

## Statistical notes for clinical researchers: Nonparametric statistical methods: 1. Nonparametric methods for comparing two groups

**Hae-Young Kim**

Department of Dental Laboratory  
Science and Engineering, College  
of Health Science & Department  
of Public Health Science, Graduate  
School, Korea University, Seoul,  
Korea

### Nonparametric statistical methods

Parametric statistical methods are implemented based on definite assumptions. For example, an independent *t*-test requires conditions of normal distributions for each group. The normality of the population distribution from which the sample data was originated may be assessed by examining graphs, by formal normality test such as the Shapiro-Wilk test or Kolmogorov-Smirnov test, or by assessment using skewness and kurtosis, as discussed in a previous session. When a substantial departure is found in data with continuous outcomes, we may consider transformation of data, e.g., by taking logarithms. If transformed data satisfy the assumptions, usual parametric methods, such as *t*-test, ANOVA, or linear regression may be applied. However if transformed data do not satisfy the assumptions, we need to choose nonparametric methods.

Nonparametric methods are called as 'distribution-free tests' because generally they don't require any assumptions about underlying population distribution. Nonparametric methods may be applied when the data do not satisfy the distributional requirements of parametric methods. In nonparametric methods, ranks of observations are used instead of the measurements themselves, which may cause somewhat loss of information. While parametric methods estimate the key parameters of the distribution such as population means, nonparametric methods mainly test the pre-set hypothesis, e.g., whether two data differ or not. As the result, nonparametric methods usually don't provide any useful parameter estimates.

Nonparametric methods may be applied on a wide range of data which is not suitable for the parametric analysis. Severely skewed continuous data or continuous data with definite outliers may be analyzed using nonparametric methods. Small-sized samples which don't guarantee the exact normality need nonparametric methods. Also data with ordinal outcomes are often analyzed using nonparametric methods.

Advantages of nonparametric methods are as follows:

- 1) Wider range of data are applicable because of no or limited assumptions.
- 2) Useful in analyzing ordered data or categorical data

Disadvantages of nonparametric methods are as follows:

- 1) Applying nonparametric methods on data satisfying assumptions of parametric methods may result in less power. However loss of power may be little or none for analysis of data which cannot satisfy the assumptions.
- 2) Tied values can be problematic and appropriate adjustment may be required.
- 3) Limited flexibility in generalizing to more complex analytic methods compared to parametric methods.

#### \*Correspondence to

Hae-Young Kim, DDS, PhD.  
Associate Professor, Department  
of Dental Laboratory Science &  
Engineering, Korea University  
College of Health Science, San 1  
Jeongneung 3-dong, Seongbuk-gu,  
Seoul, Korea 136-703  
TEL, +82-2-940-2845; FAX, +82-2-  
909-3502, E-mail, kimhaey@korea.  
ac.kr

### Nonparametric methods for comparing two groups

Table 1 shows parametric methods and nonparametric methods for comparing independent two groups and correlated two groups. The Wilcoxon rank-sum test (or the Mann-Whitney U test) is comparable to the independent *t*-test as the Wilcoxon signed-rank test is to the paired *t*-test.

**Table 1.** Parametric methods and nonparametric methods for comparing two or more groups

Comparison	Parametric method (normal distribution assumed)	Nonparametric method (distribution-free method)
Independent two groups	Independent <i>t</i> -test	Wilcoxon rank-sum test (or Mann-Whitney U test)
Correlated two groups	Paired <i>t</i> -test	Wilcoxon signed-rank test
Independent three or more groups	One-way ANOVA	Kruskal-Wallis test
Correlated three or more groups	Repeated measures one-way ANOVA	Friedman test

#### 1. Wilcoxon rank-sum test (or Mann-Whitney U test)

The Wilcoxon rank-sum test (or the Mann-Whitney U test) is applied to the comparison of two independent data whose measurements are at least ordinal. The null hypothesis is that two sets of scores are samples from the same population; therefore they do not differ systematically. Steps of the test are as follows:

