

Tukey-Kramer Post Hoc Analysis

Workflow:

1. Run one-way ANOVA using pooled within-group error variance.
2. Compare all group pairs using Tukey-Kramer unequal-n standard errors.
3. Use one family-wide Studentized Range critical value and adjusted p-values.
4. Interpret simultaneous CIs and homogeneous subset letters.

Interpretation summary:

method	use_case	anova_p_value	pooled_mse	q_critical	significant_pairs	total_pairs	smallest_group_n	largest_group_n	largest_to_smallest_n_ratio	levene_brown_forsythe_p_value	main_warning
Tukey-Kramer post hoc test	Equal-variance pairwise mean comparison after one-way ANOVA, especially when group sample sizes are unequal.	5.705728e-10	9.764634	3.642648	4	6	35	305	8.714286	0.380358	If variance heterogeneity is serious, consider Games-Howell or Tamhane's T2 instead of Tukey-Kramer.

ANOVA result:

target_variable	group_variable	number_of_groups	total_n	grand_mean	ss_between	df_between	ms_between	ss_within_error	df_within_error	ms_within_error_pooled_mse	f_statistic	p_value	eta_squared	omega_squared	alpha	anova_decision_alpha_0_05
G3	studytime	4	649	11.906009	465.077825	3	155.025942	6298.188739	645	9.764634	15.876268	5.705728e-10	0.068765	0.064341	0.05	Reject equal means

Levene / Brown-Forsythe context:

context_test	statistic	p_value	interpretation
Median-centered Levene / Brown-Forsythe equal-variance context	1.026312	0.380358	Tukey-Kramer uses pooled ANOVA error variance; check this context before relying on equal-variance post hoc results.

Group summary

group	n	mean	standard_deviation	standard_error	variance	minimum	maximum	ci95_low	ci95_high
1	212	10.844340	3.218624	0.221056	10.359541	0.0	18.0	10.411070	11.277609
2	305	12.091803	3.243125	0.185701	10.517860	0.0	19.0	11.727830	12.455777
3	97	13.226804	2.502104	0.254050	6.260524	8.0	18.0	12.728866	13.724742
4	35	13.057143	3.038410	0.513585	9.231933	6.0	19.0	12.050516	14.063769

