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Review

Primer of statistics in dental research: Part II

Ayumi Shintani PhD, MPH

Department of Clinical Epidemiology and Biostatistics, Osaka University, Japan

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ABSTRACT

The Part I of Primer of Statistics in Dental Research covered five topics that are often mentioned in statistical check list of many peer-review journals [1–3] including (1) statistical graph, (2) how to deal with outliers, (3) *p*-value and confidence interval, (4) testing equivalence, and (5) multiplicity Adjustment [4]. The Part II of the series covers another set of important topics in dental statistics including (1) selecting the proper statistical tests, (2) repeated measures analysis, (3) epidemiological consideration for causal association, and (4) analysis of agreement. First, a guide in selecting the proper statistical tests based on the research question will be laid out in text and with a table so that researchers choose the univariable statistical test by answering five simple questions. Second, the importance of utilizing repeated measures analysis will be illustrated. This is a key component of data analysis as in many dental studies, observations are considered repeated in a single patient (several teeth are measured in a single patient). Third, concepts of confounding and the use of regression analysis are explained by going over a famous observational cohort study. Lastly, the use of proper agreement analysis vs. correlation for study of agreement will be discussed to avoid a common pitfall in dental research.

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E-mail address: ayumi.shintani@epistat.med.osaka-u.ac.jp.
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1. Selecting proper statistical tests

A famous British statistician, Douglas Altman said "Numerous studies of the medical literature, in both general and specialist journals, have shown that it is common to use the right techniques wrongly, misinterpret their results, report their results selectively, cite the literature selectively, and draw unjustified conclusions. This is surely a scandal." [5]. Fig. 1 depicts the relationship between NIH research funding for 29 different diseases and disability-adjusted person-years of life lost due to these illnesses [6]. Pearson's correlation coefficient test revealed no statistical significance in the association between NIH funding and life-years lost due to these illnesses, whereas Spearman's correlation coefficient test indicated "highly" significant association. As you see in this example, choice of statistical tests can greatly influence study finding. When Pearson correlation was used in this analysis, the authors could falsely conclude that NIH did not spend money efficiently to save people's lives.

Thus needless to say, selecting a proper statistical test to address a specific research question is an extremely important task that should be viewed as an essential skill in biostatistics.

The choice of a statistical test is based on the type of data. Table 1 summarizes five essential points to select a correct statistical test. All the researcher has to do is answering each question in the table from left to right. After all the five questions are answered, the process will lead you systematically to the appropriate statistical test.

We can use the Table 2 to find out whether we should be using Pearson or Spearman in the above example of the NIH funding (Y dollars) and disability-adjusted person-years of life (X years). We are interested in evaluating the association, thus "correlation" is the answer to Question 1. For each variable, one observation is collected per disease (disease is a unit of analysis in this example, typically it is patient); thus "data are not repeated or paired" is the answer to Question 2. Outcome variable is NIH funding, which is a continuous variable (answer to Question 3), and the NIH funding variable is skewed (answer to Question 4). Pearson correlation test works only with normally distributed data. On the other hand, Spearman's test is a nonparametric test which is not influenced by data distribution. Thus it is obvious that Spearman's test is the right pick; thus, we may conclude that NIH has spent money efficiently to save people's life. Normality of data can be tested with statistical tests such as Kolmogorov–Smirnov or Shapiro–Wilk test; however, caution should be taken because these tests can be too sensitive with larger size data. For this reason, I recommend to graphically check normality using *P–P* or *Q–Q* plots.

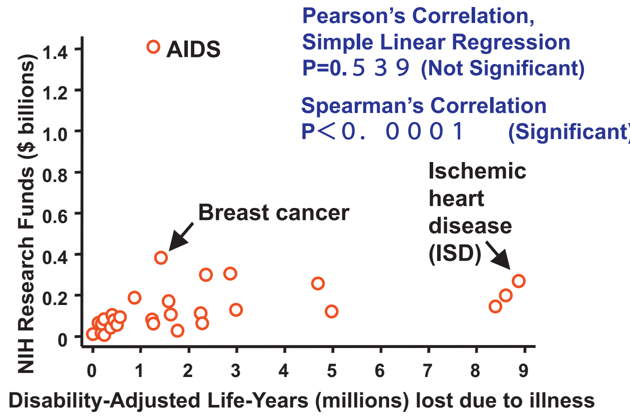

Fig. 1 – Different statistical tests provide highly different results.

2. Analysis of repeatedly measured data

One of the points in selecting proper statistical tests is whether data are repeated or paired. This is called data dependency,

Table 1 – Selecting proper statistical tests.

Q1, difference/ correlation	Q2, paired/repeated	Q3 and Q4, type of outcome (normality)	Q5, no. of groups	Valid tests
Difference	Independent (unpaired)	Continuous (normal)	2	Student's *t*-test
			>2	One-way ANOVA
		Continuous (non-normal)/ordered	2	Mann–Whitney *U* test
		categorical	>2	Kruskal–Wallis *H* test
		Nominal	2	Fisher's exact test
			≥2	Chi-square test
		Time to event		Log-rank test (Kaplan–Meier plot)
	Dependent (paired)	Continuous (normal)	2	Paired t-test
			>2	Repeated measured ANOVA
				Mixed effect regression
		Continuous (non-normal)/ordered	2	Wilcoxon signed-rank test
		categorical	>2	Friedman test
		Nominal	2	McNemar's test
Correlation		Continuous (normal)		Pearson's correlation (*r*)
		Continuous (non-normal)/ordered		Spearman's correlation (*rs*)
		Nominal (two levels)	2	Spearman/Kappa (agreement)

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Transform outcome variables for normalizing residuals.