

Statistical Analysis Plan (SAP)

1. Sample Size Calculation

The required sample size will be determined through an a priori power analysis using G*Power 3.1 software. Based on an assumed effect size of $f^2 = 0.30$, an alpha level of 0.05, and a statistical power of 0.80, the minimum sample size is calculated to be 24 participants. To account for potential dropout and ensure sufficient power for non-parametric analyses, a total of 32 adult male participants will be recruited and randomly assigned to one of two groups ($n = 16$ per group).

2. Dependent Variables

The functional recovery of the shoulder joint **will be evaluated** using three primary dependent variables across both discrete and continuous movement tasks:

- **Shoulder ROM:** Range of motion during shoulder abduction–adduction on both the dominant and non-dominant sides.
- **DDOF (Dynamical Degrees of Freedom):** The number of coordination groups contributing to shoulder movement control, defined as the number of principal components (PCs) required to explain 90% of the cumulative variance.
- **BDOF (Biomechanical Degrees of Freedom):** The total number of unique joint motions contributing to the coordination synergies. Specifically, the three joint angles with the highest loading values within each valid PC will be selected and counted without duplication.

3. Statistical Methods

All statistical analyses **will be performed** with the significance level set at $\alpha = 0.05$. Data processing and analysis **will be conducted** using Python 3.11 and MATLAB R2023b.

- **Parametric Analysis (Shoulder ROM):** The assumption of normality for the shoulder ROM data will be verified by inspection of Q–Q plots. A two-way repeated-measures ANOVA will be conducted, with group (LS vs. SL) as the between-subjects factor and test session (pre-test, post-test 1, post-test 2) as the within-subjects factor. When significant main or interaction effects **are found**, post-hoc multiple comparisons will be performed using Tukey's Honestly Significant Difference (HSD) test to adjust for Type I error inflation.
- **Non-parametric Analysis (DDOF and BDOF):** For the whole-body degrees of freedom variables (DDOF and BDOF), if the normality assumption is not satisfied, non-parametric tests will be employed. Between-group comparisons at each time point will be conducted using the Mann–Whitney U test. Within-subject comparisons across the three time points will be analyzed using the Friedman test. Where significant differences are observed, post-hoc pairwise comparisons will be conducted using the Wilcoxon signed-rank test, with a Bonferroni correction applied.