



REVIEW ARTICLE

## TIPS FOR STATISTICAL TOOLS FOR RESEARCH METHODS IN EXERCISE AND SPORT SCIENCES

Sara Aliberti<sup>1ABCD</sup>, Francesca D'Elia<sup>2ABCE</sup> and Domenico Cherubini<sup>1ABCD</sup>

<sup>1</sup>Catholic University of Murcia

<sup>2</sup>University of Salerno

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Corresponding Author: Sara Aliberti, E-mail: saliberti@alu.ucam.edu

Accepted for Publication: June 11, 2023

Published: June 30, 2023

DOI: 10.17309/tmfv.2023.3.20

### Abstract

**Study purpose.** The increasing amount of research in Exercise and Sport Sciences emphasized the use of increasingly heuristic statistical tools appropriate to the aim in terms of qualitative, quantitative, and qualitative-quantitative data. Often, a lack of knowledge of statistical tools and their appropriateness for data analysis, especially between the use of parametric and non-parametric statistical techniques, is encountered by researchers. This requires the indispensable use of statistical experts, who, for the comprehensive understanding of the research design, need the use of human and economic resources that could probably be used differently and more efficiently. The aim of this study was to provide a list of the most used statistical methods in Exercise and Sport Sciences, focusing on the distinction between parametric and non-parametric statistical processing for both quantitative and qualitative research.

**Materials and methods.** The method was the literature review with argumentative elaborations concerning the validity of the use of the statistical tools.

**Results.** A total of 22 statistical tools, both parametric and non-parametric, were found: 5 useful to test relationship, 7 to compare two groups and 10 to compare two or more groups. For each statistical tool, a scientific paper related to Exercise and Sport Sciences was collected.

**Conclusions.** These data allow developing potential guidelines, applying to Exercise and Sport Sciences, for the rigorous model of research projects with a systematic use of statistical processing in the complete hypothesis of the study.

**Keywords:** statistical analysis, parametric, non-parametric, guidelines, researchers, training.

### Introduction

The increasing amount of research in the Exercise and Sport Sciences (ESS) field emphasized the use of increasingly heuristic statistical tools appropriate to the aim in terms of qualitative, quantitative, and qualitative-quantitative data. The ability to assess performance, using tests, to derive information related to the effectiveness of training protocols, to determine the relationship between certain parameters, or simply to get feedback on the state of the athlete is a quality that is increasingly in demand in the sports field (Rojas-Valverde et al., 2020). Statistical and methodology errors are very common in sports science research (Sainani & Chamari, 2022). Expert researchers in the field of ESS often lack adequate formation in the use of statistical tools and

their appropriateness for data analysis, especially among the use of parametric and non-parametric statistical techniques.

Another problem concerns the recruitment by journals of peer reviewers who are responsible for improving the quality of manuscripts for publication by eliminating serious methodological errors (Altman, 2002; Schroter et al., 2008). Journals do not check the competence of peer reviewers, who often pass over the statistical section, because they do not consider themselves capable to give an opinion about it. As a result, several manuscripts may be published with a statistical misapplication, which is replicated by other researchers, starting a vicious cycle that results in the publication of manuscripts with a low methodological quality. For example, a very common basic error is not reporting the assumption of data normality, a necessary requirement for the application of parametric tests (Kamuk, 2020). In fact, in case of non-normally distributed data, non-parametric statistics should be applied. Inappropriate use of

statistical tools leads to misinterpretation of data (Mishra et al., 2019).

To overcome these problems, the scientific literature recommended increasing the collaboration among researchers and statisticians. Including experienced statisticians in the research team could help improve the design and quality of data analysis. In a systematic review conducted by Sainani et al. (2021), only 13.3% of the articles selected in 2019 in ESS field had a co-author affiliated with a department of biostatistics, statistics, data science, data analysis, epidemiology, mathematics, computer science, or economics. Very often, this collaboration did not seem to be successful. Difficulties in communication may arise because statisticians, in most cases, were not experts in the ESS field epistemology (Raiola et al., 2018; Raiola, 2019ab; Raiola, 2020). As a result, they must argue with the researcher for a different interpretation of the results obtained from statistical processing. In fact, statisticians tend to be more cautious regarding the interpretation of the data or a statistical significance. Thus, the full understanding of the research design required the use of human and economic resources that could probably be used differently and more efficiently. Another suggestion to overcome this problem was to improve statistical training within ESS degree programs (Sainani et al., 2021). The literature suggested that to improve the quality of research, a change at the institutional level was needed (Smaldino & McElreath, 2016). Researchers can attempt to learn applied statistics through university lectures, but also through guidelines with practical examples in the ESS field. This would also save human and economic resources.

