

Systematic Review

Trends and techniques: a statistical review of hair care product evaluation research

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ABSTRACT

The growing interest in hair care products has led to an increase in clinical studies assessing their safety and efficacy. As statistical analysis plays a critical role in validating study outcomes, it is essential to evaluate the appropriateness and reporting quality of these methods. This review systematically examines the statistical techniques used in human clinical trials on hair care to assess their suitability, consistency, and transparency. A comprehensive search of the PubMed database identified 22 eligible studies published between January 2020 and April 2025, in accordance with PRISMA guidelines. Key data extracted included study design, sample size, outcome measures, and statistical methods employed. The most frequently used techniques included the Shapiro-Wilk test for normality assessment; paired and independent t-tests; Wilcoxon signed-rank and Mann-Whitney U tests for group comparisons; and Chi-square or Fisher's exact tests for categorical data. More complex studies incorporated repeated measures ANOVA, ANCOVA, or linear mixed-effects models to manage longitudinal or multivariable data. While the majority of studies applied statistically appropriate methods, significant variation was observed in the reporting of test assumptions, effect sizes, and justification for statistical choices. Such inconsistencies may limit the reproducibility and interpretability of findings. This review highlights the need for improved standardization and transparency in the application and reporting of statistical methods in hair care research to strengthen the quality, reliability, and comparability of future clinical evidence.

Keywords: Hair growth, Hair loss, Hair thickness, Hair density, Androgenic alopecia, Female pattern hair loss

INTRODUCTION

Hair growth, hair thickness, hair density, anagen-telogen (A/T) ratio, and various scalp and hair conditions are key parameters commonly assessed in hair care research. As consumer demand for effective hair care products continues to grow, the need for robust clinical trials becomes increasingly important. These studies are critical for assessing both the safety and efficacy of hair care products. Within this context, statistical analysis plays a central role not only in validating outcomes but also in ensuring the accuracy, reproducibility, and interpretability of the generated scientific data.

In clinical research, the selection of appropriate statistical tests is guided by the type of data, distribution assumptions, study design, and specific research objectives. A biostatistician plays an important role in this process, ensuring methodological rigor from study design through to data analysis and interpretation. The Shapiro Wilk test is commonly used as a preliminary step to evaluate the normality of continuous data.¹ This is crucial for determining whether parametric or non-parametric methods should be applied. For within-group comparisons, the paired t-test is used when data are normally distributed, whereas the Wilcoxon signed-rank test serves as its non-parametric counterpart.^{2,3} These

tests help assess changes in outcomes such as hair density, thickness, or gloss from baseline to post-treatment within the same group of participants. To compare two independent groups, the independent t-test is used for normally distributed data, while the Mann Whitney U test is applied when normality is not assumed. These tests are often employed to compare treatment and control groups in terms of hair growth or fall parameters. For categorical data, the Chi-square test and Fisher's exact test are used to evaluate proportions or frequencies between groups.^{4,5} These are essential when analysing responder rates or adverse event occurrences. In studies involving repeated measurements over time, more advanced approaches such as Repeated Measures ANOVA and linear mixed models are applied to account for intra-subject variability and the interaction between treatment and time. ANCOVA is also used to adjust for baseline imbalances or confounding variables, thereby improving the precision of effect estimates.⁶

Despite the availability of these well-established methods, variability persists in how they are applied and reported across clinical studies in hair research. Some trials provide limited explanation for the selection of statistical tests or fail to report diagnostic checks such as normality or homogeneity of variance testing. Additionally, few studies consistently report effect sizes or conduct power analyses, which are important for assessing the clinical relevance and robustness of statistical findings.

This review was conducted to systematically evaluate the statistical methodologies employed in clinical studies of hair care products published between 2020 and 2025. By analysing the types of statistical tests used, their appropriateness based on study design, and reporting practices, this review aims to provide a comprehensive overview of current trends and highlight areas for improvement. Strengthening the application and reporting of statistical methods is vital to improving the quality and credibility of research in the field of hair science.

METHODS

This systematic review was conducted in accordance with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. The objective was to synthesize and analyse the statistical methodologies employed in hair care research studies.