Tukey-Kramer pairwise comparisons

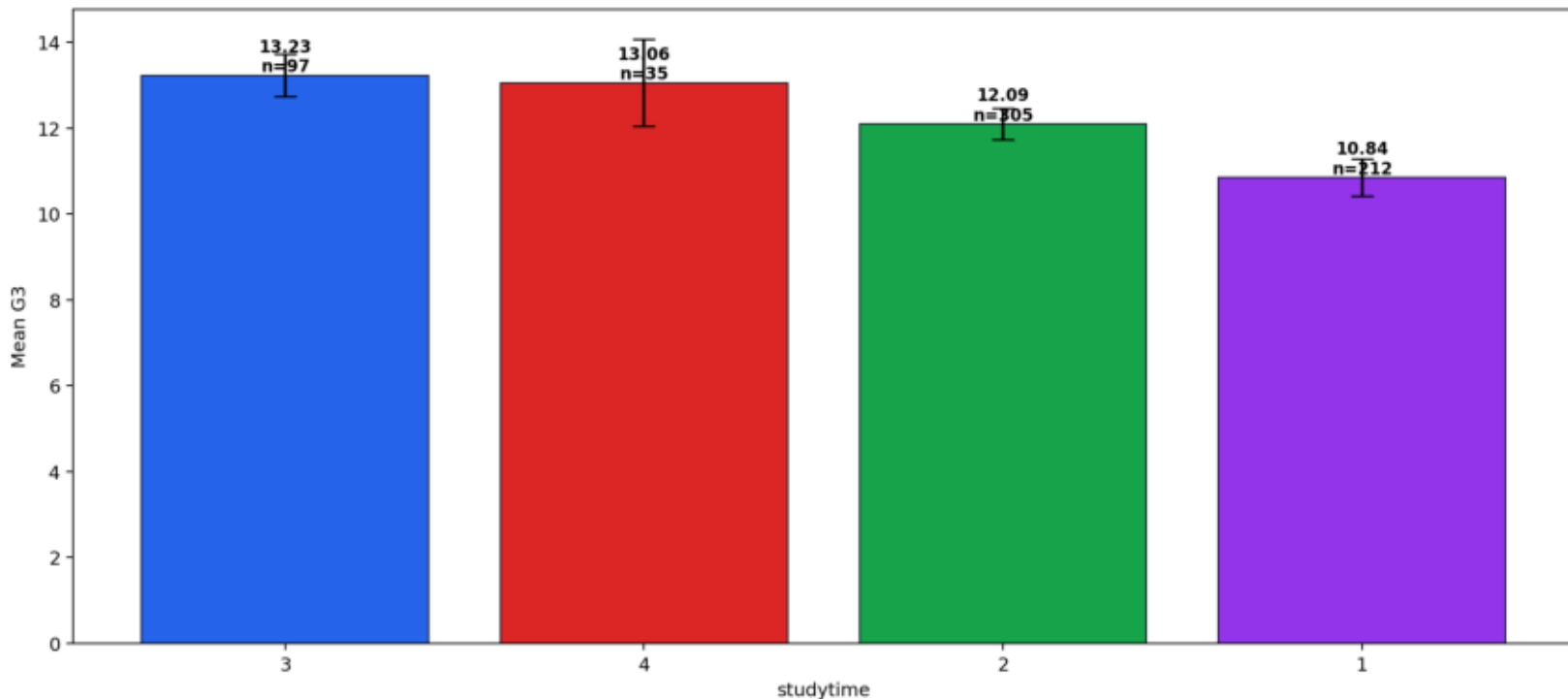
comparison_order	group_1_lower_mean	group_2_higher_mean	group_1_mean	group_2_mean	n_group_1	n_group_2	mean_difference_high_minus_low	pooled_mse	tukey_kramer_standard_error	q_statistic	df_error	k_groups_family_size	q_critical_familywise	tukey_kramer_adjusted_p_value	simultaneous_ci_low	simultaneous_ci_high	decision_alpha_0_05	method_note
1	10.844340	12.091803	10.844340	12.091803	212	305	1.247464	9.764634	0.197579	6.313752	645	4	3.642648	5.590361e-05	0.527754	1.967174	Significant True	Tukey-Kramer: pooled ANOVA MSE, unequal-n SE, one family-wide Studentized Range critical value.
2	10.844340	13.057143	10.844340	13.057143	212	35	2.212803	9.764634	0.403143	5.488874	645	4	3.642648	6.612043e-04	0.744294	3.681312	Significant True	Tukey-Kramer: pooled ANOVA MSE, unequal-n SE, one family-wide Studentized Range critical value.
3	10.844340	13.226804	10.844340	13.226804	212	97	2.382465	9.764634	0.270856	8.796057	645	4	3.642648	5.367514e-09	1.395832	3.369097	Significant True	Tukey-Kramer: pooled ANOVA MSE, unequal-n SE, one family-wide Studentized Range critical value.
4	12.091803	13.057143	12.091803	13.057143	305	35	0.965340	9.764634	0.394338	2.448001	645	4	3.642648	3.083885e-01	-0.471094	2.401774	Not significant True	Tukey-Kramer: pooled ANOVA MSE, unequal-n SE, one family-wide Studentized Range critical value.
5	12.091803	13.226804	12.091803	13.226804	305	97	1.135001	9.764634	0.257567	4.406624	645	4	3.642648	1.031067e-02	0.196775	2.073227	Significant True	Tukey-Kramer: pooled ANOVA MSE, unequal-n SE, one family-wide Studentized Range critical value.
6	13.057143	13.226804	13.057143	13.226804	35	97	0.169661	9.764634	0.435692	0.389406	645	4	3.642648	9.927036e-01	-1.417413	1.756735	Not significant True	Tukey-Kramer: pooled ANOVA MSE, unequal-n SE, one family-wide Studentized Range critical value.