Consequently, the aim of this study was to provide a list of the most used statistical methods in the ESS field, focusing on the distinction between parametric and non-parametric statistical processing for both quantitative and qualitative research. The utility was to provide guidelines to researchers, so as to facilitate the choice of statistical tool, based on the objective to be achieved through practical examples in ESS field.

## Materials and methods

### Materials for analysis

The method was the literature review with argumentative elaborations concerning the validity of the use of the statistical tool. Scholar was used as a database to search the articles, who are selected based on the author's area of expertise (ESS). The keywords used were "sports science" "training" "exercise" "statistics" "parametric" "non-parametric".

### Organization of the study

After the article of interest was identified, we proceeded with the analysis of the research method, going on to identify the variables examined, the statistical tool and the objective of the study. Correlational, comparative and experimental studies were included. Descriptive studies were excluded because they did not involve the use of statistical tests.

### Methods of analysis

Synoptic tables schematized the characteristics of the included studies with their statistical tools. Specifically, statistical tools, both parametric and non-parametric, with their own assumptions and a practical example in ESS field, were reported.

## Results

About 22 articles were examined. For each statistical tool (parametric and non-parametric) a scientific article relating to ESS was selected. Statistical tools, with their meaning, assumptions to be met and an example of a study in the ESS field are included in tables, divided into three categories: testing relationships, comparing two groups, comparing more than two groups. Table 1 showed the statistical tools

**Table 1.** Statistical tools to test relationships

	Aim	Assumption	Statistical tool	Example
Testing relationships		Linearity; normality; no sig. outliers; 2 related continuous v.	Pearson	To assess the relationship between the different COD tests (Pereira et al., 2018).
	To measure the strength and direction of relationship between 2 v.	NPA; monotonic relationship; at least 1 ordinal v.	Spearman	To examine the association between BMI and MC (Lopes et a., 2012).
		NPA; monotonic relationship; ordinal/continuous v.; small sample size	Kendall	To explore the correlation between anxiety, motivation, and others c.v. (Ruffault et al., 2020).
	Predictive analysis to explain the relationship between 1 d.v. and 1/ more i.v.	Linearity; normality; no sig. outliers; independence; homogeneity of variances; large sample size; quantitative/ dichotomous i.v.	Regression	To assess the predictive capacity of psychological profile on competitive anxiety, moods and self-efficacy in handball players (Reigal et al., 2020).
	To test the relationship between 2 v.	NPA; independence; large sample size (Chi Square); low sample size (Fisher); 2 categorical v. (at least of 2 levels)	Chi Square / Fisher	To compare differences in inclusion perceptions between 2 types of dancesport athletes and sociodemographic factors (Aliberti et al., 2022).

Note: BMI, body mass index; COD, change of direction; d.v., dependent variable; i.v., independent variable; MC, motor coordination; NPA, non-parametric assumptions; v, variable /s

