

THE EFFECTS OF DIFFERENT TEMPORALLY STRUCTURED METRONOMES ON KNEE JOINT LOADING VARIABILITY IN HEALTHY YOUNG ADULTS DURING TREADMILL WALKING: AN EXPERIMENTAL STUDY

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INTRODUCTION

While sensorimotor synchronization using isochronous metronomes is a common gait rehabilitation strategy, this approach disregards the naturally complex and fractal-like variability observed in healthy human gait. Although previous studies have shown that fractal cues preserve or restore spatiotemporal gait complexity, their impact on biomechanical parameters like knee joint loading variability remains unexplored. **Load modulation, particularly at the knee joint, is of clinical interest due to its relevance in conditions such as knee osteoarthritis.**

AIMS

This study aimed to investigate how different temporally structured metronomes (isochronous vs. fractal) affect the knee joint loading variability during treadmill walking in healthy young adults.

MATERIALS & METHODS

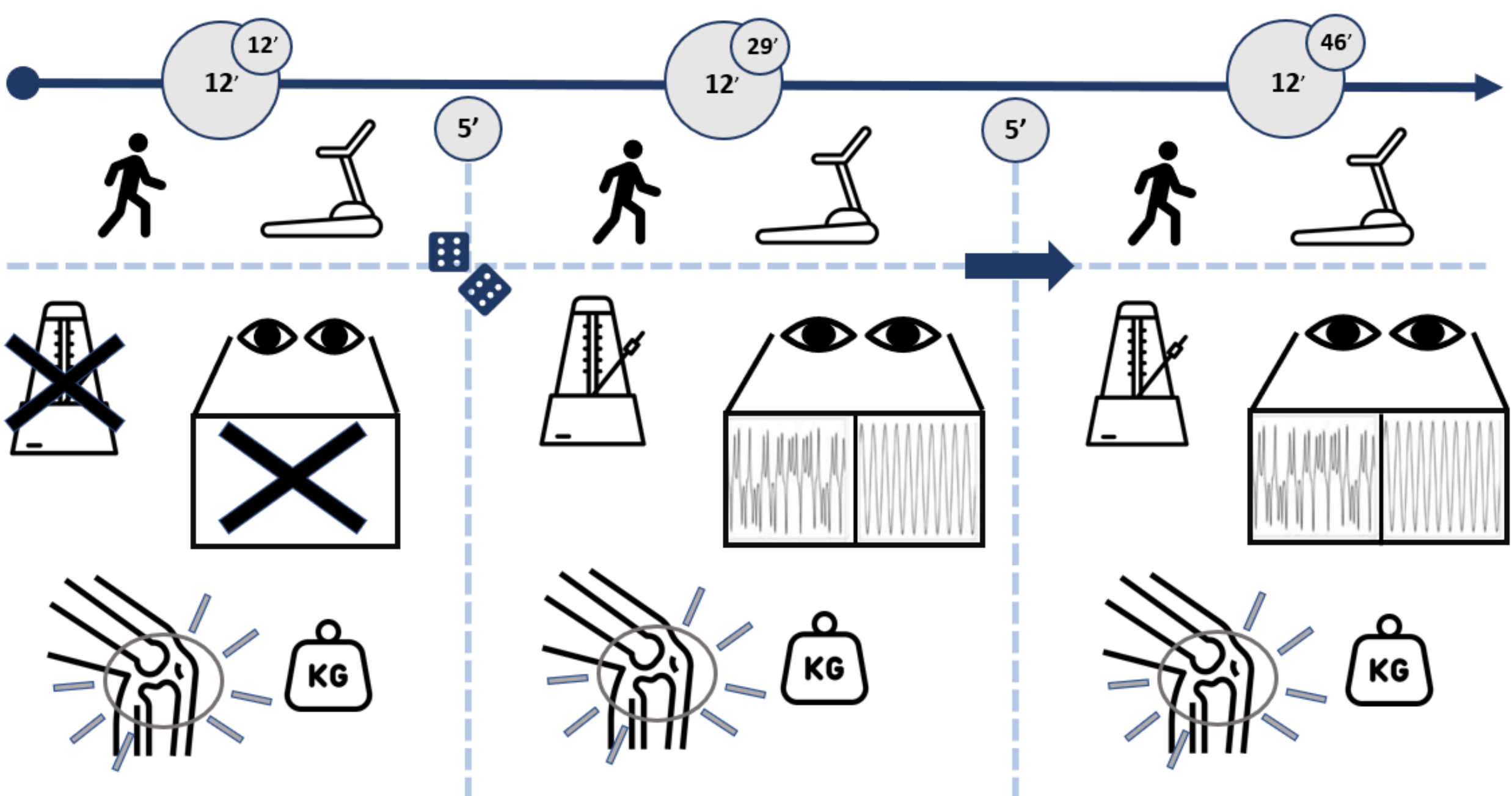


Figure 1. Study design illustration.

