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Neutrosophic Statistical Approach to Multiple Comparison Analysis

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Abstract

Objective: This study investigates the implementations of neutrosophic statistics in multiple comparison tests in situations with uncertain data, which commonly arise in real-world settings. **Methods**: This study proposed four post-hoc tests viz. Tukey-Kramer $(TKKR_N)$, Dunnet (DNT_N), Tamhane's $(T2_N)$, and Dunn (D_N) tests in undetermined situations with simulation work. The empirical levels and power calculations through simulation studies are used in a one-way design framework at a 5% significance level. **Findings**: The study reveals that Tamhane's $(T2_N)$ and Dunn (D_N) test satisfied the empirical level and performed well, including indeterminacy $I_N \in [0, .05]$ in neutrosophic multiple comparison analysis for the above four tests. Thus, an attempt is made to apply neutrosophic statistics to the suggested multiple comparison tests in a health-related application. **Novelty:** We have introduced neutrosophic statistics with simulation work for the above post hoc tests for small to medium sample sizes in uncertain situations.

Keywords: Multiple comparisons; Neutrosophic Statistics; Tukey-Kramer; Dunnet; Tamhane's (T2); Dunn tests

1 Introduction

Fundamental statistical analysis heavily relies on comparing multiple treatments or groups, which is crucial in decision-making across many scientific domains. Traditional tools like ANOVA and post-hoc tests might not be adequate in real-world scenarios with ambiguity and incomplete information. In this context of statistical analysis, multiple treatments/groups offer a structured framework for assessing pairwise comparisons between groups. Various techniques for evaluating and deciding statistically on null contrasts, or their smaller subset of multiple comparisons, have risen tremendously since the early 1950s. Tukey's HSD, Fisher's LSD, Bonferroni, Tukey-Kramer, Dunnet's, Newman-Keul, Sidak-Holm, etc., are some commonly employed post hoc tests available in the literature. In contrast, these existing classical methods are valid only for the determined datasets [(1)]. The problem involves uncertainty of the situation, which cannot give a comprehensive and reliable interpretation of an uncertain dataset [(2)].

By embracing uncertainty, this newly emerging area of Neutrosophic statistics allows for the inclusion of indeterminacy. It permits ambiguous and partial information, ensuring a more flexible handling of uncertain data in experiments. Existing probabilistic models are more effective for problems on random uncertainties because

they need much more information than the fuzzy set theories[3]. The main advantage of neutrosophic statistics is the ability to independently control the components of truth, falsehood, and indeterminacy. In contrast, fuzzy set theories deal only with the concept of membership and absence in the variables[4],[5]. Scholars are still attempting to implement this new concept in all statistical branches, including the design of experiments, nonparametric statistics, etc. Recent research highlights the application of neutrosophic statistics in solving practical issues related to health and sports industries[6]. The neutrosophic concept in experimental design was introduced through neutrosophic analysis of variance (NANOVA) for uncertain and indeterminant observations by Muhammad Aslam in 2019[7],[8]. AlAita, A. et al. implement this new approach in split-plot experimental design[9]. A few kinds of literature are available on the practical application of neutrosophic multiple comparisons only. Mohammed Albassam (2020) applied multiple comparisons in NS using actual data gathered from university students. They applied NS for the tests LSD, Scheffe, and Bonferroni in the multiple comparison study[10],[11]. Further, Kakati et al. (2024) introduced the simulation work for the post hoc tests viz. Fisher's LSD, Tukey's HSD, Scheffe, Bonferroni, and Hochberg under neutrosophic statistics to check the performance of the empirical level and power[12]. This study extended for applying neutrosophic statistics to some post hoc tests Tukey-Kramer, Tamhane's T2, and Dunnet's based on the parametric approach and Dunn's test based on the rank sum nonparametric test. A practical application is included in the study for an uncertain situation to understand the overall performance of the tests. We will also check the performance of the tests with the help of a real dataset.