Homogeneous subset letters

group	mean	n	tukey_kramer_homogeneous_subset_letters	letter_rule
3	13.226804	97		A Groups sharing a letter are not significantly different by Tukey-Kramer at alpha=.05.
4	13.057143	35		A Groups sharing a letter are not significantly different by Tukey-Kramer at alpha=.05.
2	12.091803	305		B Groups sharing a letter are not significantly different by Tukey-Kramer at alpha=.05.
1	10.844340	212		C Groups sharing a letter are not significantly different by Tukey-Kramer at alpha=.05.

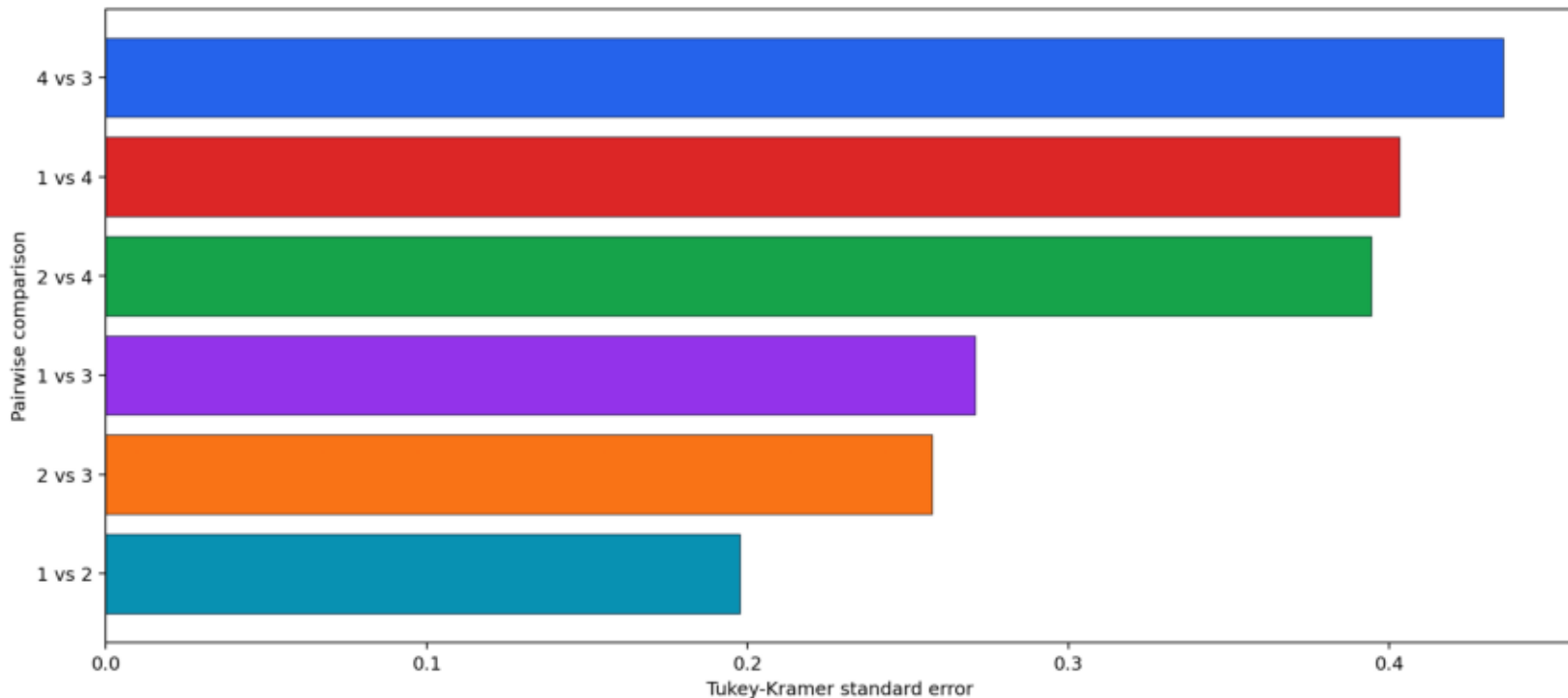
Tukey-Kramer: Group Means and Sample Sizes