**Table 2.** Statistical tools to compare two groups

	<b>Aim</b>	<b>Assumption</b>	<b>Statistical tool</b>	<b>Example</b>
Comparing 2 groups	To compare the sample mean with a standardized/hypotetical value	Normality; no sig. outliers; independence; 1 continuous d.v.	One Sample t-test	To determine the difference between the mean/median of motor score with a standardized value (Alsaedi, 2020).
	To compare the median sample with a standardized/hypotetical value	NPA; 1 continuous v.	Wilcoxon One Sample Signed-Rank test	
	To compare the mean differences between 2 paired measurements/ conditions or 2 halves/side of a subject	Normality; no sig. outliers; 1 continuous d.v.; 1 i.v. (2 categorical levels); related groups	Paired Samples t-test	To determine the difference between pre-post running in terms of jump height (Yu et al., 2020).
	To compare the medians between 2 paired measurements/ conditions	NPA; related groups; 1 ordinal/continuous d.v.; 1 i.v. (2 categorical levels)	Wilcoxon Signed-Rank test	To compare the function of the dominant and non-dominant hands (Armstrong & Oldham, 1999).
	To compare the mean differences between 2 different groups	Normality; no sig. outliers; independence; homogeneity of variances; 1 continuous d.v.; 1 i.v. (2 categorical levels); unrelated groups	Independent Samples t-test	To investigate the effects of latin dance (respect to non latin-dancers) on postural control, stability, and dynamic balance (Kiliç & Nalbant, 2022).
	To compare the mean ranks between 2 different groups	NPA; independence; 1 continuous/ordinal d.v.; 1 i.v. (2 categorical levels); unrelated groups	Mann–Whitney U test	To examine the impact of gender on hand dexterity (Haward & Griffin, 2002).
	To test differences on a dichotomous d.v. between 2 related groups	NPA; 1 dichotomous d.v.; 1 categorical i.v. with 2 related groups	McNemar's test	To compare the score of some questionnaires assessing physical activity, quality of life and sleep before and during pandemic (Wingerson et al., 2021).

Note: d.v., dependent variable; i.v., independent variable; NPA, non-parametric assumptions; v, variable /s

that have the objective of testing relationships between variables, including Pearson, Spearman, Kendall, Regression and Chi Square/Fisher.

Table 2 contained the statistical tools intended to compare two groups, including One Sample t-test, Wilcoxon One Sample Signed-Rank test, Paired Samples t-test, Wilcoxon Signed-Rank test, Independent Samples t-test, Mann–Whitney U test and McNemar's test.

Table 3 showed the statistical tools aimed to compare two or more groups including One-way ANOVA, Kruskal-Wallis One-way ANOVA, One-way repeated measures ANOVA, Friedman test, Cochran's Q test, One-way ANCOVA, Two-ways ANOVA, Two-way repeated measures ANOVA and multivariate analysis, comprising One-way MANOVA and One-way MANCOVA.

## Discussion

The present literature review aimed to collect the most used statistical tools, both parametric and non-parametric, in ESS field, explaining their meaning, usefulness and requirements for use, concluding with an application example for each one. We started from the simple relationship to the comparison of two or more groups. The first step, when collecting data, is the calculation of descriptive statistics, which allow us to collect, summarize and interpret data through coefficients, including central tendency and dispersion indices, and the observation of graphs. This step

allows us to figure out which statistical tool to choose if our goal is to go beyond describing the data. The next step is inferential statistics, which allow us to generalize the results obtained from data collected on a sample to the population from which it was drawn. They are used to test hypotheses and to make population estimates. There are two types of tests: parametric and non-parametric. The choice depends on the objective, the nature of the data and the testing of assumptions. Parametric tests, to be applied require several assumptions, as shown in the tables, the most important of which are normality of data, homogeneity of variances, and a large enough sample. When the data violate one of the assumptions, non-parametric tests, also called distribution-free, are used.

1. Pearson correlation ( $r$ ) is a parametric measure that produces a correlation coefficient that measures the strength ( $\pm 1$ ) and direction (increasing/decreasing) of linear relationships between pairs of continuous variables. The non-parametric counterpart is the Kendall or Spearman coefficient for nonnormal distributions by calculating ranks of the data (Akoglu, 2008). It is therefore useful for testing how one variable varies as the other varies, such as between different ability tests or between coordination and body mass index (BMI) (Lopes et al., 2012; Pereira et al., 2018).

