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RESEARCH ARTICLE

THE COMPARISON OF LARGE SAMPLE MEANS BY THE TAKIAR Z TEST AND THE NORMAL Z TEST

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ABSTRACT

In my last study (Takiar R, 2024), for the Normal samples of size below 30, a new test, named, Takiar Z test, was evolved to test the significant differences between two sample means. The test basically utilizes the relationship seen between the Range and the SD and the technique of regression, to develop a new set of Cut-off levels for small samples, for the three levels of α namely 5%, 10% and 15%. In that study it was also shown that the Takiar Z test is a better option than the t-test. Further, the validity of the former test was shown to be higher than the t-test. In the current study, the application of Takiar Z test is extended to the large samples for testing the significance differences between two sample means and the results obtained are compared with that of traditional Z-test. Utilizing the relationship between the ratio of Range to standard devitation and the sample size, a new set of Cut-off levels are suggested for three α levels namely 1%, 5% and 10%.

The study carried out 12500 mean comparisons, spread over 5 large sample sizes (40, 60, 80, 120 and 160) and the 5 pairs of distinct normal populations {(P7, P8), (P8, P9), (P9, P10), (P7, P9), (P8,P10)}. For α = 1% and for all the sample sizes pooled, the validity of the Takiar Z test is observed to be 48.4%, much ahead than seen in the case of the Z test (38.0%). For α = 5%, the validity is seen to be 58.5% for the Takiar Z test, registering almost 3% absolute rise than seen in the case of the Z test (55.6%) which is relatively more than 5%. Similarly, for α = 10%, the validity of Takiar Z test is seen to be 65.4% as against 64.2% seen in the case of Z test. Thus, the Takiar Z test is shown to be performing consistently better than the Z test at all the selected three α levels. Therefore, for large samples, for mean comparisons, the use of Takiar Z-test is recommended instead of the traditional Z-test.

Keywords: Large samples, Z test, Takiar Z test, Comparison, Validity

INTRODUCTION

In my last study (Takiar R, 2024), for the Normal samples of size below 30, a new test, named Takiar Z test, was evolved to test the significant differences between two sample means. The test basically utilizes the relationship seen between the Range to SD ratio with that of sample size, combined with the technique of regression, to develop a new set of Cut-off levels for small samples, for the three levels of α namely 5%, 10% and 15%. For α = 5%, it was shown there that the Takiar Z test can pick up relatively more percentage of the expected significant differences than the Z-EV test. The Z-test, when utilized with the estimated sample variance, for small samples, is termed as a Z-EV test. The Z-EV test was shown to be picking up only 29.9% of the expected significant differences as against 42.0%, picked up by the Takiar Z test. Thus, showing that the newly developed Takiar Z test is better than the traditional Z test, in picking up the correct significant differences between the two-sample means. The basic difference between the Z-EV test and the Takiar Z-test is that the later test utilizes the cut-off values developed in the referred study instead of the traditional values based on the Normal table. In the current study, an attempt is made to extend the use of Takiar Z test for large samples? The present study is therefore designed with the following objectives:

OBJECTIVES

- To explore the relationship between the Range and the Standard Deviation for the Normal samples of sizes above 30.
- The relationship seen between the Range and the SD to be utilized, to define the Cut-off levels for large samples, for the selected three levels of α.
- To compare the validity of the Takiar Z test and the Z-EV test, in picking up the correct significant differences between the two-sample means.

MATERIALS AND METHODS

Z TEST FOR COMPARISON OF TWO MEANS

For two independent samples, to compare and decide whether two samples have comparable means or not, the statistics used is:

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{S} \quad \text{where } S = \sqrt{\frac{\sigma^2{}_1}{n_1} + \frac{\sigma^2{}_2}{n_2}} \quad \text{.........................} (1)$$

For Z statistics, the sample means are taken as the estimates of the respective population means and σ is assumed to be known and comparable for the populations. For the study purposes, the sample estimates of σ are used in the formula (1) and such a Z test is termed as the Z-EV test. For the Z-EV test, the formula used for estimating the sample variance is given as $\mathrm{SDP}^2 = \frac{1}{n}\boldsymbol{\Sigma}(\boldsymbol{x_i} - \boldsymbol{\mu})^2$. For large samples, Z-EV test is simply termed as the Z test.