2 Test Procedures

For pairwise mean comparison in a one-way design, the mathematical model is taken as

$$Y_{(ij)N} = \mu_{jN} + \epsilon_{(ij)N} : (\mathrm{i} = 1, 2, \ldots, \mathrm{n}, \mathrm{j} = 1, 2, \ldots, \mathrm{J}) : \mathrm{N} \in [\mathrm{L}, \mathrm{U}] \tag{1}$$

Where $Y_{(ij)N}$ is the j[th] neutrosophic sample observation from the i[th] neutrosophic population and $\epsilon_{(ij)N}$ is the neutrosophic iid random error effect. Here, the neutrosophic population mean and standard deviation can be written as

$$\mu_N \in \left[\frac{\sum_{i=1}^{N_L} Y_L}{N_L}, \frac{\sum_{i=1}^{N_U} Y_U}{N_U} \right]; \mu_N \in [\mu_L, \mu_U] \text{ and} \tag{2}$$

$$\sigma_N \in \left[\sqrt{\frac{\sum_{i=1}^{N_L} (Y_L - \mu_L)}{N_L - 1}}, \sqrt{\frac{\sum_{i=1}^{N_U} (Y_L - \mu_U)}{N_U - 1}} \right], \sigma_N \in [\sigma_L, \sigma_U] \tag{3}$$

2.1 Neutrosophic Dunnett's $(\mathbf{DNT_N})$ Test

Dunnett (1955) suggested a multiple comparison test statistic for comparing means from experimental treatment groups against a control group. Now, the neutrosophic form of the test statistic is

$$DNT_N = \frac{\overline{y}_{iN} - \overline{y}_{1N}}{\left[\frac{S_{iN}^2}{n_{iN}} + \frac{S_{1N}^2}{n_{1N}} \right]^{1/2}}; 1 \neq i; \overline{y}_{iN} - \overline{y}_{1N} \in [\overline{y}_{iL} - \overline{y}_{1L}, \overline{y}_{iU} - \overline{y}_{1U}] \tag{4}$$

Here, '1' represents the control group. Dunnett's critical value for comparing mean difference = $\mathrm{t}_{Dunnett} \sqrt{\frac{2MS_w}{n}}$. $\mathrm{t}_{dunnett}$ can be calculated from Dunnett's table. Therefore, the neutrosophic form of DNT_N where E_N and FI_N are determinant and indeterminant parts is defined as

$$DNT_N = E_N + FI_N; I_N \in [I_L, I_U] \tag{5}$$

The test reduces to the classical Dunnett's test if $I_N = 0$.

2.2 Neutrosophic Tukey-Kramer test

The neutrosophic Tukey-Kramer test ($TKKR_N$) extends by the Kramer (1956) for unequal sample sizes of Tukey's (1953) test. The neutrosophic Tukey-Kramer test is

$$TKKR_N = \frac{\overline{y}_{iN} - \overline{y}_{jN}}{S_N[\frac{1}{n_{iN}} - \frac{1}{n_{jN}}]^{1/2}}; \overline{y}_{iN} - \overline{y}_{jN} \in [\overline{y}_{iL} - \overline{y}_{jL}, \overline{y}_{iU} - \overline{y}_{jU}] \tag{6}$$

Where $TKKR_N \in [TKKR_L, TKKR_U]$. The $100(1-\alpha)\%$ neutrosophic CI for $\hat{\mu}_{iN} - \hat{\mu}_{jN}$ as

$$\overline{y}_{iN} - \overline{y}_{jN} \pm SR_{\alpha,k,v} S_N \left[\frac{1}{n_{iN}} - \frac{1}{n_{jN}}\right]^{1/2} \tag{7}$$

The neutrosophic form of the test is defined as

$$TKKR_N = G_N + \mathrm{H}I_N; I_N \in [I_L, I_U] \tag{8}$$

Where G_N and $\mathrm{H}I_N$ are determinant and indeterminant parts of the neutrosophic Tukey-Kramer test. The test reduces to the classical Tukey-Kramer test if $I_N = 0$.