2. Regression analysis is a predictive analysis to explain the relationship between a dependent variable and one or more independent variables, for example the capacity of psychological profile on competitive anxiety, moods, and

**Table 3.** Statistical tools to compare two or more groups

	Aim	Assumption	Statistical tool	Example
Comparing more than 2 groups (1 i.v.)	To compare the mean differences of more than 2 groups	Normality; no sig. outliers; independence; homogeneity of variances; 1 i.v. (2/more categorical levels); 1 continuous d.v.	One-Way ANOVA	To test the differences in postural control in 3 groups: judoists, dancers and CON group (Perrin et al., 2002).
	To compare the mean ranks of more than 2 groups	NPA; independence; 1 i.v. (2/more categorical levels); 1 ordinal/continuous d.v.	Kruskal-Wallis One-Way ANOVA	To verify the impact of age (3-level) on performance of the Moberg Pick-Up Test (Amirjain et al., 2007).
	To compare the mean differences between 2/more related groups	Normality; no sig. outliers; sphericity; 1 continuous d.v.; 1 i.v. (2/more categorical levels); related groups	One-way repeated measures ANOVA	To investigate the effect of an 11-week intervention of classical ballet and contemporary dance training on hip extensor flexibility and strength (Di Pasquale & Wood, 2017).
	To compare the mean ranks of 2/more related groups	NPA; 1 group measured 3/more times; 1 ordinal/continuous d.v.	Friedman test	To compare humor subscales of 3 basket matches (Pinto et al., 2022).
	To test differences on a dichotomous d.v. between 3/more related groups	NPA; related groups; large sample size; 1 dichotomous d.v.; 1 i.v. (3/more categorical levels)	Cochran's Q test	To test the changes in physical activity and its importance in 3 different time-points in elderly (Lefferts et al., 2022).
Comparing more than 2 groups (2 i.v.)	To test the adjusted mean differences between 2/more i. groups (unrelated) on a d.v.	The same of one way-ANOVA + 1/more continuous cov.; linearity between cov. and d.v.; homogeneity of regression slopes; homogeneity of cov.	One-way ANCOVA	To compare the changes in agility between 2 groups, EXP (plyometric) and CON, using pre-test scores as covariate (Chtara et al., 2017).
	To compare the mean differences between groups split into 2 factors	The same of one-way ANOVA + 2 i.v. (2/more categorical levels)	Two-ways ANOVA	To compare changes in YBT-LQ among athletes with gender and sports classification (one vs. multiple) as i. factors (Gorman et al., 2012).
	To compare the mean differences between related groups split into 2 factors	The same of one-way repeated measures ANOVA + 2 within-subjects factors (2/more categorical levels)	Two-ways repeated measures ANOVA	To compare the effect of a 12-week low-volume HIIT training (EXP and CON) on body composition, strength, balance, and mobility (García-Pinillos et al., 2019).
Comparing i. groups on more than 1 d.v.	To simultaneously compare the means of multiple d.v. across 2/more i. groups	Normality; no sig. outliers; homogeneity; large sample size; independence; 2/more continuous d.v.; 1 i.v. (2/more categorical levels)	One-way MANOVA	To determine differences in SMS subscales between competitive and non-competitive windsurfers (Modroño & Guillén, 2016).
	To simultaneously compare the adjusted mean differences of multiple d.v. across 2/more i. groups	The same of one-way ANCOVA + 2/more continuous d.v.	One-way MANCOVA	To examine difference between medallist and non medallist fencers in anthropometry, PP and MC, using maturity and chronological age as cov. (Norjali et al., 2018).

Note: CON, control; cov., covariate /s; d.v., dependent variable; EXP, experimental; HIIT, high intensity interval training; i.v., independent variable; MC, motor coordination; NPA, non-parametric assumptions; PP, physical performance; sig., significant; SMS, sport motivation scale; v, variable /s; YBT LQ, Lower Quarter Y Balance Test

self-efficacy in handball players (Reigal et al., 2020). Then there are different types of regressions depending on the variables collected and the objective.

3. Chi Square is a non-parametric independence test that crosses two variables through a cross table with the objective of testing for dependence. It is useful for processing questionnaire responses or comparing differences in perceptions between two samples. One example is to analyze differences in perceptions between athletes with and without disabilities toward sports inclusion (Aliberti et al., 2022).

Fisher's test has the same function but is used when there is a value less than 5 in the adjacency table. The Chi Square is often accompanied by Phi ( $\phi$ ), Cramer's V (V) or odds ratio (OR), to quantify the strength of the association identified (Kim, 2017).