A comprehensive literature search was performed using the PubMed database. The search strategy combined medical subject headings (MeSH) and relevant keywords related to hair care and statistical methodologies. The keywords used included "hair growth", "hair loss", "hair thickness", "hair density", "androgenic alopecia" and "female pattern hair loss." The search was limited to articles published between January 2020 to April 23, 2025.

The initial search yielded 442 articles. After the removal of 247 duplicate entries, 195 unique articles remained. These articles underwent a two-step screening process: (1) title and abstract screening 22 articles were included, followed by (2) full-text reviews. 22 were included by particular attention paid to whether the statistical methods were clearly described or not. Based on the inclusion and exclusion criteria, 420 articles were excluded. Ultimately, 22 studies were included in the final review, and detailed data extraction was conducted on 22 of these studies.

Inclusion criteria encompassed all full-text articles of prospective clinical trials with outcome data available involving human subjects in hair care studies and descriptions of statistical methods mentioned in articles. Exclusion criteria were non-human studies, pediatric populations, non-English publications, studies without a statistical section, studies with incomplete or missing data, and unpublished or non-peer-reviewed data.

Information collected included study characteristics (title, authors, publication year, journal, study design, sample size), patient characteristics (age and sex), intervention details (statistical methods), and outcomes (incidence, efficacy measures, safety). We systematically recorded results, including main findings.

All data were systematically recorded, and findings were synthesized to identify trends and common statistical approaches in hair care research. The results were reported according to PRISMA guidelines, including a flow diagram outlining the study selection process and tables summarizing the key characteristics and findings of the included studies.

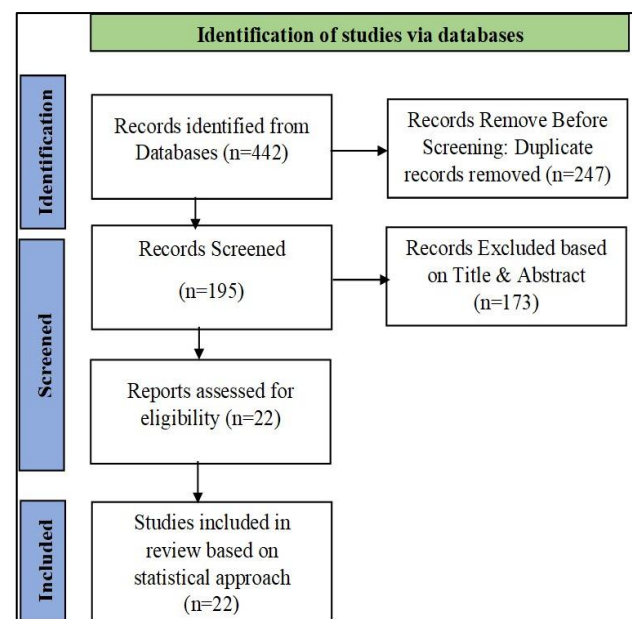


Figure 1: PRISMA flow diagram.

*These 22 articles listed include only those focusing on statistical approaches and do not cover articles related to introductory or background sections.

RESULTS

A variety of statistical methodologies were employed across the included 22 studies, tailored to data type, study design, and research objectives.

In a study involving 100 participants, continuous variables were analysed to evaluate hair loss, hair quality, and scalp microbiota parameters. The Shapiro Wilk test was used to assess data normality, which revealed significant deviations from a normal distribution. As a

result, non-parametric Mann-Whitney U test was used for between-group comparisons, and parametric paired t-test was used for within-group analyses.¹ In a study with 80 participants on saw palmetto oil, categorical variables like hair thinning areas and self-assessments analysed using Chi-square tests. Normality was checked with Shapiro-Wilk test, guiding within-group comparisons via paired t-tests or Wilcoxon signed-rank tests. Between-group comparisons of hair comb and pull test scores, hair density, thickness, and A/T ratio used independent t tests or Mann-Whitney U tests based on data distribution.⁷

