Chapter 2
Paired Continuous Data (Paired T-Test, Wilcoxon Signed Rank Test, 10 Patients)

1 General Purpose

Studies where two outcomes in one patient are compared with one another are often called crossover studies, and the observations are called paired observations.

As paired observations are usually more similar than unpaired observations, special tests are required in order to adjust for a positive correlation between the paired observations.

2 Schematic Overview of Type of Data File

Outcome 1	outcome 2
.	.
.	.
.	.
.	.
.	.
.	.
.	.
.	.
.	.

3 Primary Scientific Question

Is the first outcome significantly different from second one.

4 Data Example

The underneath study assesses whether some sleeping pill is more efficaceous than a placcebo. The hours of sleep is the outcome value.

| Outcome 1	Outcome 2
6,1	5,2
7,0	7,9
8,2	3,9
7,6	4,7
6,5	5,3
8,4	5,4
6,9	4,2
6,7	6,1
7,4	3,8
5,8	6,3

Outcome = hours of sleep after treatment

5 Analysis: Paired T-Test

The data file is in extras.springer.com and is entitled "chapter2pairedcontinuous". Open it in SPSS. We will start with a graph of the data.

Command:
Graphs....Bars....mark Summary separate variables....Define....Bars Represent: enter "hours of sleep [outcomeone]"....enter "hours of sleep [outcometwo]".... click Options....mark Display error bars....mark Confidence Intervals....Level (%): enter 95,0....Continue....click OK.

Error bars: 95,00% CI
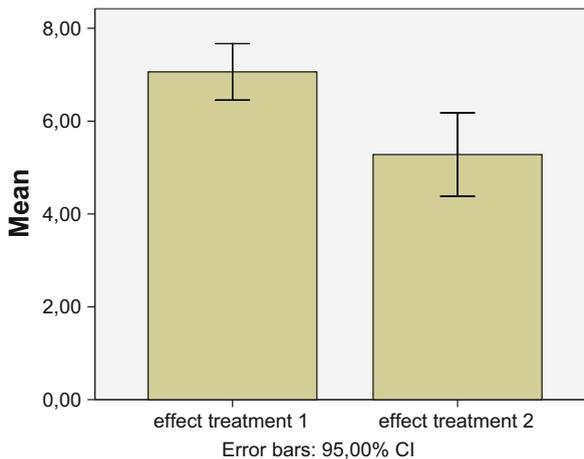
The above graph is in the output. It shows that the mean number of sleeping hours after treatment 1 seems to be larger than that after treatment 2. The whiskers represent the 95 % confidence intervals of the mean hours of sleep. They do not overlap, indicating that the difference between the two means must be statistically significant. The paired t-test can analyze the level of significance. For analysis the module Compare Means is required. It consists of the following statistical models:

Means,
One-Sample T-Test,
Independent-Samples T-Test,
Paired-Samples T-Test and
One Way ANOVA

Command:
Analyze....Compare Means....Paired Samples T Test....Paired Variables: Variable 1: enter [outcomeone]....Variable 2: enter [outcometwo]....click OK.

Paired samples test

	Paired differences							
				95 % confidence interval of the difference				
	Mean	Std. Deviation	Std. Error mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair1	Hours of sleep – hours of sleep	1,78000	1,76811	,55913	,51517	3,04483	3,184	9	,011

The above table is in the output. The outcomeone performs significantly better than does the outcometwo at a p-value of 0.011, which is much smaller than 0.05. The difference is, thus, statistically highly significant.

6   Alternative Analysis: Wilcoxon Signed Rank Test

If the data do not have a Gaussian distribution, this method will be required, but with Gaussian distributions it may be applied even so. For analysis 2 Related Samples in Nonparametric Tests is required.

Command:
Analyze....Nonparametric....2 Related Samples....further as above (Wilcoxon has already been marked in the dialog window).

Test statistics[a]

	Hours of sleep – hours of sleep
Z	−2,346[b]
Asymp. Sig. (2-tailed)	,019

[a]Wilcoxon signed ranks test
[b]Based on positive ranks

   As demonstrated in the above table, also according to the nonparametric Wilcoxon's test the outcomeone is significantly larger than the outcometwo. The p-value of difference here equals p = 0.019. This p-value is larger than the p-value of the paired t-test, but still a lot smaller than 0.05, and, so, the effect is still highly significant. The larger p-value here is in agreement with the type of test. This test takes into account more than the t-test, namely, that Nongaussian data are accounted for. If you account more, then you will prove less. That's why the p-value is larger.

7   Conclusion

The significant effects indicate that the null hypothesis of no difference between the two outcomes can be rejected. The treatment 1 performs better than the treatment 2. It may be prudent to use the nonparametric tests, if normality is doubtful like in the current small data example given. Paired t-tests and Wilcoxon signed rank tests need, just like multivariate data, more than a single outcome variable. However, they can not assess the effect of predictors on the outcomes, because they do not allow for predictor variables. They can only test the significance of difference between the outcomes.

8   Note

The theories of null hypotheses and frequency distributions and additional examples of paired t-tests and Wilcoxon signed rank tests are reviewed in Statistics applied to clinical studies 5th edition, Chaps. 1 and 2, entitled "Hypotheses data stratification" and "The analysis of efficacy data", Springer Heidelberg Germany, 2012, from the same authors.