2.3 Neutrosophic Tamhane (T2) method

Tamhane's (1979) two pairwise multiple comparison procedures for unequal variance can be defined as

$$T2_N = \frac{[\overline{y}_{iN} - \overline{y}_{jN}]}{[\frac{{S_{iN}}^2}{n_{iN}} + \frac{{S_{jN}}^2}{n_{jN}}]^{1/2}}; \overline{y}_{iN} - \overline{y}_{jN} \in [\overline{y}_{iL} - \overline{y}_{jL},\ \overline{y}_{iU} - \overline{y}_{jU}] \tag{9}$$

If $T2_N \geq t_{\alpha^* v}$ then $T2_N$ will be rejected, where $t_{\alpha^* v}$ is two sided $\alpha^*[\alpha^* = (1 - \frac{1-\alpha}{k^*})$, where $k^* = \frac{k(k-1)}{2}]$ point of k normal variate for Student's t-distribution with v df. In the neutrosophic form of the Tamhane test $T2_N$, R_N and $\mathrm{S}I_N$ are determinant and indeterminant parts. The test is defined as

$$TK_N = G_N + \mathrm{H}I_N; I_N \in [I_L,\ I_U] \tag{10}$$

The test reduces to the classical Tukey-Kramer test if $I_N = 0$.

2.4 Neutrosophic Dunn ($\mathbf{D_N}$) Test

Dunn (1964) introduced a rank-based distribution-free test statistic for multiple comparisons. Now, the proposed neutrosophic Dunn test can be expressed as

$$D_N = \frac{\overline{R}_{iN} - \overline{R}_{jN}}{[{S_N}^2(\frac{1}{n_{iN}} + \frac{1}{n_{jN}})]^{1/2}}; \overline{R}_{iN} - \overline{R}_{jN} \in (\overline{R}_{iL} - \overline{R}_{jL}, \overline{R}_{iU} - \overline{R}_{jU}) \tag{11}$$

where, ${S_N}^2 = \frac{N(N+1)}{12}\left(\frac{1}{n_{iN}} + \frac{1}{n_{jN}}\right)$

For tied rank, ${S_N}^2 = \frac{N(N+1)}{12} - \frac{\sum_i^g t_i}{12(N-1)}\left(\frac{1}{n_{iN}} + \frac{1}{n_{jN}}\right)$; where g = tied group.

Now, the neutrosophic form of the Dunn test with determinant part M is

$$D_N = X + YI_N; I_N \in [I_L,\ I_U] \tag{12}$$

For indeterminant part I_N is zero then D_N comes down to the original classical test only.

3 Simulation Results

A simulation study was conducted to compare the empirical level and power of the tests and also to determine the significance of the experimental design. For T = 4 treatments in this study, 10,000 normal random samples are generated at a significance level of 5%. For the simulation work, the indeterminacy $I_N \in [0, .05]$ is taken. The empirical level of the test statistic under the null hypothesis and the power for the alternative hypothesis is determined by dividing the frequency of the null hypothesis rejected by the number of replications produced. The simulation work summary is listed below for equal and unequal variances, sample sizes, and location parameters. The equal and unequal number of sample size groups are considered as (5, 5, 5, 5) and (10, 10, 10, 10), (6, 8, 10, 6), (5, 7, 6, 5), (5, 10, 10, 5) and (5, 10, 15, 20). The location parameters (0, .5, 0, 0), (.5, 0, 1, 0), (0, .7, 1, 0), (.5, .7, 1, .6) and (.1, .3, .5, .7) and the scale parameters (1, 1, 1, 1), (.5, 1, 2, 2), (1, 2, 2, 1), (.5, 1.5, 3, 2) and (1, 3, 4, 6) for the study. The closeness to the nominal level in the indeterminacy interval of the lower and upper intervals helps to assume possible appropriate sample observations. The simulation results of empirical levels and powers of the tests for equal and unequal sample sizes and variances are summarised in Tables 1, and 2 below, respectively.