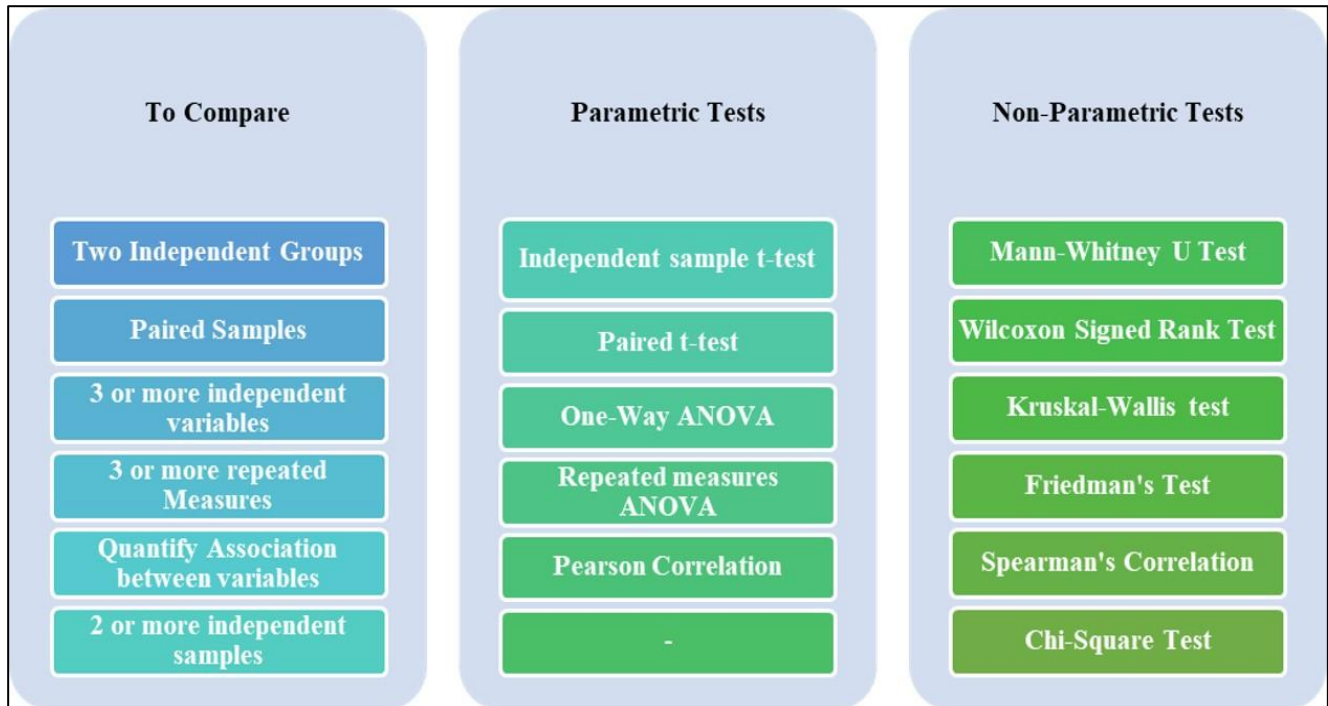


Figure 2: Classification of statistical procedure.

In a double-blind study of ADSC-CM plus minoxidil for hair regeneration in 34 males with AGA, normality of continuous variables (anthropometrics, age, alopecia onset, trichoscan results) was assessed with the Shapiro-Wilk test. Baseline comparisons used independent t-tests or Mann-Whitney U tests, while categorical data (Hamilton-Norwood grade, medical history, treatments, smoking, complaints, satisfaction) were analysed with Chi-square or Fisher's exact tests. Within-group changes were evaluated by paired t-tests or Wilcoxon signed-rank tests, and percent hair growth changes were compared using one-way ANOVA or Kruskal-Wallis tests.⁸ In a trial with 66 females comparing topical cetirizine plus minoxidil to placebo plus minoxidil, qualitative hair growth data were reported as frequencies (%) and quantitative data (density, thickness) as mean±SD. Between-group comparisons used t-tests, and categorical data were analysed with Chi-square, Fisher's exact, or Mann-Whitney U tests. Within-group changes in hair follicles were assessed by repeated measures ANOVA and mixed-effects RM-ANOVA evaluated time, group, and interaction effects.⁹