DESCRIPTION OF THE NORMAL POPULATIONS

For the study purposes, six Normal populations are considered. The details of the populations are shown in Table 1.

Table 1: The Description of the Normal Populations with Specified Mean and SDP

POPULATION	P1	P2	P3	P4	P5	P6
N	200	200	200	200	200	200
MEAN	55.5	44.21	65.77	76.14	51.92	70.63
SDP	16.013	11.697	17.946	12.861	12.861	17.161

SELECTION OF SAMPLES AND SAMPLE SIZE

From each of the six populations, 50 random samples of size 30, 50, 75, 100, 125, 150 and 175 are generated, using the program developed on the Visual basic and pooled. Thus, in total 300 samples are generated for each sample size.

DATA COLLECTED

From each sample, the following statistics are collected: Sample size (n), Minimum value (MIN), Maximum (MAX), Mean and SDP.

GENERATION OF PERCENTILE VALUES

From each sample, the following percentile values are generated like P(0.5), P(99.5), P(2.5), P(97.5.0), P(5.0), P(95.0), from the data, using the Excel function PERCENTILE.INC

TYPES OF RANGES

Based on the percentile values the following three types of Ranges are calculated.

- 99% Range = R99 = P(99.5) - P(0.5)
- 95% Range = R95 = P(97.5) - P(2.5)
- 90% Range = R90 = P(95.0) – P(5.0)

DEFINTION OF RANGE TO SDP RATIOS

For each sample size**,** the following three Range to SDP ratios are calculated.

R99/SDP, R95/SDP, R90/SDP

To cover the variability in Range to SDP ratios, arising possibly due to difference in parameters of the different populations, the Range to SDP ratios of 50 samples each, generated for each sample size, are pooled. Thus, for each sample size, 300 Range to SDP ratios are obtained.

DEVELOPMENT OF REGRESSION EQUATION FOR SDP TO RANGE

The means of R99/SDP ratios, derived for different sample sizes namely 30, 50, 75, 100, 125, 150 and 175 are utilized to develop a regression equation. For this, the log of the sample size is considered as X and the mean of the corresponding R99/SDP ratio is taken as Y. Thus, for the sample size, ranging from 30-358, the Cut-off values are estimated. Similar, exercise is attempted in case of R95/SDP and R90/SDP ratios.

DEVELOPMENT OF TABULATED VALUES FOR α (1%, 5%, 10%)

- The R99/SDP values derived with the help of the regression equation for different sample sizes are taken to represent as the critical values when α = 1%
- The R95/SDP values derived with the help of the regression equation for different sample sizes are taken to represent as the critical values when α = 5%
- The R90/SDP values derived with the help of the regression equation for different sample sizes are taken to represent as the critical values when α = 10%

In generations of above Cut-off levels, one assumption is made. It is assumed that the range is distributed equally among both the sides of the mean. For comparing two sample means with different n say n_1 and n_2, the Cut-off level should be seen for $(n_1 + n_2)/2$. In case, a fraction is obtained, it should be rounded off to the nearest integer and that integer should be taken to view the Cut-off level.

TESTS SELECTED FOR TESTING THE SIGNIFICANCE DIFFERENCES AMONG SAMPLE MEANS

• Z test

• Takiar Z test

The basic difference between the Z test and the Takiar Z-test is that the later test uses the cut-off values developed in the current study instead of traditional values based on the Normal table.

VALIDITY OF TESTS WHEN MULTIPLE COMPARISONS ARE MADE

In general, for testing two sample means, the hypothesis statements are given as follows: $H_o : m_1 = m_2$ and $H_1: m_1 \neq m_2$

When it is known that the samples drawn, are from different normal populations, it is logical to reject the Null Hypothesis. Thus, the validity of the test under consideration can be defined as follows:

Validity = [Number of significant differences found correctly /500] *100

Where 500 is the number of Mean Comparisons made.