- **Participants:** 14 healthy young adults (23.4 ± 1.5 years; 9 males).
- **Design:** Cross-sectional experimental design. 12' treadmill walking trials: 1 uncued trial; 2 cued trials (isochronous and fractal, randomized). The visual cues were a personalized metronome in the form of a vertical moving bar with which participants were asked to synchronize their heel strike.
- **Outcomes:** Fractal scaling exponent of the knee joint load (α -load); Fractal scaling exponent of inter-stride intervals (α -ISIs); Coefficient of variation of knee joint load (CV-Load).
- **Data collection:** Three-dimensional kinematics and ground reaction forces recorded using a motion capture system and a force-instrumented treadmill.
- **Data analysis:** Knee joint moments computed using Visual3D and analysis performed in MATLAB.
- **Statistical analysis:** One-way repeated-measures ANOVA. Tukey post-hoc tests used for pairwise comparisons. Partial eta squared (η^2) reported for effect sizes. Significance threshold: $p < 0.05$.

RESULTS & DISCUSSION

No significant main effects were observed for knee joint loading variability, indicating that neither metronome type altered the variability or complexity of joint loading. However, a **significant effect was found for the inter-stride intervals**, with the fractal and uncued conditions maintaining statistical persistence ($\alpha > 0.5$), while the isochronous condition showed anti-persistent behaviour resembling gait patterns typical of aging.

While temporally structured metronomes significantly influence spatiotemporal gait dynamics, they do not affect knee joint loading variability in healthy adults. This suggests that joint variability is governed by different control mechanisms, possibly influenced by motor redundancy and compensatory strategies.

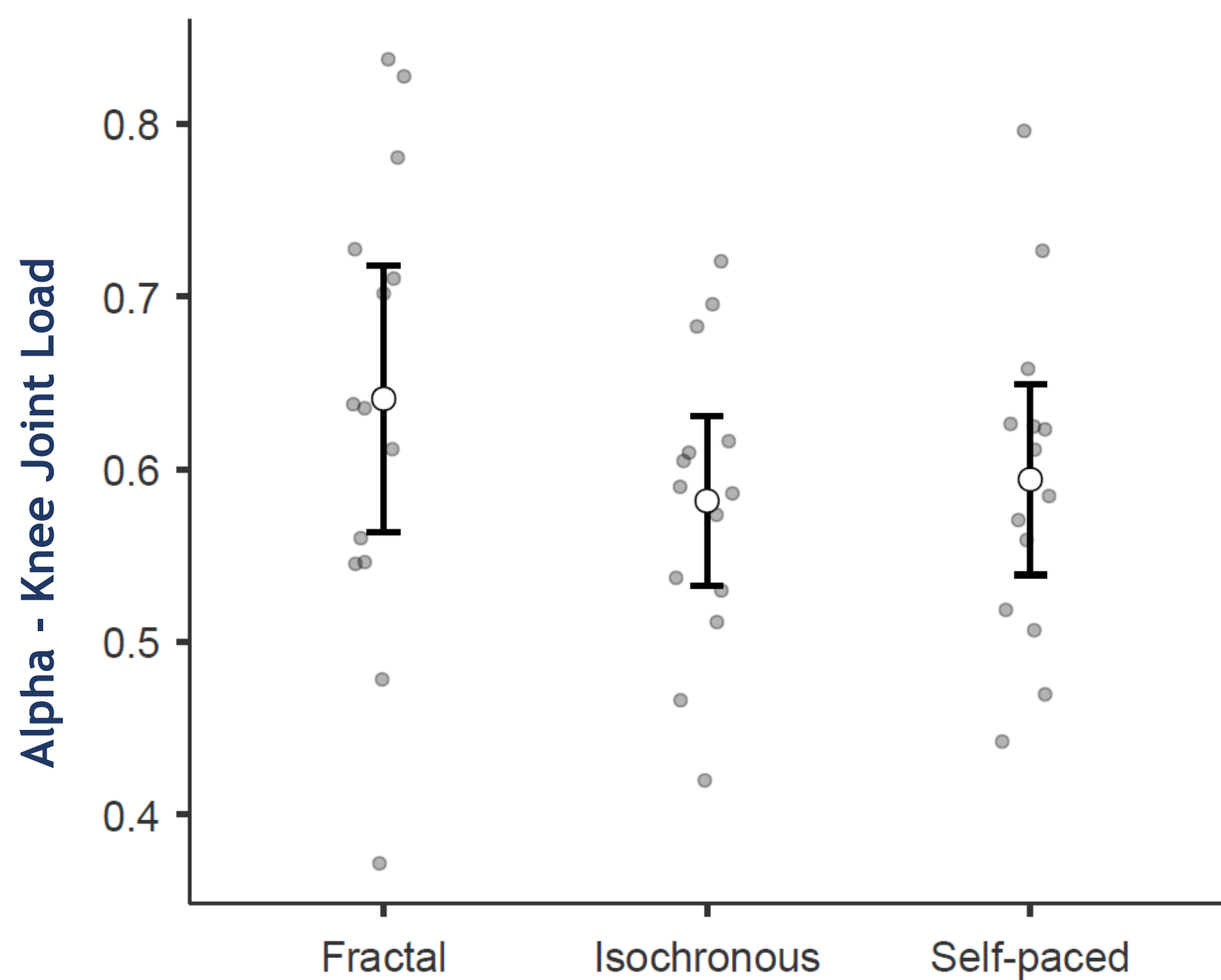


Figure 2. The α -load mean values listed for each condition.