Bars show group means with descriptive 95% CIs; labels show unequal-n context for Tukey-Kramer.



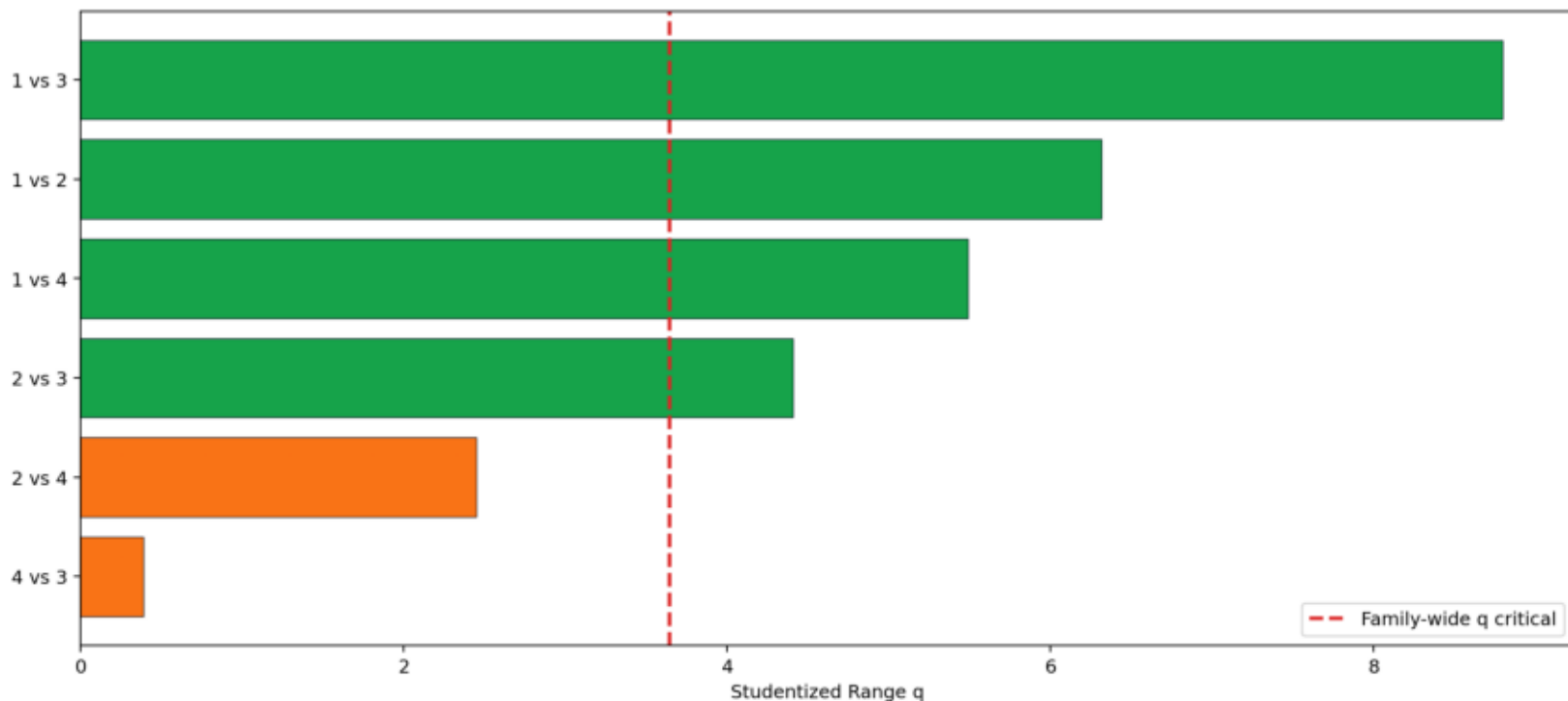
Tukey-Kramer Unequal-n Standard Errors