Table 1. Empirical Levels of some selected multiple comparison tests for neutrosophic statistics under equal and unequal sample sizes and variances at 0.05 level

Sample sizes n_i	Value of SD (σ_i)	DNT_N	$TKKR_N$	$T2_N$	D_N
	1 1 1 1	[.0570, .0569]	[.0608, .0443]	[.0457, .0383]	[.0458, .0435]
	.5 1 2 2	[.0991, .0969]	[.0526, .0475]	[.0585, .0500]	[.0548, .0500]
5 5 5 5	1 2 2 1	[.0852, .0833]	[.0712, .0602]	[.0551, .0516]	[.0487, .0472]
	.5 1.5 3 2	[.1076, .1135]	[.0581, .0516]	[.0611, .0550]	[.0517, .0467]
	1 3 4 6	[.1112, .1105]	[.0347, .0350]	[.0628, .0600]	[.0568, .0517]
	1 1 1 1	[.0852, .0833]	[.0602, .0441]	[.0551, .0516]	[.0487, .0472]
	.5 1 2 2	[.0562, .0565]	[.0669, .0585]	[.0522, .0497]	[.0498, .0463]
6 8 10 6	1 2 2 1	[.0427, .0415]	[.0836, .0700]	[.0536, .0527]	[.0402, .0363]
	.5 1.5 3 2	[.0973, .0957]	[.0800, .0709]	[.0596, .0556]	[.0490, .0472]
	1 3 4 6	[.1736, .1706]	[.0723, .0704]	[.0585, .0572]	[.0600, .0580]
	1 1 1 1	[.0657, .0656]	[.0558, .0431]	[.0590, .0563]	[.0567, .0505]
	.5 1 2 2	[.1484, .1483]	[.0784, .0675]	[.0624, .0615]	[.0537, .0475]
5 10 10 5	1 2 2 1	[.0404, .0425]	[.0973, .0853]	[.0503, .0492]	[.0352, .0333]
	.5 1.5 3 2	[.0658, .0672]	[.1022, .0936]	[.0512, .0484]	[.0452, .0400]
	1 3 4 6	[.1638, .1612]	[.1283, .1243]	[.0652, .0646]	[.0522, .0475]
	1 1 1 1	[.0878, .0872]	[.0629, .0511]	[.0656, .0636]	[.0432, .0402]
	.5 1 2 2	[.0901, .0839]	[.0286, .0237]	[.0647, .0627]	[.0657, .0603]
5 10 15 20	1 2 2 1	[.0382, .0353]	[.0431, .0410]	[.0615, .0625]	[.0542, .0522]
	.5 1.5 3 2	[.1021, .0923]	[.0382, .0336]	[.0669, .0667]	[.0595, .0540]
	1 3 4 6	[.1048, .1044]	[.0497, .0477]	[.0620, .0624]	[.0542, .0483]
	1 1 1 1	[.0445, .0425]	[.0580, .0432]	[.0663, .0571]	[.0285, .0283]
	.5 1 2 2	[.0750, .0766]	[.0581, .0481]	[.0630, .0580]	[.0335, .0303]
10 10 10 10	1 2 2 1	[.0699, .0692]	[.0623, .0487]	[.0510, .0501]	[.0572, .0497]
	.5 1.5 3 2	[.0115, .0114]	[.0559, .0487]	[.0588, .0582]	[.0285, .0250]
	1 3 4 6	[.1382, .1353]	[.0375, .0356]	[.0615, .0625]	[.0542, .0522]
	1 1 1 1	[.0332, .0342]	[.0660, .0391]	[.0493, .0507]	[.0467, .0415]
	.5 1 2 2	[.0490, .0507]	[.0717, .0503]	[.0516, .0571]	[.0495, .0467]
14 18 16 20	1 2 2 1	[.0594, .0587]	[.0824, .0563]	[.0523, .0511]	[.0492, .0460]
	.5 1.5 3 2	[.0763, .0779]	[.0872, .0822]	[.0520, .0564]	[.0500, .0473]
	1 3 4 6	[.1444, .1441]	[.0658, .0574]	[.0513, .0519]	[.0483, .0462]

Table 2. Empirical power of the multiple comparison tests for neutrosophic statistics under equal and unequal sample sizes, variances, and means at 0.05 level