4. Several t-test students were found. The first is the one-sample t-test, useful to compare the sample mean with a standardized/hypothetical value. The non-parametric is Wilcoxon One Sample Signed-Rank test. The most used measure of effect size for a t-test is the Cohen's d (Cohen, 1998).

5. The paired dependent samples t-test compares the mean differences between two paired measurements/conditions or two halves/side of a subject. For example, it can be used to test for the existence of a difference in pre-test post-test scores, difference in measurements taken under two different conditions in the same subject, difference in measurements taken from two halves or sides of a subject. The analogous non-parametric test is the Wilcoxon Signed-Ranks test.

6. The independent samples t test compares the mean differences between two different groups. The non-parametric versions is the Mann-Whitney U test. An example can be comparing postural control, stability, and dynamic balance in Latinists versus non-Latinists (Kiliç & Nalbant, 2022).

7. McNemar test is used to test differences on a dichotomous variable between two related groups. Practically, it measures the consistency in responses across two variables for example the difference in dichotomous answers of some variables before and during pandemic (Wingerson et al., 2021).

8. One-way ANOVA compares the means of two or more independent groups. For example, it is used to test for differences in postural control in three different groups of athletes (Perrin et al., 2002). Only in the case of significance is the post hoc test such as, for example, the Bonferroni post-hoc considered because the ANOVA is an omnibus test, i.e., it does not specify between which groups there is significance; consequently, post hoc allows for rotational comparisons between groups. The analogous non-parametric test is the Kruskal-Wallis One-way ANOVA. Partial eta squared ( $\eta^2$ ) is the most commonly way to measure the effect size of different variables in ANOVA models (Richardson, 2011).

9. One-way ANOVA with repeated measures is used to compare three or more groups composed of the same subjects. For example, it can be useful when we want a pre - in itinere and post intervention group, like three basket matches, to verify the changes in humor (Pinto et al., 2022). The non-parametric version is the Friedman test.

10. Cochran's Q test is used to determine whether there are differences on a dichotomous dependent variable (2-level like yes/no) between three or more related groups. For example, it is used in longitudinal studies (differences over time). An example would be to test the changes in physical activity practice and its importance in three different time-points (Lefferts et al, 2022).

11. One-way ANCOVA (analysis of covariance) is an extension of one-way ANOVA to incorporate a covariate. The covariate is a variable that can influence the results, consequently, it is included in the statistical calculation to control for it. An example of a covariate might be the pretest score of a physical test, when the objective of the study is to compare the changes in agility between two groups (Chtara et al., 2017).

12. Two-way ANOVA is used to test the interaction between the two independent variables, for example the gender and sports classification, on the dependent variable, like balance test (Gorman et al., 2012). Then, the ANOVA can be three-way or more-way, depending on the number of independent variables.

13. Two-way ANOVA for repeated measures is used to compare mean differences between groups that have

been divided on two within-subjects' factors. It is one of the most widely used instruments in experimental studies with pre-test post-test design with control group. An example of a study is testing the effect of a 12-week low-volume HIIT training (experimental and control group) on body composition, strength, balance, and mobility (García-Pinillos et al., 2019) where the two within-subjects variables are time x conditions.

14. Finally, we have included an example of multivariate analysis, starting with the one-way MANOVA, used to determine whether differences exist between independent groups on more than one continuous dependent variable. One example is to test the differences between competitive and non-competitive windsurfers on sports motivational scale score (Modroño & Guillén, 2016). MANOVA can be two or more way, depending on the number of independent variables.

15. One-way MANCOVA, on the other hand, is an extension of the one-way MANOVA that incorporate a covariate, like ANCOVA. An example is to examine the difference between medalist and non-medalist fencers in physical performance, coordination, and anthropometry, using maturity and chronological age as covariate (Norjali et al., 2018).