Unlike classic equal-n HSD, Tukey-Kramer changes the SE for each pair using both group sample sizes.



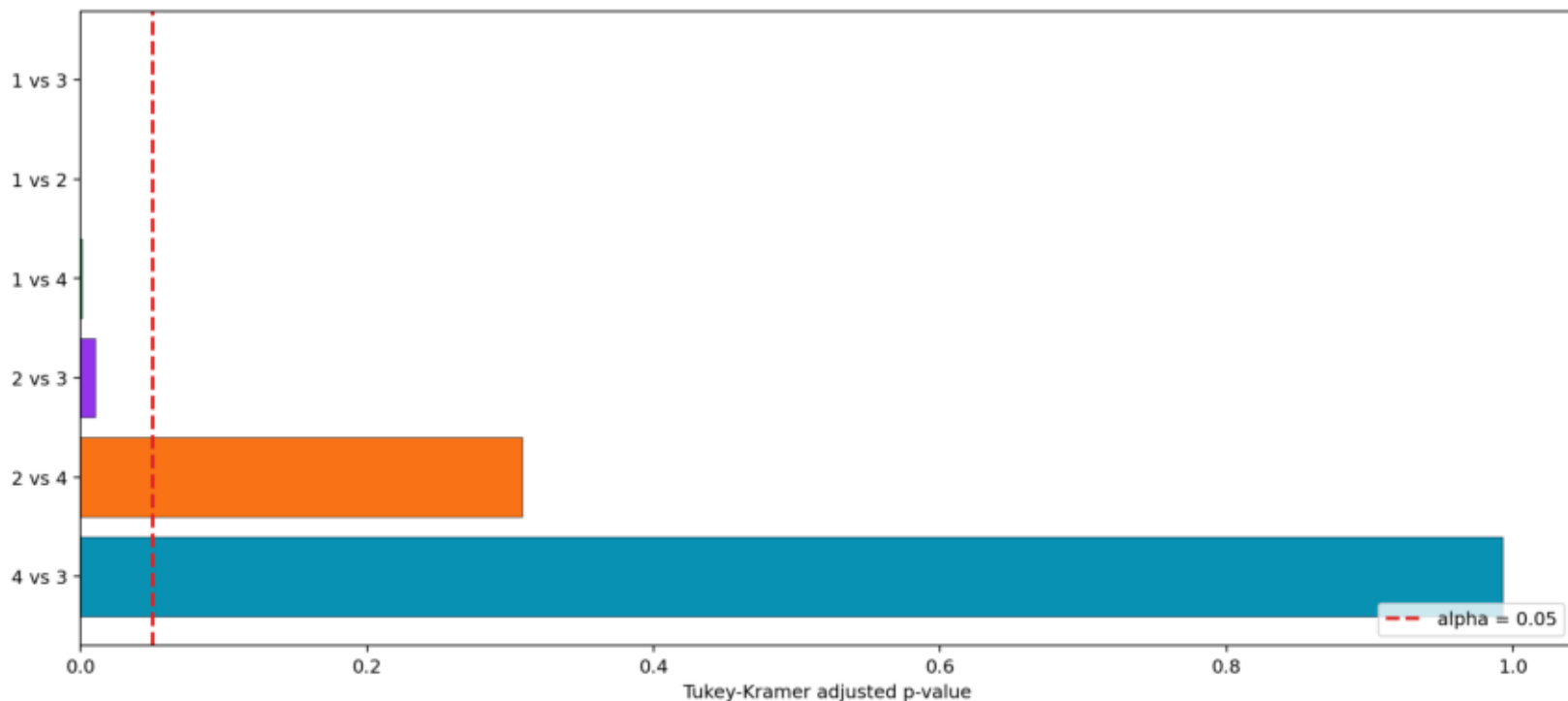
Tukey-Kramer q Statistics vs One Family-Wide Critical Value