Sample sizes n_i	Value of SD (σ_i)	Value of means (μ_i)	DNT_N	$TKKR_N$	$T2_N$	D_N
5 5 5 5	1 1 1 1	0 0 .5 0	[.1203, .1127]	[.0625, .0434]	[.0638, .0885]	[.0712, .0725]
		0 0 1 0	[.3943, .3488]	[.0633, .0390]	[.1798, .2529]	[.1473, .1478]
		0 .5 1 0	[.3459, .3074]	[.0589, .0356]	[.1571, .2242]	[.1395, .1395]
		.1 .3 .5 .8	[.1579, .1404]	[.0465, .0269]	[.0676, .1080]	[.2325, .2328]
5 5 5 5	.5 1 2 2	0 0 .5 0	[.1366, .1298]	[.0538, .0469]	[.0651, .0804]	[.0642, .0648]
		0 0 1 0	[.2528, .2343]	[.0555, .0443]	[.1124, .1354]	[.0952, .0957]
		0 .5 1 0	[.2273, .2113]	[.0533, .0393]	[.1034, .1438]	[.0915, .0915]
		.1 .3 .5 .8	[.1457, .1325]	[.0454, .0368]	[.0684, .0911]	[.1327, .1327]
6 8 10 6	1 1 1 1	0 0 .5 0	[.1622, .1560]	[.1267, .0938]	[.1131, .1393]	[.0915, .0922]
		0 0 1 0	[.6600, .5935]	[.3811, .2702]	[.4798, .5626]	[.2268, .2278]
		0 .5 1 0	[.5542, .5018]	[.2821, .1846]	[.3596, .4357]	[.1988, .1988]
		.1 .3 .5 .8	[.1940, .1784]	[.0680, .0446]	[.1094, .1524]	[.1007, .1008]
5 10 15 20	.5 1.5 3 2	0 0 .5 0	[.0499, .0483]	[.1157, .1426]	[.0893, .0890]	[.0438, .0450]
		0 0 1 0	[.1332, .1299]	[.1504, .1469]	[.1897, .2065]	[.0810, .0813]
		0 .5 1 0	[.1114, .1076]	[.2339, .2898]	[.1837, .2182]	[.0778, .0778]
		.1 .3 .5 .8	[.0347, .0340]	[.1427, .1721]	[.1300, .1748]	[.1385, .1387]
5 10 15 20	1 1 2 3	0 0 .5 0	[.0233, .0241]	[.1723, .1422]	[.0985, .1036]	[.0438, .0445]
		0 0 1 0	[.0797, .0805]	[.6258, .4410]	[.3019, .3179]	[.0960, .0963]
		0 .5 1 0	[.0780, .0780]	[.9491, .8260]	[.2322, .2499]	[.0777, .0777]
		.1 .3 .5 .8	[.0180, .0175]	[.4802, .4158]	[.1030, .1155]	[.0420, .0422]
14 12 8 6	1 1 1 1	0 0 .5 0	[.2810, .2549]	[.6317, .4501]	[.3185, .2896]	[.1633, .1615]
		0 0 1 0	[.5701, .4468]	[.4651, .4273]	[.5862, .4869]	[.3952, .3937]
		0 .5 1 0	[.2590, .1554]	[.4455, .3359]	[.3481, .2466]	[.3927, .3922]
		.1 .3 .5 .8	[.3642,.3324]	[.4651, .4273]	[.4682, .4272]	[.2053, .2050]
14 12 8 6	2 1 1 .5	0 0 .5 0	[.1437, .1346]	[.3251, .2998]	[.3292, .2439]	[.1825, .1822]
		0 0 1 0	[.5665, .5205]	[.3315, .1582]	[.4599, .2845]	[.4100, .4100]
		0 .5 1 0	[.4302, .3945]	[.4548, .4803]	[.5451, .4947]	[.4022, .4021]
		.1 .3 .5 .8	[.1376, .1205]	[.4270, .3680]	[.3707, .2598]	[.2048, .2038]