THE NORMAL POPULATIONS SELECTED FOR TESTING THE VALIDITY

For testing the validity of the Cut-off levels developed in the study, it is thought logical to select samples from new populations and then comparisons to be attempted. The new normal populations selected for study purposes are shown in Table 2.

The Scheme of sample Mean Comparisons when drawn from different populations is shown in the Table 3. For the study purposes, 5 sample sizes (40, 60, 80, 120, 160) are considered. For each sample size, 500 samples are generated using the V-Basic program. Thus, 2500 sample mean comparisons are attempted for each of the five selected pairs of populations {(P7,P8), (P8,P9), (P9,P10), (P7,P9), (P8,P10)}. Overall, 12500 mean comparisons are attempted.

Table 2: The Description of the Normal Populations Selected for Testing the Validity

POPULATION	**P7**	**P8**	**P9**	**P10**
N	200	200	200	200
MEAN	36.24	38.18	40.8	43.77
SDP	8.368	9.054	11.673	12.546

THE SCHEME OF MEAN COMPARISONS AMONG DIFFERENT SAMPLE SIZES

Table 3: The Scheme of Sample Mean Comparisons When Drawn from the Different Normal Populations

	Population		Mean Comparisons	Pairs of Population		Total Mean Comparisons
	P7	P8				
Sample Size	40	40	500	P7	P8	2500
	60	60	500	P8	P9	2500
	80	80	500	P9	P10	2500
	120	120	500	P7	P9	2500
	160	160	500	P8	P10	2500
	Total		2500	Total		12500

RESULTS

The comparison of populations means, for five pairs of populations and their significance is shown in Table 4. All mean comparisons attempted are shown to be significantly different from each other. This allows us to compare the means of samples drawn from different pairs of populations, expecting them to be different.

The Mean values of Range to SDP ratios by varying Sample size, along with the Correlation coefficient (r), Slope (b) and Intercept (a) are shown in Table 5. The ratios shown in the table are: R99/SDP, R95/SDP, and R90/SDP. The Log values of Sample size are taken as the X values and the corresponding average values of ratios are taken as the Y values. For R99/SDP, for the sample size of 30, the mean ratio is observed to be 4.05 and it increased to 4.82 for the sample size of 175. The corresponding mean ratios for R95/SDP are observed to be 3.56 and 3.88, respectively. For R90/SDP, it changed to 3.1 to 3.27 respectively.

The correlation is attempted between the Range/SDP ratio on one hand and Log of sample size on the other hand. The correlations ranged from 0.993 for R99/SDP to 0.929 for the ratio of R90/SDP. The Slope values for the selected three Range ratios are observed to be 0.986, 0.409 and

0.211, respectively. The high correlations observed, suggests that the models fitted are good and can be used for generating different cut-off levels for the sample size of 30 to 358.

Table 4: The Comparison of Means by the Selected Pairs of Populations

POPULATION	**P7**	**P8**	**P9**	**P7**	**P8**
N1	200	200	200	200	200
MEAN	36.24	38.18	40.8	36.24	38.18
SDP	8.368	9.054	11.673	8.368	9.054
POPULATION	**P8**	**P9**	**P10**	**P9**	**P10**
N2	200	200	200	200	200
MEAN	38.18	40.8	43.77	40.8	43.77
SDP	9.054	11.673	12.546	11.673	12.546
Z-VALUE	**2.225**	**2.508**	**2.451**	**4.49**	**5.11**
P VALUE	0.027	0.013	0.015	< 0.001	< 0.001

Table 5: The Mean of Different Ratios by the Sample size (n = 300)