## Conclusions

This study collected the most useful statistical tools in the ESS field by explaining their meaning, assumptions, non-parametric version, and a practical example for a better understanding of their application. Future studies could further explore the application of each statistical tool in the ESS field. An institutional change is required to better prepare future researchers by proposing university courses (D'Elia, 2019; D'Isanto, 2019; D'Isanto et al., 2022) aimed to improve the knowledge and application of statistical tools according to the objective. Meanwhile, these data allow the predisposition of potential guidelines, applying to ESS, for the rigorous model of research projects to systemic utilize of statistical processing in the complete hypothesis of the study. Furthermore, the study aims to urge researchers to first investigate the nature of the data, and then test the assumptions necessary to be able to apply a statistical tool, which may be parametric or non-parametric.

## Conflict of interest

The authors declare no conflict of interest.

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## ПОРАДИ ЩОДО СТАТИСТИЧНИХ ІНСТРУМЕНТІВ ДЛЯ МЕТОДІВ ДОСЛІДЖЕННЯ В ГАЛУЗІ ФІЗИЧНИХ ВПРАВ І СПОРТИВНИХ НАУК

Сара Аліберті<sup>1ABCD</sup>, Франческа Д'Елія<sup>2ABCE</sup>, Домініко Керубіні<sup>1ABCD</sup>

<sup>1</sup>Католицький університет Святого Антонія

<sup>2</sup>Університет Салерно

Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; Е – збір коштів

Реферат. Стаття: 12 с., 2 табл., 1 рис., 43 джерела.

**Мета дослідження.** Зростаюча кількість досліджень у галузі фізичних вправ і спортивних наук надала особливого значення використанню дедалі більш евристичних статистичних інструментів, які відповідають меті з погляду якісних, кількісних та якісно-кількісних даних. Часто дослідники стикаються з браком знань про статистичні інструменти та їх придатність для аналізу даних, особливо між використанням параметричних і непараметричних статистичних методів. Це вимагає обов'язкового залучення статистичних експертів, які для всебічного розуміння схеми проведення дослідження потребують використання людських та економічних ресурсів, які, імовірно, можна було б використати інакше та ефективніше. Метою цього дослідження було наведення переліку статистичних методів, які найчастіше використовують у галузі фізичних вправ і спортивних наук, зосереджуючи увагу на відмінності між параметричною та непараметричною статистичною обробкою як для кількісних, так і для якісних досліджень.

**Матеріали та методи.** Методом був огляд літератури з аргументованими уточненнями щодо обґрунтованості використання таких статистичних інструментів.

**Результати.** Загалом було знайдено 22 статистичні інструменти, як параметричні, так і непараметричні: 5 корисних для перевірки наявності зв'язку, 7 – для порівняння двох груп і 10 – для порівняння двох або більше груп. Для кожного статистичного інструменту була підібрана наукова стаття, пов'язана з фізичними вправами та спортивними науками.

**Висновки.** Ці дані дозволяють розробити потенційні рекомендації, що стосуються фізичних вправ і спортивних наук, для суворой моделі дослідницьких проєктів із систематичним використанням статистичної обробки в повній гіпотезі дослідження.

**Ключові слова:** статистичний аналіз, параметричний, непараметричний, рекомендації, дослідники, навчання.

**Information about the authors:**

**Aliberti, Sara:** s.aliberti17@studenti.unisa.it; <https://orcid.org/0000-0002-2470-4032>; Department of Physical Activity and Sports Science, Catholic University of Murcia, Av. de los Jerónimos, 135, Guadalupe 30107, Murcia, Spain.

**D'Elia, Francesca:** fdelia@unisa.it; <https://orcid.org/0000-0003-1441-8101>; Department of Human, Philosophical and Education Sciences, University of Salerno, Via Giovanni Paolo II, 132, 84084 Fisciano SA, Italy.

**Cherubini, Domenico:** dcherubini@ucam.edu; <https://orcid.org/0000-0002-5207-7558>; Department of Physical Activity and Sports Science, Catholic University of Murcia, Av. de los Jerónimos, 135, Guadalupe 30107, Murcia, Spain.

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**Cite this article as:** Aliberti, S., D'Elia, F., & Cherubini, D. (2023). Tips for Statistical Tools for Research Methods in Exercise and Sport Sciences. *Physical Education Theory and Methodology*, 23(3), 470-477. <https://doi.org/10.17309/tmfv.2023.3.20>

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Received: 16.05.2023. Accepted: 11.06.2023. Published: 30.06.2023

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