4 Discussion

This section includes the outcomes of the simulation work under neutrosophic statistics based on the four multiple comparison tests. In our study, indeterminacy interval $I_N \in [0,\ .05]$ are considered in generating an indeterminacy set of random observations. Neutrosophic empirical output in indeterminacy interval helps to assume the possible position of the sample observations. Table 1 depicts the empirical levels of the four tests. The tests $TKKR_N$ and DNT_N are somewhat either higher or lower than the nominal level in some cases, mainly for unequal variances. But D_N and TM_N tests continuously maintain the nominal level in both neutrosophic intervals. Table 2 provides the empirical power results for all four tests with equal and unequal sample sizes with unequal variances for four location parameter groups. The result depicts that the power of the $TKKR_N$ followed by DNT_N have large power values but are comparatively far from the nominal levels. Kakati et al. (2024) observed that the empirical level didn't fully satisfy the nominal level for the post hoc tests Fisher's LSD test, Tukey's HSD, Bonferroni (BT_N), Scheffe, and Hochberg (HB_N) under neutrosophic statistics. Moreover, empirical power values also display variability in the indeterminacy intervals[12]. On the other hand, levels of TM_N and D_N satisfied in almost all situations. Therefore, we can choose D_N or TM_N tests for neutrosophic multiple comparison analysis from the above tests. The simulation power output of small difference location parameters shows a small difference between indeterminacy intervals for almost all the tests. It implies the minimum uncertainties among sample groups.

Real Application:

In this study, we have used the same problem of neutrosophic multiple comparison analysis on Kakati et al. [12]. An illustration is used to evaluate multiple comparison tests of daily ICU occupancy of COVID-19 patients in Pakistan, focusing on age groups, from December 2020 [13].

Table 3. The Daily ICU occupancy of Corona patients in Pakistan in Dec 2020

Day/Age	55 and above	35-55	35 and below
1	[443, 450]	[359, 361]	[460, 465]
2	[421, 426]	[352, 365]	[427, 429]
3	[436, 450]	[445, 455]	[407, 410]
4	[376, 385]	[410, 410]	[378, 380]
5	[458, 458]	[458, 464]	[364, 368]
6	[408, 420]	[410, 415]	[345, 349]
7	[422, 425]	[463, 470]	[342, 346]
8	[431, 440]	[580, 584]	[345, 345]
9	[459, 462]	[432, 440]	[313, 318]
10	[369, 369]	[379, 379]	[277, 280]
11	[360, 360]	[370, 370]	[268, 271]
12	[431, 445]	[584, 589]	[259, 262]
13	[403, 415]	[410, 416]	[256, 260]
14	[436, 445]	[587, 590]	[251, 251]
15	[376, 376]	[415, 415]	[249, 249]
16	[370, 370]	[419, 422]	[223, 227]
17	[443, 443]	[357, 357]	[209, 211]
18	[445, 445]	[467, 472]	[187, 191]
19	[355, 365]	[415, 418]	[173, 175]
20	[450, 450]	[358, 358]	[168, 168]

Source: Sherwani, R. A. et al. (2021)

The null hypothesis of the application states no significant difference in COVID-19 patients' daily ICU occupancy based on their age groups. Table 4 provides the neutrosophic ANOVA results of the COVID-19 data.

Table 4. The NANOVA table for the COVID-19 data

Source	n df	NSS	NMSS	F_N	P_N-value
Between samples	[2, 2]	[225452.1, 233571.03]	[112726.05, 116785.515]	[24.14, 24.53]	[<.001, <.001]
Within samples	[57, 57]	[266210.75, 271423.95]	[271423.95, 4761.8237]		
Totals	[59, 59]	[491662.85, 504994.98]			

For the application that displays NANOVA provides P_N-value [<.001, <.001] shows at least one significant pair between neutrosophic means in an indeterminacy interval. We calculate the mean difference for the first three tests and the rank difference for the Dunn test. Table 5 shows the pairwise comparison analysis of the neutrosophic population pair group [1, 1] with [3, 3] and [2, 2], with [3, 3] at the $\alpha = .05$ level of significance for the four tests shows extremely small power values (<.001) indicating a strong statistical significance. At the same time, treatment pairs [1, 1] with [2, 2] showed no statistically significant difference between the groups. We noticed parametric tests display comparatively wider variability, whereas nonparametric Dunn test results remain centered around moderate effects. The result implies that the daily ICU occupancy is not the same for the age groups 55 years and above as for the age groups 35 and below. Also, the daily ICU occupancy is not the same for the age groups 35-55 as it is for the age groups 35 and below. Similarly, the pair between [1, 1] and [2, 2] shows that calculated significance values are more significant than $\alpha = .05$ for all tests. That implies the average daily ICU occupancy is the same for the age groups 55 years and above, with the age group 35-55.