In a review article involving 136 subjects, the Shapiro Wilk test was used to assess normality, and homoscedasticity was tested using either the F-test or Fligner test. Group differences were analysed using the Mann Whitney U test and the Wilcoxon rank-sum test for hair density, hair count, hair length, and hair thickness parameters, and the PERMANOVA test is used to check the difference in diversity level between the control and probiotic treatment.² In a study of 88 participants, hair density, thickness, and gloss were evaluated from baseline to post-baseline using either the paired t-test or the Wilcoxon rank-sum test.¹⁰ In a randomized placebo-controlled study with 100 participants, the efficacy of *Gynostemma pentaphyllum* extract was assessed via hair elasticity, glossiness, hair count, diameter, and satisfaction scores. Independent t-tests compared groups, while paired t-tests assessed within-group changes. Repeated measures ANOVA or linear mixed models analysed variables like glossiness, and ANCOVA was used to adjust for confounders.¹¹

In a randomized open-label study with 64 AGA patients, chi-square tests compared responder rates between standardized non-activated PRP and topical minoxidil via global photography. Changes in hair count, density, and anagen hair at 12 weeks were analysed with paired t-tests, while between-group comparisons used independent t-tests or Mann-Whitney tests.⁴ In a study of 30 participants, within-group changes from week 0 to week 16 for hair growth parameters were analysed using paired-sample t-tests. Between-group comparisons were done using the Mann Whitney U test. ANOVA was also employed to compare pre- and post-intervention outcomes within groups.¹² In a double-blind, vehicle-controlled study of hair regeneration with 44 participants, changes in total hair count and thickness were the primary outcomes. Normality was tested with Shapiro-Wilk. Between-group comparisons of hair count and diameter used t-tests or Mann-Whitney U tests. Investigator photo assessments were analysed by Chi-square or Fisher's exact tests. Within-group changes used paired t-tests or Wilcoxon tests. Repeated measures ANOVA evaluated changes over time, and ANCOVA adjusted for baseline differences in hair count when comparing groups.⁵

In a sham device-controlled trial with 80 participants, quantitative data were reported as mean $\pm$ SD and analysed using independent t-tests. Categorical variables were presented as frequencies (%) and assessed using Chi-square or Fisher's exact tests. Changes in hair density and thickness were evaluated with t-tests and ANCOVA, adjusting for age, sex, site, and their interactions. Satisfaction scores were analysed using ANCOVA and repeated-measures ANOVA with similar adjustments.¹³

In this randomized, double-blind, placebo-controlled study of BiovaBio™ 450 mg oral product, continuous variables included age, weight, height, and BMI, while categorical variables comprised sex, race, and ethnicity. Changes from baseline within each group were analysed using either the paired t-test or the Wilcoxon signed-rank test, depending on data distribution. Comparisons of changes from baseline between groups were conducted using the two-sample t-test or the Wilcoxon rank-sum test. Differences in proportions between groups were assessed using Fisher's exact test for small sample sizes; otherwise, the chi-square test was applied.¹⁴ In a phase 3 randomized trial for androgenic alopecia, data were analysed using a mixed linear model for repeated measures (MMRM), with treatment, centre, visit, and treatment-by-visit interaction as fixed effects, and baseline hair count as a covariate.¹⁵ In another study of FPHL, differences in terminal hair rate, hair density, and hair diameter between baseline and weeks 12 and 24 were evaluated using paired t-tests. Between-group comparisons for various hair study parameters were performed using one-way ANOVA, while categorical data were analysed with the Chi-square test.¹⁶

In a study comparing magnesium to placebo, qualitative alopecia variables were analysed using the Chi-square

test and reported as percentages. Paired t-tests were used for within-group comparisons, while independent t-tests assessed differences between groups. ANCOVA was applied to adjust for baseline serum magnesium, energy intake, and initial values.¹⁷ In this androgenetic alopecia study, analysis of hair density and total hair count parameters used statistical tests for within-group comparisons, which were the paired t-test and Wilcoxon signed-rank test. Between-group mean differences were commonly evaluated using the independent t-test or Mann Whitney U test.³ In the hair growth study, changes in hair count, width, and growth at week 24-were analysed using a mixed linear model for repeated measures, with treatment, centre, visit, and treatment-by-visit interaction as fixed effects, and baseline hair count as a covariate. Correlation between repeated measures was modelled, and treatment differences at week 24 were estimated with 95% confidence intervals using the Newton-Raphson algorithm.¹⁸ In this safety and efficacy of a nutraceutical in improving hair growth and quality in men with thinning hair study, hair growth and quality parameters were analysed using Student's t-tests for paired samples, while between-group comparisons used independent-sample t-tests. Proportions and categorical measures were assessed using the Chi-square or Fisher's exact test. Repeated outcome measurements at baseline, day 90, and day 180 were analysed using ANCOVA with Tukey's HSD post hoc tests.¹⁹