A pair is significant when its observed q exceeds the fixed Tukey-Kramer family critical value.



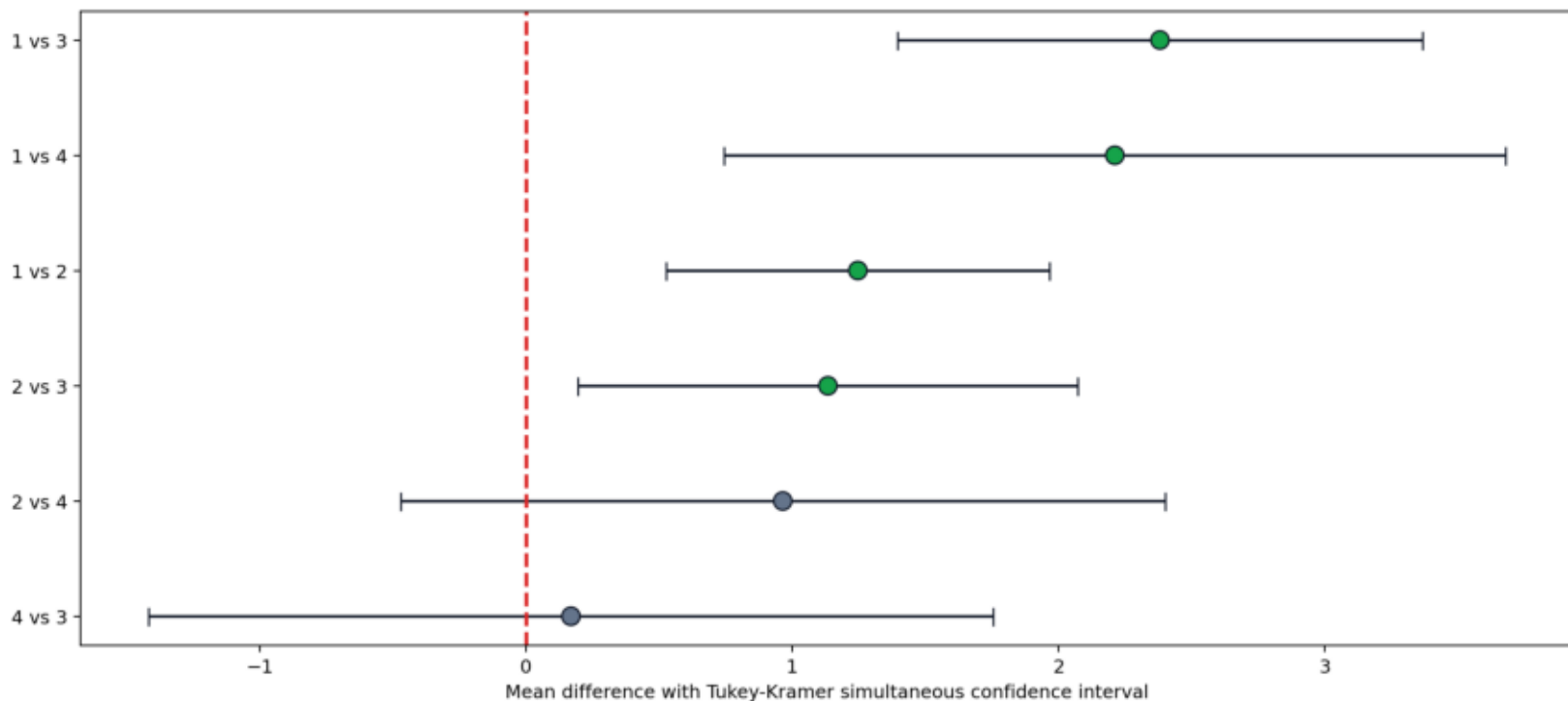
Tukey-Kramer Adjusted p-value Ranking

Adjusted p-values control the family-wise error rate across all pairwise comparisons.



