

STATISTICAL ANALYSIS PLAN

Acute effects of five interventions on maximal wrist-flexion strength and on precise force and position modulation of the wrist: randomised five-period crossover trial. SAP version 1.0, 28 September 2026.

ClinicalTrials.gov Submission reference number: **50317**

Authors: Grgur Kovačić; Tatjana Trošt.

Status of this document

The 2019 proposal foresaw descriptive statistics, paired t-tests for change within each condition, and Dunnett's test comparing each condition to the baseline measurement (Statistica 13.3). During the analysis (2025), it became clear that the baseline could not serve as a control because tracking performance improved systematically across visits, and that four participants had incomplete series; the analysis was therefore specified as described below, after data collection but before results were submitted for publication. Analyses labelled "exploratory" were specified after inspection of the data. All analyses are reproducible from the deposited data and code (<https://urn.nsk.hr/urn:nbn:hr:117:012259>).

1. Data and units of analysis

The unit of analysis is the participant ($n = 56$); 276 intervention visits (four visits missing). Occasion values: peak force = highest of three contractions; tracking error and other tracking variables = mean of three trials; range of motion = single measurement. Change within a visit is expressed as the natural logarithm of the post/pre ratio and reported as percentage change with 95% confidence intervals back-transformed from the log scale.

2. Primary analyses (hypotheses H1 and H2)

For each of the three primary outcomes: (a) within-intervention change tested with one-sample t-tests on the log ratios, Holm-corrected across the five interventions, with Cohen's d_z ; (b) comparison between interventions with a linear mixed model of the log ratio with intervention, visit order (1–5, linear) and sex as fixed effects and participant as random intercept (REML; Satterthwaite degrees of freedom), reported as estimated marginal means, deviations of each intervention from the mean of all five (uncorrected) and all ten pairwise comparisons with Holm correction; (c) sex $\times$ intervention interaction by likelihood-ratio test; (d) sensitivity analysis with visit order as a categorical factor. A hypothesis is considered supported for a given intervention and outcome when the within-intervention change is significant after Holm correction and in the hypothesised direction. Significance level $p < 0.05$, two-sided.

3. Analyses of the post hoc research questions

P1 (learning): pre-intervention values across visits 0–5 analysed with a linear mixed model of the log value with visit as fixed effect and participant as random intercept (slope = % change per visit); consecutive visits compared with paired t-tests; within-visit change modelled with and without visit order to quantify how much of the apparent intervention effect is explained by repeated performance.

P2 (range of motion): change after each intervention as for the primary outcomes (paired analysis and mixed model).

4. Exploratory analyses

Change by repetition position (post repetition k versus pre repetition k, uncorrected one-sample t-tests); equivalence tests (TOST) against a bound derived from the design sensitivity ($d_z = 0.38$) for non-significant changes; dispersion of individual changes (Levene's test) and the standard deviation of true individual responses relative to the condition without a mean change (Atkinson & Batterham, 2015; Hopkins, 2015); a directional contrast of the two stretching protocols versus the three other interventions; sex differences in participant means and in subgroups matched for range of motion or peak force; correlations between the three dimensions.

5. Measurement properties

Within-occasion reliability from two-way ANOVA of the three trials per occasion (ICC(3,1), ICC(3,3), ICC(2,1), SEM, MDC95, typical error as CV from log data), averaged over the eleven occasions with cluster-bootstrap confidence intervals; between-visit reliability from the six pre-intervention occasions (ICC(3,1), ICC(2,1), SEM, MDC95); redundancy among the sixteen exported tracking variables by arithmetic identities and correlations; sample sizes for future paired designs from the observed SD of change.

6. Missing data and software

Missing visits (four) are handled by the mixed models under the missing-at-random assumption; no imputation. Analyses were performed in jamovi 2.5 (GAMLj) and reproduced in Python 3.10 (pandas, SciPy, statsmodels).