Table 5. Multiple comparisons for Daily ICU occupancy of Corona patients

Tests	Group (i)	Groups (j)	N. Mean diff (i-j)	Neutrosophic SE.	Sig. values	95% Neutrosophic CI for Mean	
						Lower Interval	Upper Interval
Tukey-Kramer	[1, 1]	[2,2]	[-18.90, -16.30]	[21.61, 21.82]	[.674, .887]	[-92.44, 54.64]	[-90.56, 57.96]
		[3, 3]	[119.55, 123.45]	[21.61, 21.82]	[.006, <.001]	[46.01, 193.09]	[49.19, 197.71]
	[2, 2]	[1, 1]	[18.90, 16.30]	[21.61, 21.82]	[.674, .887]	[-54.64, 92.44]	[-90.56, 90.56]
		[3, 3]	[138.45, 139.75]	[21.61, 21.82]	[.009, <.001]	[64.91, 211.99]	[65.49, 214.01]
	[3, 3]	[1, 1]	[-119.55, -123.45]	[21.61, 21.82]	[.006, <.001]	[-193.09, -46.01]	[-197.71, -49.19]
		[2, 2]	[-138.45, -139.75]	[21.61, 21.82]	[.009, <.001]	[-211.99, -64.91]	[-212.71, -65.49]
Dunnett	[1, 1]	[2,2]	[-18.90, -16.30]	[21.61, 21.82]	[.385, .458]	[-62.18, 24.38]	[-59.997, 27.397]
		[3, 3]	[119.55, 123.45]	[21.61, 21.82]	[<.001, <.001]	[76.28, 162.83]	[79.753, 167.147]
	[2, 2]	[1, 1]	[18.90, 16.300]	[21.61, 21.82]	[.385, .458]	[-24.38, 62.18]	[-27.397, 59.997]
		[3, 3]	[138.45, 139.75]	[21.61, 21.82]	[<.001, <.001]	[95.17, 181.72]	[96.053, 183.447]
	[3, 3]	[1, 1]	[-119.55, -123.45]	[21.61, 21.82]	[<.001, <.001]	[-162.83, -76.27]	[-167.15, -79.75]
		[2, 2]	[-138.45, -139.75]	[21.61, 21.82]	[<.001, <.001]	[-181.72, -95.17]	[-183.45, -96.05]
Tamhane	[1, 1]	[2,2]	[-18.90, -16.30]	[18.26, 18.51]	[.671, .769]	[-65.36, 27.56]	[-63.37, 30.77]
		[3, 3]	[119.55, 123.45]	[20.68, 20.89]	[<.001, <.001]	[66.65, 172.45]	[70.08, 176.82]
	[2, 2]	[1, 1]	[18.90, 16.30]	[18.26, 18.51]	[.671, .769]	[-27.56, 65.36]	[-30.77, 63.37]
		[3, 3]	[138.45, 139.75]	[25.30, 25.45]	[<.001, <.001]	[75.19, 201.70]	[76.03, .203.47]
	[3, 3]	[1, 1]	[-119.55, -123.45]	[20.68, 20.88]	[<.001, <.001]	[-172.45, -66.65]	[-176.82, -70.08]
		[2, 2]	[-138.45, -139.75]	[25.30, 25.49]	[<.001, <.001]	[-201.70, -75.19]	[-203.47, -76.03]
Dunn	[1, 1]	[2,2]	[.1250, -.9000]	[5.99, 5.59]	[.436, .492]	[-15.07, 13.27]	[-15.32, 13.52]
		[3, 3]	[23.50, 23.03]	[5.99, 5.59]	[<.001, <.001]	[8.86, 37.20]	[8.60, 37.45]
	[2, 2]	[1, 1]	[-.1250, .9000]	[5.99, 5.59]	[.436, .492]	[-13.27, 15.07]	[-13.52, 15.32]
		[3, 3]	[23.37, 23.93]	[5.99, 5.59]	[<.001, <.001]	[9.76, 38.10]	[9.50, 38.35]
	[3, 3]	[1, 1]	[-23.50, -23.03]	[5.99, 5.59]	[<.001, <.001]	[-37.20, -8.86]	[-37.45, -8.60]
		[2, 2]	[-23.37, -23.93]	[5.99, 5.59]	[<.001, <.001]	[-38.10, -9.76]	[-38.35, -9.50]