In this androgenetic alopecia botulinum toxin treatment study, Normality was evaluated using the Shapiro-Wilk test. For normally distributed data comparisons of follicle counts and average follicle width between groups were conducted using the independent-samples t-test. Repeated measures ANOVA and post hoc multiple comparisons were used to assess differences between the botulinum toxin and control groups at various time points before and after treatment. Data that were not normally distributed were reported as median (interquartile range), with between-group differences analysed using the nonparametric Mann-Whitney U-test. Categorical variables were expressed as frequencies, and comparisons of distributions were made using the chi-square test or Fisher's exact test where appropriate.²⁰ In one study, comparisons over time were conducted using the non-parametric Friedman and Wilcoxon tests. Between-group comparisons of quantitative variables used the Mann Whitney U test, and categorical variables were analysed using the Chi-square or exact test. Linear regression was used to adjust for age and disease duration, and Spearman correlation tested associations between quantitative variables (baseline beta catenin level and change in beta catenin level).²¹

In this phase 2a oral setipiprant vs. placebo study on scalp hair growth, ANCOVA models with treatment as a fixed effect and age as a covariate assessed LS mean changes and differences for TAHC, SSA, and IGA endpoints. Baseline values were included as a covariate for TAHC. Type III sum of squares and two-sided t-tests determined significance. Missing data for coprimary

endpoints (TAHC, SSA) were imputed using last-observation-carried-forward up to week 24; no imputation was done for IGA.⁶ In a comparative study of fractional CO₂ laser alone vs. with topical dutasteride, quantitative variables vellus hair, terminal hair, diameter diversity, and single pilosebaceous unit-were analysed using Kruskal-Wallis and Mann-Whitney U tests; within-

patient comparisons used the Wilcoxon signed-rank test. Categorical variables peripilar sign, yellow dot, and black dot were assessed using the Chi-square or exact test, with repeated measures analysed via the McNemar test. Spearman correlation was used to assess relationships in photographic evaluations between groups.²²

Table 1: Statistical tests and study findings.

Statistical test	Study findings	References
Shapiro Wilk test	Hair comb, pull test scores, hair density, hair thickness, A:T ratio, hair loss, hair quality, scalp microbiota parameters	1, 5, 7, 8 and 20
Independent t test	Hair comb, pull test scores, hair density, hair thickness, A:T ratio, hair loss, hair quality, scalp microbiota parameters, hair elasticity, satisfactory score, hair diameter	1, 3-9, 11, 13, 14, 17, 19 and 20
Paired t test	Hair comb, pull test scores, hair density, hair thickness, A:T ratio, hair loss, hair quality, scalp microbiota parameters, hair gloss, hair elasticity, satisfactory score, terminal hair rate	1, 3-5, 7, 8, 10, 11, 12, 14, 16, 17 and 19
One-way ANOVA	Hair growth rate	8, 12 and 16
Repeated measures ANOVA	Hair follicle, hair glossiness, hair count, satisfaction score	5, 9, 11, 13, 15, 18, 19 and 20
Mann-Whitney U test	Hair comb, pull test scores, hair density, hair thickness, A:T ratio, hair loss, hair quality, scalp microbiota parameters, hair count, hair length, hair diameter	1-5, 7, 9, 12, 20-22
Wilcoxon signed rank test	Hair comb, pull test scores, hair density, hair thickness, A:T ratio, hair loss, hair quality, scalp microbiota parameters, hair growth rate, hair length, hair count, hair gloss	1-3, 5, 7, 8, 10, 14, 21 and 22
Kruskal-Wallis test	Hair growth rate, vellus hair, terminal hair, diameter diversity	8 and 22
Friedman's test	Beta calcium level	21
Spearman correlation	Association between baseline beta-catenin level and change, photographic evaluation	21 and 22
Chi-square test	Hair thinning, self-assessment, Hamilton Norwood grade, global photography	4, 5, 7, 9, 13, 14, 16, 17, 19-22
PERMANOVA	Diversity level	2
F test	Hair density, hair count, hair length, hair thickness	2
ANCOVA	Hair glossiness, hair count, hair density, hair thickness, serum magnesium, energy intake, hair growth	5, 6, 11, 13 and 17
Linear regression	Adjust age and disease duration	21