SAMPLE SIZE	R99/SDP	R95/SDP	R90/SDP
30	4.05	3.56	3.1
50	4.35	3.69	3.2
75	4.52	3.74	3.25
100	4.64	3.8	3.24
125	4.71	3.82	3.26
150	4.77	3.87	3.28
175	4.82	3.88	3.27
r	0.993	0.993	0.929
b	0.986	0.409	0.211
a	2.641	2.973	2.82

The Table 6, provides the Cut-off levels for Takiar Z test, for α = 1%. It is to be noted that for α = 1%, the Cut-off levels are provided for the sample size, ranging from 30 to 358. Accorddingly, the Cut-off levels ranged from 2.049 to 2.580. It is to be noted that for α = 1%, the standard Z value is given as 2.58 which is toward higher side as compared to calculated Cut-off levels.

The Table 7, provides the Cut-off levels for Takiar Z test, for α = 5%. The Cut-off levels are noted to be varying from 1.789 to 2.009 for the sample size of 30 to 358, respectively. In case of α = 5%, the standard Z-value is noted to be 1.96 which is again towards higher side as compared to calculated Cut-off levels.

Table 6: The Cut-off Levels by the Sample size for the Takiar Z Test for α = 1%

n	Tabulated	n	Tabulated	n	Tabulated	n	Tabulated
30	2.049	72	2.236	114	2.335	198	2.453
32	2.063	74	2.242	118	2.342	206	2.461
34	2.076	76	2.248	122	2.349	214	2.470
36	2.088	78	2.254	126	2.356	222	2.478
38	2.100	80	2.259	130	2.363	230	2.485
40	2.111	82	2.264	134	2.369	238	2.492
42	2.121	84	2.269	138	2.376	246	2.499
44	2.131	86	2.274	142	2.382	254	2.506
46	2.140	88	2.279	146	2.388	262	2.513
48	2.150	90	2.284	150	2.394	270	2.519
50	2.158	92	2.289	154	2.399	278	2.526
52	2.167	94	2.294	158	2.405	286	2.532
54	2.175	96	2.298	162	2.410	294	2.538
56	2.183	98	2.302	166	2.415	302	2.543
58	2.190	100	2.307	170	2.420	310	2.549
60	2.197	102	2.311	174	2.425	318	2.554
62	2.204	104	2.315	178	2.430	326	2.560
64	2.211	106	2.319	182	2.435	334	2.565
66	2.218	108	2.323	186	2.440	342	2.570
68	2.224	110	2.327	190	2.444	350	2.575
70	2.230	112	2.331	194	2.449	358	2.580

Table 7: The Cut-off Levels by the Sample size for the Takiar Z Test for α = 5%

n	Tabulated	n	Tabulated	n	Tabulated	n	Tabulated
30	1.789	72	1.867	114	1.907	198	1.956
32	1.795	74	1.869	118	1.910	206	1.960
34	1.800	76	1.871	122	1.913	214	1.963
36	1.805	78	1.874	126	1.916	222	1.967
38	1.810	80	1.876	130	1.919	230	1.970
40	1.814	82	1.878	134	1.922	238	1.973
42	1.819	84	1.88	138	1.924	246	1.976
44	1.823	86	1.882	142	1.927	254	1.979
46	1.827	88	1.884	146	1.929	262	1.981
48	1.831	90	1.886	150	1.932	270	1.984
50	1.834	92	1.888	154	1.934	278	1.987
52	1.838	94	1.89	158	1.936	286	1.989
54	1.841	96	1.892	162	1.939	294	1.992
56	1.844	98	1.894	166	1.941	302	1.994
58	1.847	100	1.896	170	1.943	310	1.996
60	1.850	102	1.898	174	1.945	318	1.998
62	1.853	104	1.899	178	1.947	326	2.001

64	1.856	106	1.901	182	1.949	334	2.003
66	1.859	108	1.903	186	1.951	342	2.005
68	1.861	110	1.904	190	1.953	350	2.007
70	1.864	112	1.906	194	1.955	358	2.009

The Table 8, provides the Cut-off levels for Takiar Z test, for α = 10%. The Cut-off levels are shown to be varying from 1.566 to 1.680 for the sample size of 30 to 358, respectively. The standard Z-value is noted to be 1.645 which is again towards higher side as compared to calculated Cut-off levels up to the sample size of 166.