5 Conclusions

Selection of the appropriate test procedures helps access the available information in experimental situations. By applying neutrosophic statistics in multiple comparison analyses, more proper decisions can be made to acknowledge potentially uncertain information. So, it may help the researchers in such tests and imprecise data for appropriate conclusions. Results of the study show that neutrosophic Tamhane $(T2_N)$ and neutrosophic Dunn (D_N) test well performed in the overall study of neutrosophic multiple comparison analysis.

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- This article does not contain any studies involving animal studies.
- This article does not contain any studies by the authors with human participants.

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References

1) Smarandache F. Introduction to neutrosophic statistic. Infinite Study. 2014. https://doi.org/10.54216/IJNS.150203.
2) Patel S, Naik V, Patel P. An analysis of application of multiple comparison tests (post-hoc) in Anova in recently published medical research literature. *National Journal of Community Medicine*. 2015;6(1):117–120. Available from: https://njcmindia.com/index.php/file/article/view/1143/901.
3) Smarandache F. Neutrosophic Statistics is an extension of Interval Statistics, while Plithogenic Statistics is the most general form of statistics (second version). *International Journal of Neutrosophic Science*. 2022;19(1):148–165. https://doi.org/10.54216/IJNS.190111.
4) Smarandache F. Indeterminacy in neutrosophic theories and their applications. Infinite Study. 2021. https://doi.org/10.54216/IJNS.150203.
5) Aslam M. A new attribute sampling plan using neutrosophic. *Complex & Intelligent Systems*. 2019;5:365–370. https://doi.org/10.1007/s40747-018-0088-6.
6) Zhang H. Neutrosophic Approaches for Analyzing the Interaction Between the Sports Industry and Community Health: A Multi-Attribute Decision-Making Perspective. *Neutrosophic Sets and Systems*. 2025;77:1. Available from: https://digitalrepository.unm.edu/nss_journal/vol77/iss1/2.
7) Aslam M. Neutrosophic analysis of variance: application to university students. *Complex & Intelligent Systems*. 2019;5(4):403–407. https://doi.org/10.1007/s40747-019-0107-2.
8) Aslam M. A new failure-censored reliability test using neutrosophic statistical interval method. *International Journal of Fuzzy Systems*. 2019;21(4):1214–1220. https://doi.org/10.1007/s40815-018-0588-y.
9) AlAita A, Talebi H, Aslam M, Sultan KA. Neutrosophic statistical analysis of split-plot designs. *Soft Computing*. 2023;27(12):7801–7811. https://doi.org/10.1007/s00500-023-08025-y.
10) Aslam M, Albassam M. Presenting post hoc multiple comparison tests under neutrosophic statistics. *Journal of King Saud University-Science*. 2020;32(6):2728–2732. https://doi.org/10.1016/j.jksus.2020.06.008.
11) Albassam M, Khan N, Aslam M. The W/S Test for Data Having Neutrosophic Numbers: An Application to USA Village Population. *Complexity*. 2020. https://doi.org/10.1155/2020/3690879.
12) Kakati N, Gogoi B. A Study of Multiple Comparison Tests with Imprecise and Uncertain Information. *Indian Journal of Science and Technology*. 2024;17(35):3669–3677. https://doi.org/10.17485/IJST/v17i35.1547.
13) Sherwani RAK, Shakeel H, Awan WB, Faheem M, Aslam M. Analysis of COVID-19 data using neutrosophic Kruskal Wallis H test. *BMC Medical Research Methodology*. 2021;21:1–7. https://doi.org/10.1186/s12874-021-01410-x.