DISCUSSION

This systematic review provides a comprehensive overview of the statistical methodologies commonly employed in clinical trials evaluating hair care products. Analysis of the (22) included studies revealed a consistent adherence to established statistical conventions, with the choice of analytical tools largely guided by the nature of the data, whether continuous or categorical, its distribution, and the underlying study design.

Normality assessments, appropriate use of parametric and nonparametric tests, and repeated measures analyses were frequently reported, suggesting a general alignment with best practices in clinical research methodology.

Across the 22 included studies, continuous variables were most frequently analysed using statistical methods such as paired t-tests, independent t-tests, Wilcoxon signed-

rank tests, and Mann-Whitney U tests.^{3,14,20} Comparable similar statistical techniques have also been employed in related dermatological research, including studies on seborrheic dermatitis, hair growth promotion, gray hair reduction and ayurvedic hair oil on controlling hair fall reflecting a broader consistency in methodological practices within the field.²³⁻²⁷ The selection between parametric and non-parametric tests was typically guided by preliminary normality assessments, with the Shapiro–Wilk test being the most commonly used method for evaluating data distribution.^{1,8}

For categorical variables, the Chi-Square test and Fisher's exact test were standard.^{4,5,8,9,11,13,17,20} These tests selected based on sample size and expected frequency counts, in alignment with standard statistical guidance. Few studies also incorporated McNemar's test for repeated categorical measures, though its use relatively limited. This may point to missed opportunities to fully leverage statistical methods suited for paired data structures.

Given the longitudinal nature of many trials, more advanced statistical approaches such as repeated measures ANOVA, ANCOVA, and linear mixed-effects models were employed to evaluate treatment effects over time for hair density, hair rate, and hair diameter parameter and to adjust for confounders including age, sex, and baseline differences.^{15-17,19} While the use of these models indicates methodological advancement, the quality of reporting often lacked sufficient detail regarding model specifications, including assumption testing, the distinction between fixed and random effects, and the interpretation of interaction terms. These omissions compromise the robustness of conclusions and hinder replication efforts.

The issue of sample size also emerged as a recurrent theme. Many studies included relatively small cohorts, often fewer than 50 participants. While non-parametric tests were generally used appropriately under these conditions, formal reporting of sample size justification, statistical power, and effect sizes was inconsistent. These omissions can obscure the clinical relevance of statistically significant findings, particularly in a field where subjective and aesthetic outcomes play a significant role.

Looking ahead, the integration of more standardized reporting frameworks would be beneficial. Adoption of reporting guidelines such as CONSORT, as well as increased alignment with statistical analyses and methods in the published literature (SAMPL) recommendations for statistical transparency, could help ensure greater clarity and reproducibility. This is especially pertinent as hair research increasingly incorporates complex outcome measures, including digital imaging, trichoscopy metrics, and patient-reported assessments.

To summarize, existing studies indicate a mostly correct application of statistical techniques in hair care product studies, showcasing an increasing level of complexity in both study design and analysis. But there is a need for improved consistency in the reporting and justification of statistical methods to aid in evidence synthesis and guide best practices in upcoming research.

CONCLUSION

This review demonstrates that clinical studies investigating treatments for androgenetic alopecia and related hair parameters employ a consistent and methodologically sound range of statistical techniques. Selection of statistical tests was largely influenced by data distribution, sample size, and study design. Frequently used methods included t-tests, Wilcoxon signed-rank tests, Mann-Whitney U tests for continuous variables, and Chi-square or Fisher's exact tests for categorical data. Advanced techniques such as repeated measures ANOVA, linear mixed models, and ANCOVA were commonly applied in studies with multiple time points to account for time-related effects and

confounding variables. Tests for normality and homogeneity of variance were appropriately used to guide the choice between parametric and non-parametric approaches. Despite overall adherence to good statistical practices, future research would benefit from greater standardization in reporting and clearer justification of statistical methods to improve reproducibility and comparability across studies.

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