Table 8: The Cut-off Levels by the Sample size for the Takiar Z Test for α = 10%

n	Tabulated	n	Tabulated	n	Tabulated	n	Tabulated
30	1.566	72	1.606	114	1.627	198	1.653
32	1.569	74	1.607	118	1.629	206	1.654
34	1.572	76	1.609	122	1.630	214	1.656
36	1.574	78	1.61	126	1.632	222	1.658
38	1.577	80	1.611	130	1.633	230	1.659
40	1.579	82	1.612	134	1.635	238	1.661
42	1.582	84	1.613	138	1.636	246	1.662
44	1.584	86	1.614	142	1.637	254	1.664
46	1.586	88	1.615	146	1.639	262	1.665
48	1.588	90	1.616	150	1.640	270	1.667
50	1.589	92	1.617	154	1.641	278	1.668
52	1.591	94	1.618	158	1.642	286	1.669
54	1.593	96	1.619	162	1.643	294	1.671
56	1.595	98	1.62	166	1.644	302	1.672
58	1.596	100	1.621	170	1.646	310	1.673
60	1.598	102	1.622	174	1.647	318	1.674
62	1.599	104	1.623	178	1.648	326	1.675
64	1.601	106	1.624	182	1.649	334	1.677
66	1.602	108	1.625	186	1.650	342	1.678
68	1.604	110	1.626	190	1.651	350	1.679
70	1.605	112	1.626	194	1.652	358	1.680

VALIDITY OF THE TAKIAR Z TEST IN RELATION TO THE Z -TEST

The 500 samples of varying sample sizes (40, 60, 80, 120 and 160) are generated from each of the Population namely P7, P8, P9 and P10. The sample means are compared for five pairs of populations namely (P7,P8), (P8,P9), (P9,P10), (P7,P9) and (P8,P10). The results obtained from the significant tests, based on 2500 mean comparisons, for each sample size are summarized in Fig.1 for α = 1% .

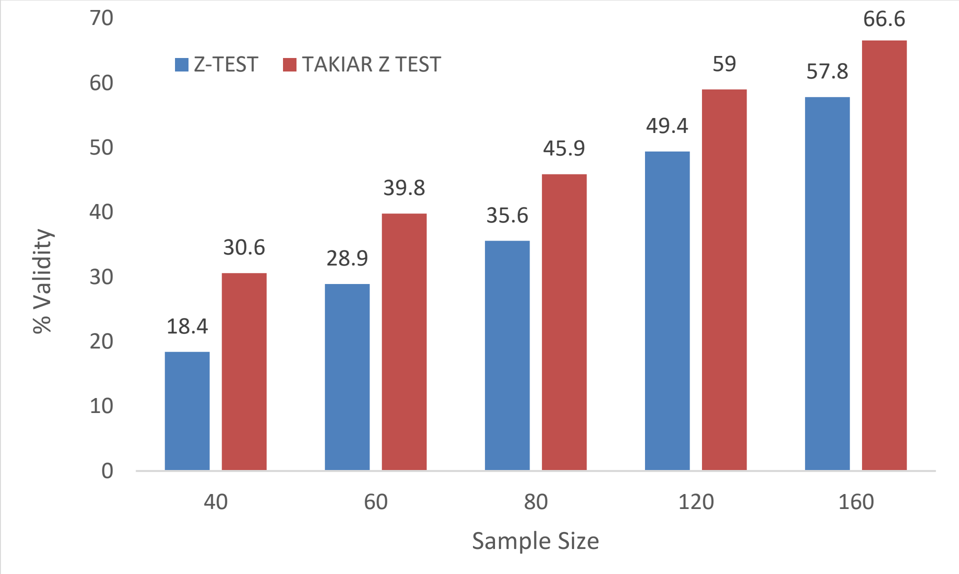

Fig. 1: The Percentage Validity by the Significance tests and the Sample size for α = 1% - Pooled Over all pairs of Population samples (n = 2500)

From the Fig. 1, for all the sample sizes, the performance of the Takiar Z test is observed to be far better than the Z test. For the sample size of 40, the validity of Takiar Z test is 30.6% as against 18.4 % seen in the case of Z test, about 66 % relatively better performance than the Z test. Similarly, for the sample size of 160, the validity of Takiar Z test is observed to be 66.6 % as against 57.8 % seen in the case of Z test. Again, a relative rise of about 15% in the validity of Takiar Z test.