1<sup>st</sup> step: Transformation of observed scores into ranks

Observed score			Rank		
Groups	A	B	Groups	A	B
Data	11	2	Data	7	2
	14	9		8	6
	7	0		4	1
	8	5		5	3
			Sum of ranks	24	12

2<sup>nd</sup> step: **W** (Difference from the rank sum of A group to the rank sum of B group) = 24 - 12 = **12**

3<sup>rd</sup> step: Calculation of the probability of the observed case or more extreme cases

a) Number of all possible cases when 4 observations were selected from the set with 8 observations:

$$8! / (4! * 4!) = 70$$

b) Number of cases with larger difference of rank sum from A group to B group = 4 cases

Rank combinations of A group with (5, 6, 7, 8), (4, 6, 7, 8), (3, 6, 7, 8), and (4, 5, 7, 8).

4<sup>th</sup> step: Calculation of probability

a) *p* value for one-sided test = 4 / 70 = 0.057

b) *p* value for two-sided test = 2 \* (4 / 70) = **0.114** (exact *p* value)

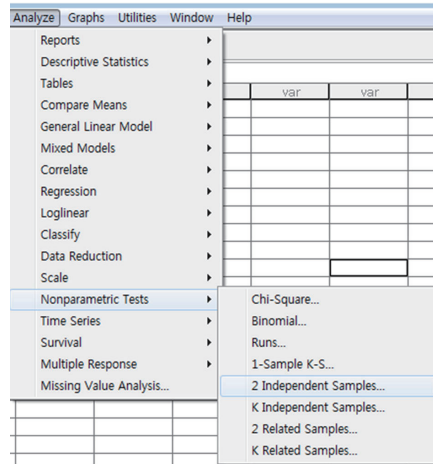
If sample size is large (> 20), asymptotic *p* value (below e) is used for the statistical determination.

The Wilcoxon rank-sum test using the SPSS statistical package is according to following procedures:

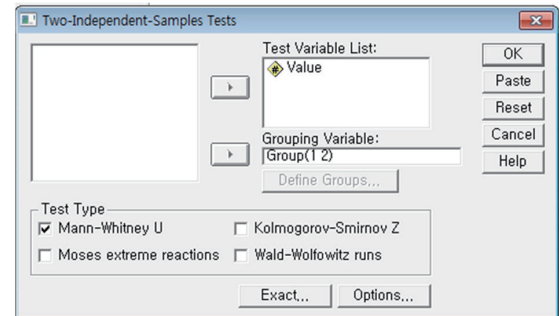
(a) data

	Group	Value	var
1	1	11	
2	1	14	
3	1	7	
4	1	8	
5	2	2	
6	2	9	
7	2	0	
8	2	5	
9			

(b) Analyze - Nonparametric tests  
- 2 Independent samples



(c) Define test variable and grouping variable



(d) Sum of ranks

Ranks				
	Group	N	Mean Rank	Sum of Ranks
Value	1	4	6,00	24,00
	2	4	3,00	12,00
	Total	8		

(e) Wilcoxon W and *p* values

Test Statistics <sup>b</sup>	
	Value
Mann-Whitney U	2,000
Wilcoxon W	12,000
Z	-1,732
Asymp. Sig. (2-tailed)	,083
Exact Sig. [2*(1-tailed Sig.)]	,114 <sup>a</sup>

a. Not corrected for ties.

b. Grouping Variable: Group

## 2. Wilcoxon signed-rank test

The Wilcoxon signed-rank test is applied to the comparison of two repeated or correlated data whose measurements are at least ordinal. The null hypothesis is that there is no difference in two paired scores. Steps of the test are as follows:

- 1<sup>st</sup> step: Compute difference scores between two paired values
- 2<sup>nd</sup> step: Assign ranks from the smallest absolute difference to the largest one
- 3<sup>rd</sup> step: Provide signs, + or -, according to the direction of the differences and compute sum of positive and negative ranks, respectively.
- 4<sup>th</sup> step: Set T = Smaller absolute value of positive or negative rank sum. T = 4 (negative rank sum)

An example of calculating sum of positive and negative ranks is shown in the Table 2.

