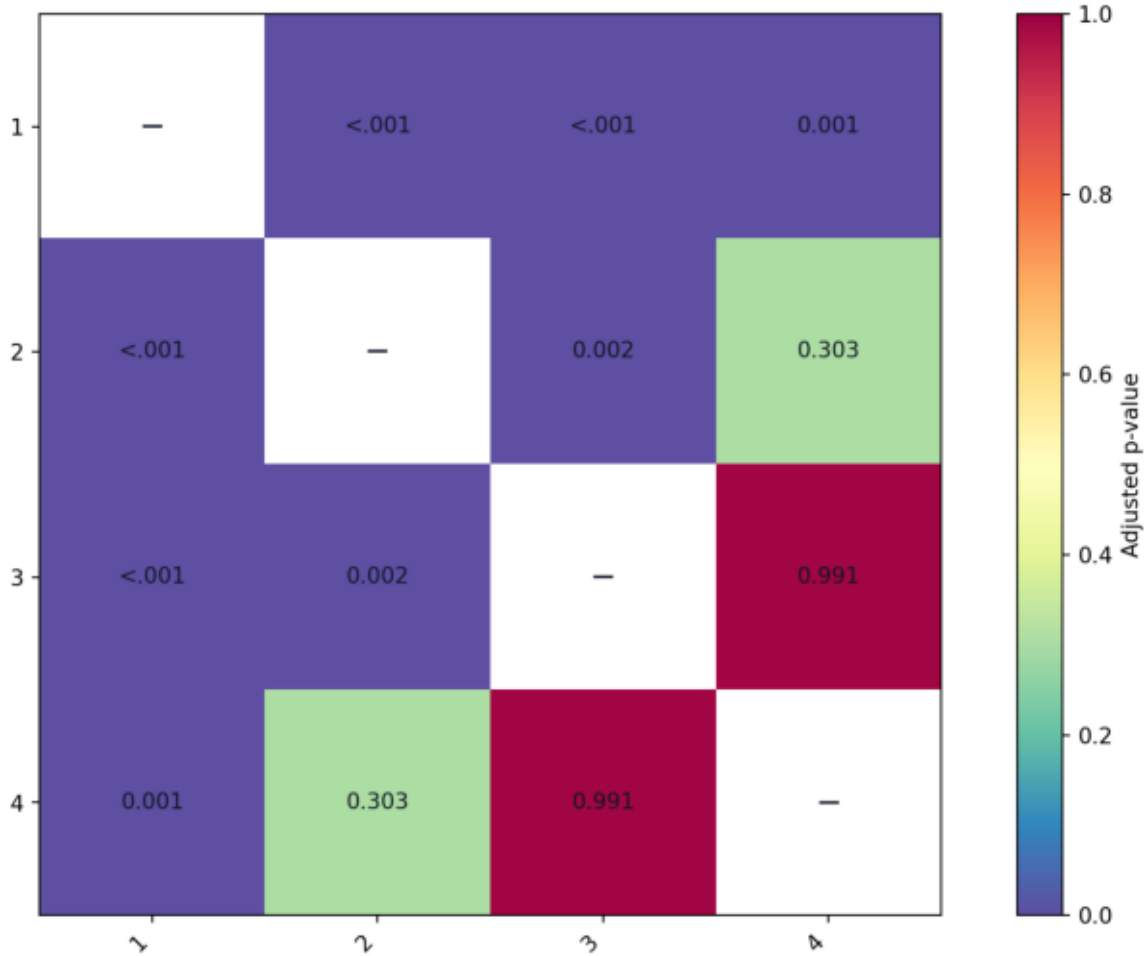
Red bars indicate pairwise differences below the 0.05 decision threshold.




Games-Howell Test: Colorful Mean Difference Intervals
Intervals crossing zero suggest no adjusted pairwise difference at alpha 0.05.
3 - 4
2 - 4
2 - 3
1 - 2
1 - 4
1 - 3
Comparison
−3
−2
−1
0
1
Mean difference with Games-Howell 95% CI

Games-Howell Test: Colorful Pairwise p-value Heatmap

Lower p-values mark stronger evidence of a post-hoc group difference.



Games-Howell Test: Colorful Group Size and SD Context

This test is useful when sample sizes and variances are not comfortably equal.