The results obtained from the significant tests, based on 2500 mean comparisons, for each sample size namely 40, 60, 80, 120 and 160 are summarized in Fig. 2 for α = 5%.

From the Fig. 2, again, for all the sample sizes, the performance of the Takiar Z test is observed to be better than the Z test. For the sample size of 40, the validity of Takiar Z test is 40.6 % as against 35.8% seen in the case of Z test, about 13% relatively, better performance than the Z test. Similarly, for the sample size of 160, the validity of Takiar Z test is observed to be 75.8% as against 74.0% seen in the case of Z test. Again, a rise of about 2.4% in the validity of Takiar Z test.

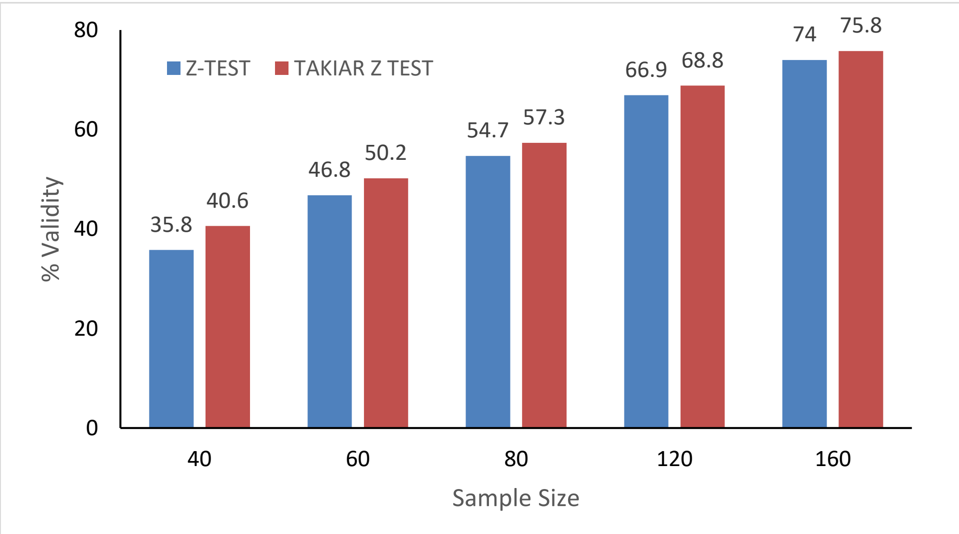

Fig. 2: The Percentage Validity by the Significance tests and the Sample size for α = 5% - Pooled Over all pairs of Population samples (n = 2500).

The results obtained from the significant tests, based on 2500 mean comparisons, for each sample size namely 40, 60, 80, 120 and 160 are summarized in Fig. 3 for α = 10%.