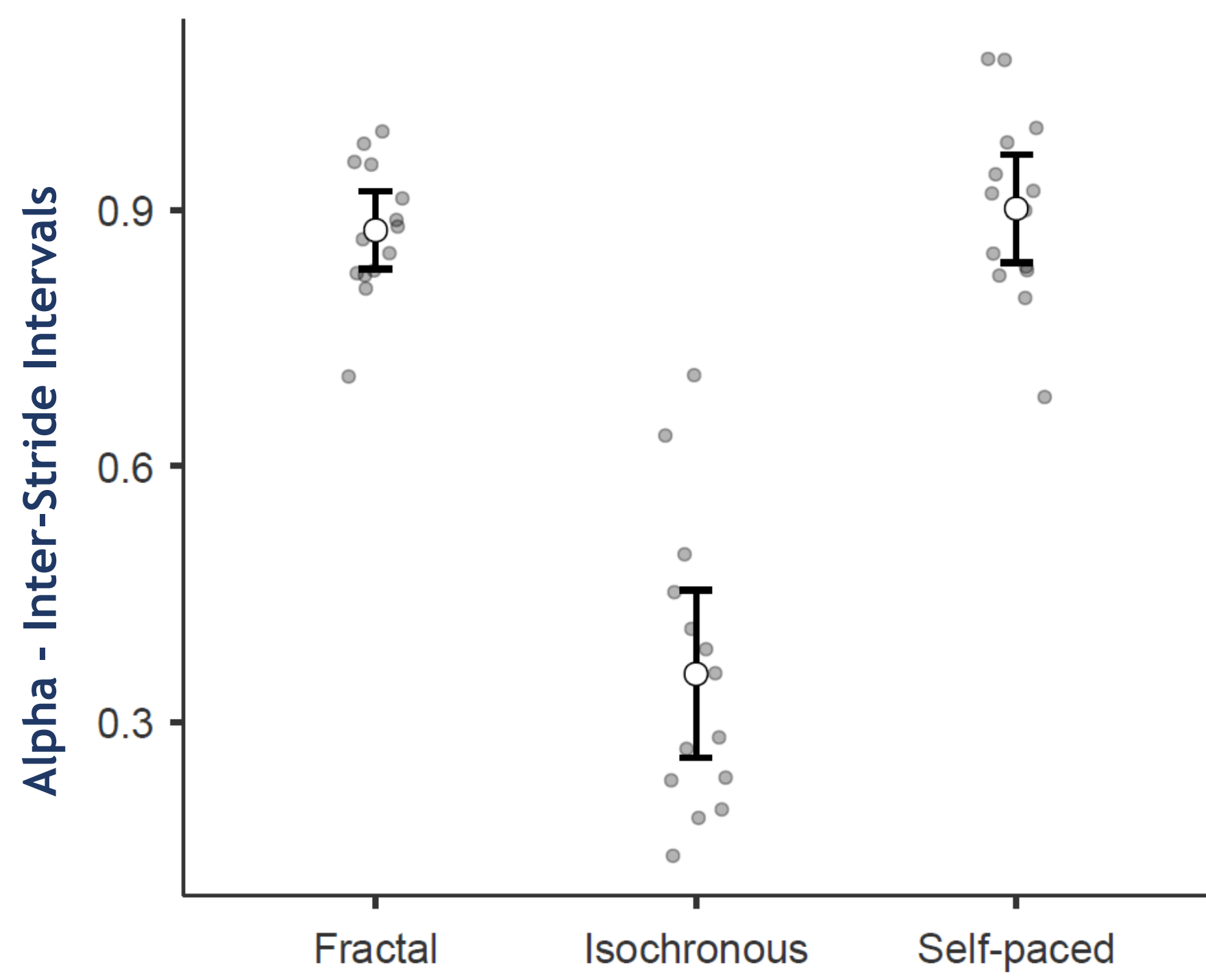


Figure 3. The α -ISIs mean values listed for each condition.

CONCLUSIONS

Despite the null findings in load variability, the fractal cues preserved healthy gait dynamics and statistical persistence in inter-stride intervals, supporting their relevance in rehabilitation contexts. Future studies should explore whether similar effects extend to other joints and clinical populations, particularly those with altered joint mechanics or reduced gait complexity.

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