**Table 2.** Procedures from 1<sup>st</sup> step to 3<sup>rd</sup> step of the Wilcoxon signed-rank test

No	Before	After	Difference	Ranks	Positive	Negative
1	36	21	15	11	11	
2	23	24	-1	-1		1
3	48	36	12	10	10	
4	54	30	24	12	12	
5	40	32	8	7	7	
6	32	35	-3	-3		3
7	50	43	7	6	6	
8	44	40	4	4	4	
9	36	30	6	5	5	
10	29	27	2	2	2	
11	33	22	11	9	9	
12	45	36	9	8	8	
Sum					74	4 (= T)

5<sup>th</sup> step: Wilcoxon signed rank test

a) Small sample size ( $N < 20$ ): find the  $p$  value for  $T$  value and sample size  $n$  in the table for the Wilcoxon signed-rank test.

For this example,  $p$  value = 0.0017 for  $T = 4$  when sample size = 12.

b) Larger sample size ( $N > 20$ ): use  $z$  distribution approximation.

$$Z = \frac{T - \frac{N(N-1)}{4}}{\sqrt{\frac{N(N+1)(2N+1)}{24}}}$$

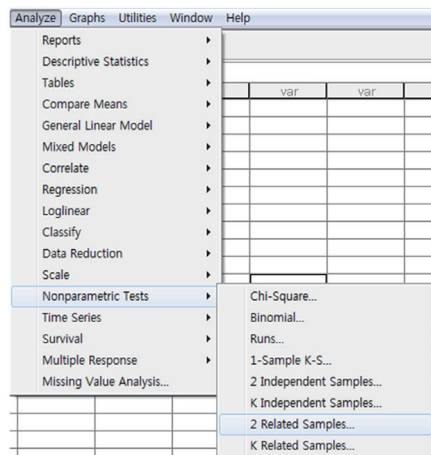
Statistical decision: reject null hypothesis if  $|z| > 1.96$  at the significance level  $\alpha = 0.05$ . If the sample size was larger than 20, the asymptotic  $p$  value 0.006 (below e) could be used.

The Wilcoxon signed-rank test using the SPSS statistical package is according to following procedures:

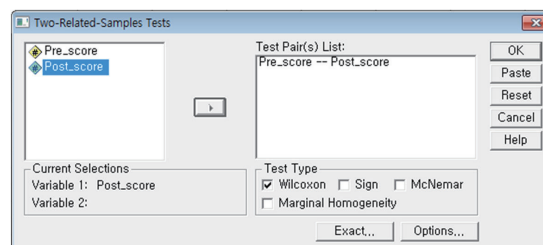
(a) data

	Pre_score	Post_score	var
1	36	21	
2	23	24	
3	48	36	
4	54	30	
5	40	32	
6	32	35	
7	50	43	
8	44	40	
9	36	30	
10	29	27	
11	33	22	
12	45	36	
13			

(b) Analyze - Nonparametric tests  
- 2 Related samples



(c) Define test pair list



(d) Mean ranks (positive, negative)

Ranks				
		N	Mean Rank	Sum of Ranks
Post_score - Pre_score	Negative Ranks	10 <sup>a</sup>	7.40	74.00
	Positive Ranks	2 <sup>b</sup>	2.00	4.00
	Ties	0 <sup>c</sup>		
	Total	12		

a. Post\_score < Pre\_score

b. Post\_score > Pre\_score

c. Post\_score = Pre\_score

(e) Z-value and p values

Test Statistics <sup>b</sup>	
	Post_score - Pre_score
Z	-2.746 <sup>a</sup>
Asymp. Sig. (2-tailed)	.006

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test