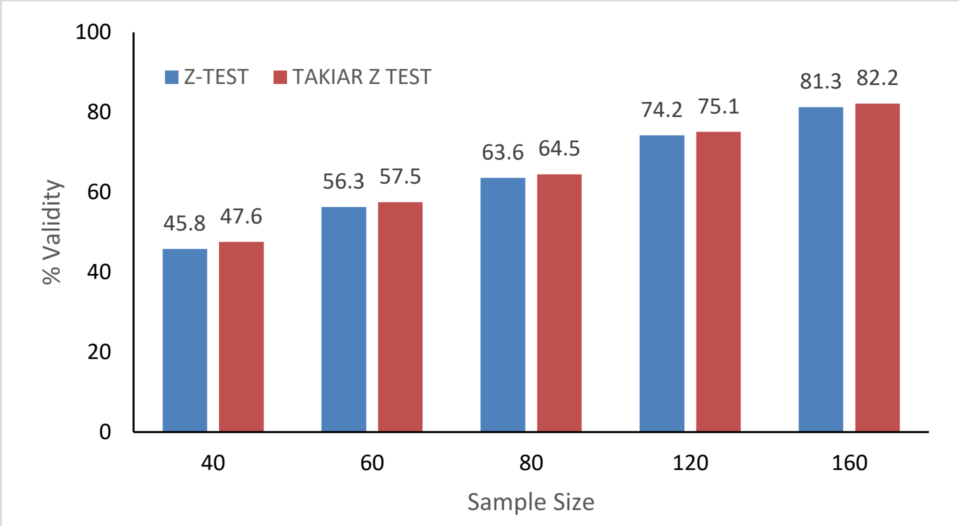

Fig. 3: The Percentage Validity by the Significance tests and the Sample size for α = 10% - Pooled Over all pairs of Population samples (n=2500)

From the Fig. 3, again, it is noted that the performance of the Takiar Z test is slightly better than the Z test. The Takiar Z test, irrespective of the sample size, can pick up higher percentage of mean differences, correctly than picked up by the Z test However, it should be noted that the results of comparisons are based on same samples, so any gain by the Takiar Z test, no matter how small, should be taken as the gain by the Takiar Z test.

The results the significant tests, obtained for varying α levels, pooled for all sample sizes, based on 12500 mean comparisons, are summarized in Fig. 4

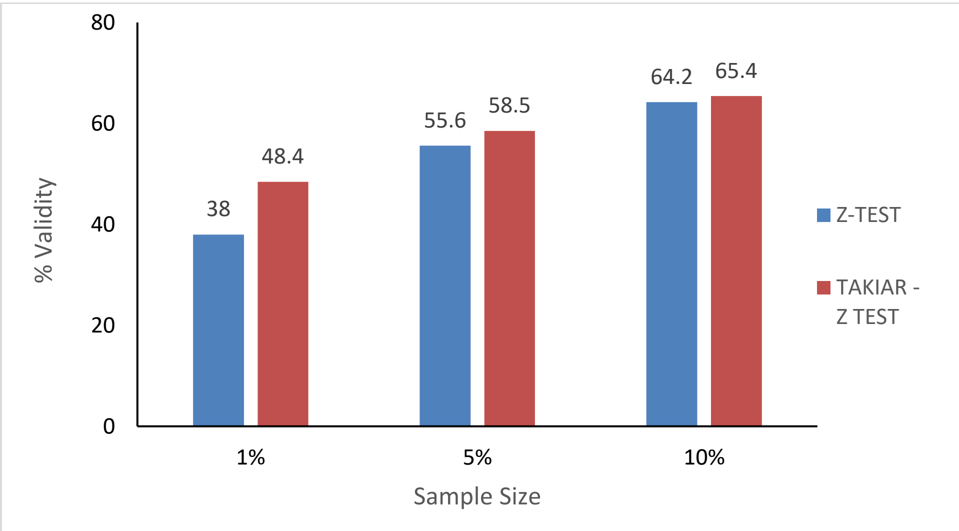

Fig. 4: The Percentage Validity by the Significance tests, pooled over all Sample sizes and all pairs of populations by varying α levels (n=12500)

At all α levels, the Takiar Z test picks up correctly, a higher percentage of mean differences as compared to the Z test. The Takiar Z test picks up around 27.3%, 5.2% and 1.9% relatively more mean differences correctly than the Z test at α level of 1%, 5% and 10%, respectively.

DISCUSSION

In my last study, the concept of Takiar Z test was introduced for the small samples, ranging from 4 to 30 (Takiar R, 2024). In the current study, the extension of the concept of the Takiar Z test is attempted for large sample size. The study has developed a set of new cut-off levels for the sample size varying from 30 to 358, for α levels of 1%, 5% and 10%.

