

INVITED LECTURE

THE METHODOLOGICAL PRINCIPLES OF USING ANALYSIS OF DIFFERENCES IN SCIENTIFIC RESEARCH IN PHYSIOTHERAPY

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Abstract

INTRODUCTION: Goal of this paper was to review methodological usage principles of most frequently used analyses of differences in scientific research in physiotherapy.

DISCUSSION: In accordance with the aim, t-test and ANOVA's, both for independent samples and for repeated measures are discussed and highlighted from aspects of practice in physiotherapy. Appropriateness and limitations of methods are given and explained. **Conclusion:** Recommendation for appropriate reporting of t-test results in scientific research is given.

KEY WORDS: t-test, ANOVA, significance, assumptions

METODOLOŠKI PRINCIPI KORIŠTENJA RAZLIKA U ZNANSTVENIM ISTRAŽIVANJIMA U FIZIOTERAPIJI

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Sažetak

UVOD: Cilj ovog rada je pregled metodoloških načela o korištenju najčešće korištenih analiza razlika u znanstvenom istraživanju u fizioterapiji. Razrada: U skladu s ciljem, t-test i ANOVA, oboje za nezavisne uzorke i za ponovljene mjere, opisani su i istaknuti iz aspekta prakse fizioterapije. Prikadnost i ograničenja metode su dati i objasniti. Zaključak: U radu je data preporuka za odgovarajuće izvještavanje o rezultatima t-testa u znanstvenom istraživanju.

KLJUČNE RIJEČI: t-test, ANOVA, značajnost, pretpostavke

Introduction

In scientific practice in physiotherapy, often researcher don't just look to describe and analyze one set of data obtained from precisely planned and realized measurements done on one homogenous group of examinees (1-6). Instead, two or three or even more groups of examinees are usually observed and compared (7-12).

Discussion

Usually, goal is to identify and from practical point of view explain „sources of variations“ if statistically significant differences between observed groups (i.e. independent samples) can be identified. Statistical analysis and appropriate hypothesis in above mentioned approaches are different and they depend on number of observed groups (Table 1). Similarly, measurements can be done on the same sample of examinees but in the different time points (i.e. dependent samples) (13-16). It is important to underline that measured variable (usually on interval or ratio scale) is called dependent variable or criterion or response while categorical variable is called independent variable or factor.

TABLE 1. Overview of statistical analysis and appropriate hypothesis in dependence of number of groups and sample type

	Dependent samples	Independent samples
2 groups	t test for dependent samples $H_0: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$	t test for independent samples $H_0: \mu_1 = \mu_2$ $H_1: \mu_1 \neq \mu_2$
k groups (k>2)	one way repeated measures ANOVA $H_0: \mu_1 = \mu_2 = \dots = \mu_k$ $H_1: \mu_i \neq \mu_j$ for some i, j	one way ANOVA $H_0: \mu_1 = \mu_2 = \dots = \mu_k$ $H_1: \mu_i \neq \mu_j$ for some i, j

As can be seen from table 1, T-tests are used to compare the population means from two different groups of data (T-test for independent samples) or population means of two measurements of the same group in two different time points. More precisely, they will point out if population means are significantly different from one another (H1) or if they are statistically/practically the same (H0). Furthermore, if dealing with more than 2 groups (k groups), ANOVA is used to compare the population means from k different groups of data (one way ANOVA or ANOVA for independent samples) or population means of k measurements of the same group in k different time points. As in T-test, ANOVA will identify if population means are significantly different from one another (H1) or if they are statistically/practically the same (H0). Level of statistical significance (type I error) is usually set at $\alpha = 5\%$.

If the means are significantly different or equivalently if hypothesis H0 is rejected, one can say that the independent variable, had a significant effect on the variable being measured, dependent variable (DV). Also, researcher must be aware that calculating effect size parameter is one of the most important outcomes of empirical studies. From practical point of view it is a measure of the practical significance of results. From scientific point of view, effect sizes can be used to determine the sample size for follow-up studies, or examining effects across studies (17-21).

Assumptions for appropriate usage of difference analysis

All statistical tests have assumptions for their appropriate usage. Relatively trivial assumption for independent samples analyses is independence of observations. Reporting it is usually skipped in scientific researches. Second, due to their influence on type I error, data have to be checked for significant outliers. Furthermore, for all above mentioned statistical analyses, assumptions are that dependent variable is approximately normally distributed within each group. That condition can be easily checked by using Kolmogorov Smirnov or Shapiro Wilks test. Both theory and practice agree that the t-test and ANOVA are robust tests with respect to the assumption of normality. More precisely, even distribution of dependent variables may deviate away from normality, it does not have a large influence on Type I error rates. The exception to this is independent samples analyses when the ratio of the size of the groups is greater than approximately 1.5 (22-25). If normality assumption is roughly violated, or data is purely nonparametric (for, example data is on ordinal scale) or ratio of group sizes is sufficiently large, transformations so the data becomes normally distributed can be applied. Also, non-parametric Mann-Whitney U Test can be applied due to the fact it that does not require normality of variables.

For independent samples, very important assumption is homogeneity of variances. Equivalently, variances of groups have to be "almost" equal. If variances of observed groups appear to be significantly unequal, this can affect the Type I error rate (26). Usually, the assumption of

homogeneity of variance can be tested using Levene's Test of equality of variances. While testing for the homogeneity of variances, test statistics (F value) and a significance level (p-value) is calculated. As usual, if the significance level is greater than 0.05, variances of groups can be treated as equal. However, if $p < 0.05$, hypothesis of equality of groups' variances is rejected. If researcher by using the Levene's Test, detect statistically significant differences between variances, correction by not using the pooled estimate for the error term for the t-statistic can be applied (26-29). Similarly, adjustments to the degrees of freedom using the Welch-Satterthwaite method can be done. Levene's test is usually integrated in any serious software package dealing with difference analysis. Similarly, in repeated measures ANOVA, assumption of sphericity have to be checked.

Appropriate Reporting of t- test results

Simple question appears: "How to provide optimal amount of information for readers to fully understand the results when independent t-test was applied?". From practical point of view, researcher has to report: results of normality testing, results of equality of variances testing, both groups means and standard deviations, the actual t-test result and the direction of the difference. Additionally, researcher might also wish to include the difference between the groups along with the 95% confidence intervals. Hypothetical example is given of appropriate reporting t- test result: "...by using Kolmogorov Smirnov test, it was found that BMI was normally distributed for both experimental and control group ($p > 0.20$ for both groups). Furthermore, homogeneity of variance was checked by Levene's Test for equality of variances. Therefore, an independent t-test was applied. BMI value of the control group (23.15 ± 2.52 kg/m²) were significantly higher than the experimental group (21.56 ± 1.79 kg/m²) ($t(64) = 3.012$; $p = 0.007$) with a difference of 1.59 (95% CI: 0.86 to 3.32) kg/m². Cohen's d was chosen as effect size parameter and it was found to be moderate high ($C-d=0.53$).

Conclusion

T-test and ANOVA are frequently used in scientific research in physiotherapy. Knowing their appropriateness, limitations and optimal way to report results is an essential to easily "skip unnecessary problems" during process of publishing results of scientific research.

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