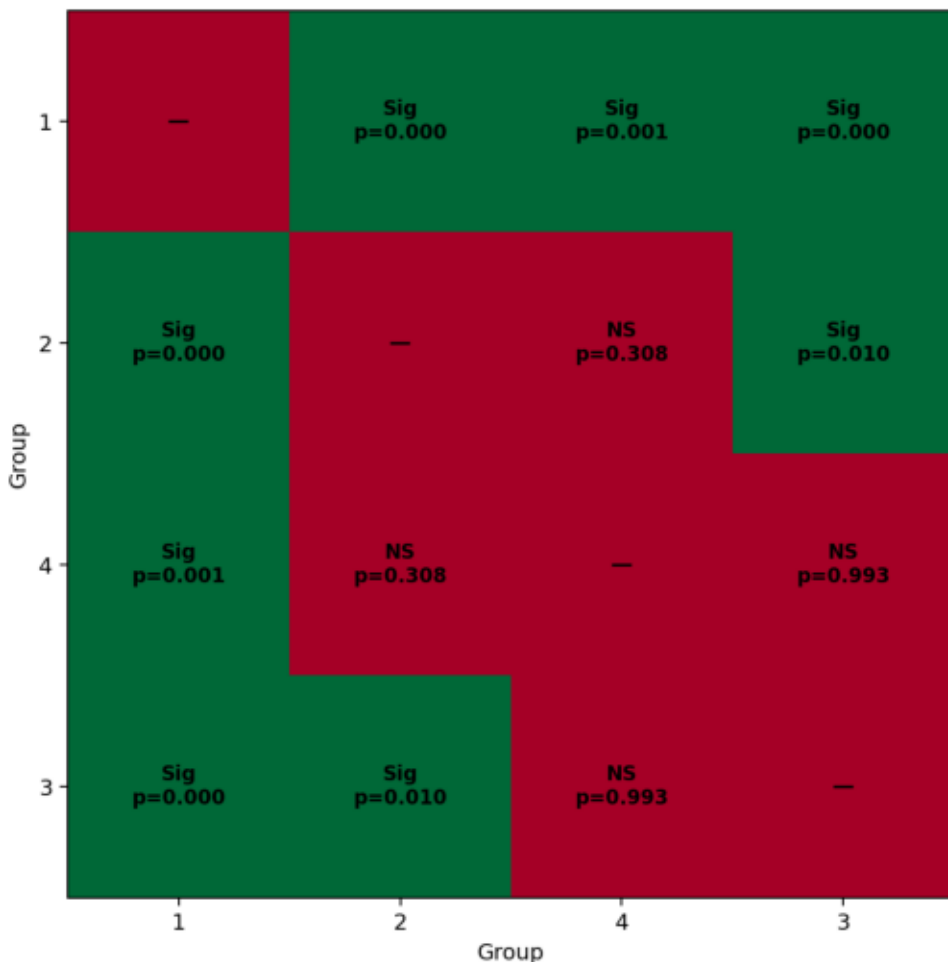
Tukey-Kramer Simultaneous Confidence Intervals

Intervals that do not cross zero indicate significant pairwise mean differences.