It is always important to establish the validity of any newly developed test like Takiar Z test as compared to well-established test like Z test. To test the validity of the Cut-off points suggested for varying sample size, 2500 mean comparisons are attempted between each pair of the population samples, spread over 5 sample sizes namely 40, 60, 80, 120 and 160, arising from {(P7,P8), (P8,P9), (P9,P10), (P7,P9), (P8,P10)}. Thus, the results discussed, are based on 12500 mean comparisons for each sample size. The Takiar Z test, as compared to the Z test, showed, uniformly, a higher validity in picking up the significant differences between two sample means when drawn from different normal populations and known to be significantly different from each other.

For α = 1%, the validity of the Takiar Z test is observed to be 48.4%, much ahead than seen in the case of the Z test (38.0%). For α = 5%, the validity is seen to be 58.5%, registering almost 3% absolute rise than seen in the case of the Z test (55.6%) which is relatively more than 5%. Similarly, in the case of α = 10%, the validity of Takiar Z test is seen to be 65.4% as against 64.2% seen in the case of Z test. Thus, at all the selected three levels of α, Takiar Z test outperforms as compared to the Z test.

SUMMARY OF OBSERVATIONS

- The study has explored the extended use of Takiar Z test to large samples.
- The results are based on 12,500 mean comparisons, spread over 5 small sample sizes (40, 60, 80, 120, 160), drawn from the 5 pairs of distinct populations {(P7,P8), (P8,P9), (P9,P10), (P7,P9), (P8,P10)}.
- For α = 1%, the validity of the Takiar Z test is observed to be 48.4%, much ahead than seen in the case of the Z test (38.0%).
- For α = 5%, the validity is seen to be 58.5% for the Takiar Z test, registering almost 3% absolute rise than seen in the case of the Z test (55.6%) which is relatively more than 5%.
- For α = 10%, the validity of Takiar Z test is seen to be 65.4% as against 64.2% seen in the case of Z test.
- The Takiar Z test is shown to be performing better than the Z test.

RECOMMENDATIONS

- In case of large samples, for mean comparisons, the use of Takiar Z-test is advocated in the place of traditionally used Z test as it results in higher validity than the Z test.
- It is better to use α=10%, as compared to α=5%, traditionally used, for mean comparisons, as it results in improvement of the validity.
- For Cut-off levels, according to the selected sample size, the values provided in Table 6, Table 7, and Table 8, should be referred for α=1%, α=5%, and α=10%, respectively.

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Biography

Dr. Ramnath Takiar

I am a Post graduate in Statistics from Osmania University, Hyderabad. I did my Ph.D. from Jai Narain Vyas University of Jodhpur, Jodhpur, while in service, as an external candidate. I worked as a research scientist (Statistician) for Indian Council of Medical Research from 1978 to 2013 and retired from the service as Scientist G (Director Grade Scientist). I am quite experienced in large scale data handling, data analysis and report writing. I have 72 research publications, with 1250 citations to my credit, published in national and International Journals, related to various fields like Nutrition, Occupational Health, Fertility and Cancer epidemiology. During the tenure of my service, I attended three International conferences namely in Goiana (Brazil-2006), Sydney (Australia-2008) and Yokohoma (Japan-2010) and presented a paper in each. I also attended the Summer School related to Cancer Epidemiology (Modul I and Module II) conducted by International Agency for Research in Cancer (IARC), Lyon, France from 19th to 30th June 2007. After my retirement, I joined my son at Ulaanbaatar, Mongolia. I worked in Ulaanbaatar as a Professor and Consultant from 2013-2018 and was responsible for teaching and guiding the Ph.D. students. I also taugth Mathematics to undergraduates and Econometrics to MBA students. During my service there, I also acted as the Executive Editor for the in-house Journal “International Journal of Management”. I am also acting as a reviewer for few International Journals. I am still active in research and have published 12 research papers during 2021-24.