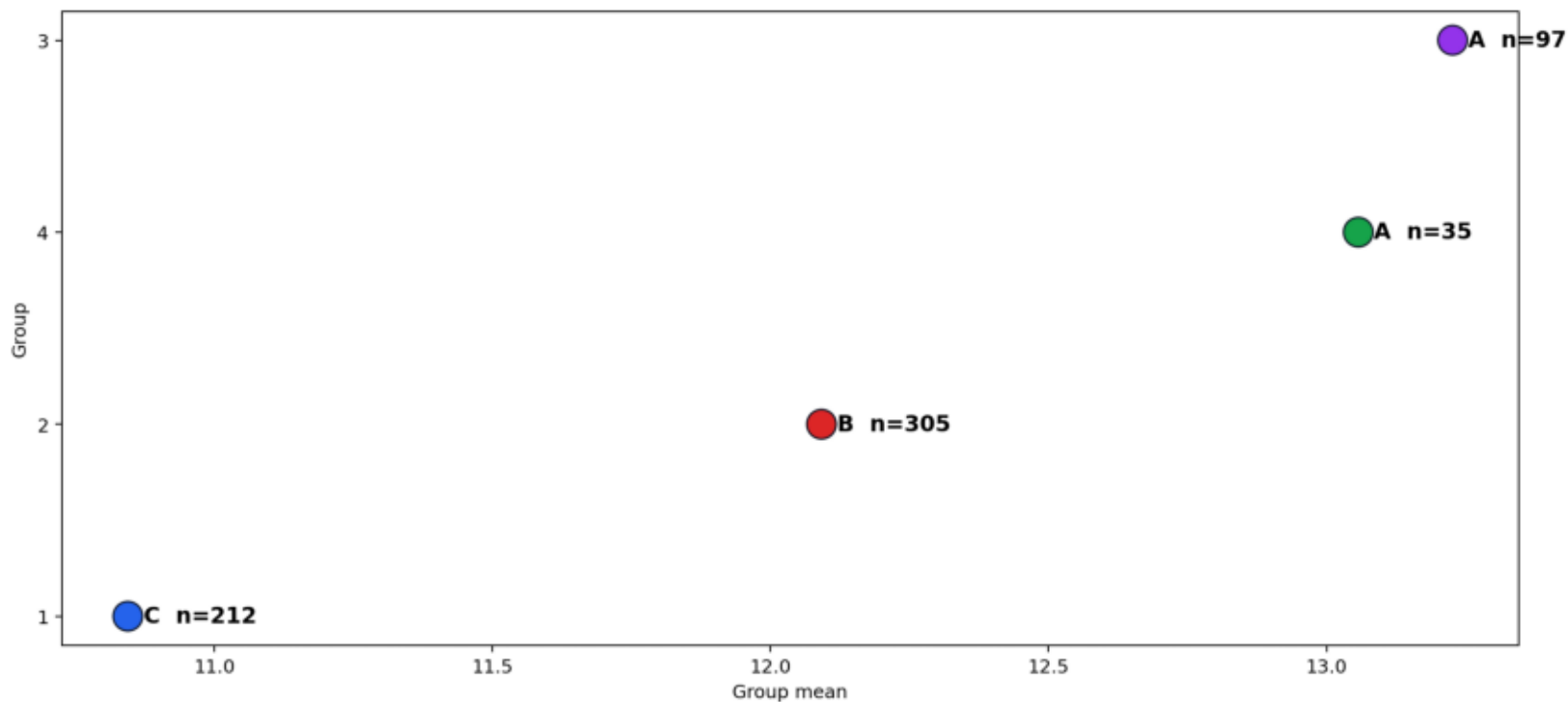
Tukey-Kramer Pairwise Decision Matrix

Matrix marks significant and non-significant pairwise decisions after family-wise adjustment.



Tukey-Kramer Homogeneous Subset Letters

Groups sharing a letter are not significantly different at the family-wise alpha level.



Tukey-Kramer Method Report Card

Summary of omnibus evidence, family critical value, significant pairs, sample-size imbalance, and pooled variance.

