# Comparison of inter-jointed coordination during underwater undulatory swimming according to different skill level

**Tsunokawa T.**[1,2], Nakazono Y.[3], Otsuka T.[3], Kudo S.[1]
[1]Institute of Health and Sport Sciences, University of Tsukuba, Ibaraki, Japan
[2] Advanced Research Initiative for Human High Performance (ARIHHP), University of Tsukuba, Ibaraki, Japan
[3]Graduate School of Comprehensive Human Sciences, University of Tsukuba, Ibaraki, Japan
Email: tsunokawa.takaaki.ke@u.tsukuba.ac.jp

## Summary

The purpose of this study was to compare inter-jointed coordination patterns at the lower limb joints during underwater undulatory swimming (UUS) at different skill levels. Modified vector-coding techniques were used to evaluate the inter-jointed coordination patterns. Two male swimmers of different skill levels participated in this study. Underwater motion capture was used to obtain 3D coordinates of the trunk and lower limbs. The inter-jointed coordination of the hip-knee was obtained from the angle-angle diagrams. As a result, higher skill level swimmer showed a higher ratio of anti-phase and higher kick frequency. These results suggest the importance of the anti-phase as a preparatory motion for continuous movement in UUS.

## Introduction

In UUS, increasing kick frequency is important for performance. Multiple joint motions are involved in UUS, the coordination of these motions has not been clarified. Therefore, the purpose of this study was to compare kinematics and inter-jointed coordination patterns at the lower limb joints during UUS at different skill levels.

## Methods

Two male swimmers performed the 20 m UUS with maximal effort. One had a higher skill level (Participant A) and the other had a lower skill level (Participant B).

13 LED markers were affixed to the right lower limb for 3D motion analysis by underwater motion-capture. Local coordinate systems in the trunk, thigh, and leg were defined to calculate the joint angles as the Cardan angles.

The modified vector-coding technique uses angle-angle diagrams to calculate the coupling angle (Hamill et al., 2000). Coupling angles were calculated from a vector adjoining two successive time points relative to the right horizontal at the angle-angle diagram. The coupling angles and contribution of each joint angle was displayed using the classification described in previous studies (Needham et al., 2020). The inter-jointed coordination patterns were distinguished by their in-phase and anti-phase behaviors (Figure 1). In-phase means that two joints move the foot vertically in the same direction; conversely, the two joints move in opposite directions in the anti-phase.

## Results and Discussion

Swimming velocity and kick frequency were 1.71 m/s and 2.27 Hz for participant A and 1.36 m/s and 1.92 Hz for participant B, respectively. Figure 1 shows inter-jointed coordination patterns between hip and knee. Participant A had a higher ratio of anti-phase in one cycle, shown in purple and green line. And for participant A, all eight phases appeared in sequence in counterclockwise as shown in Figure 1.

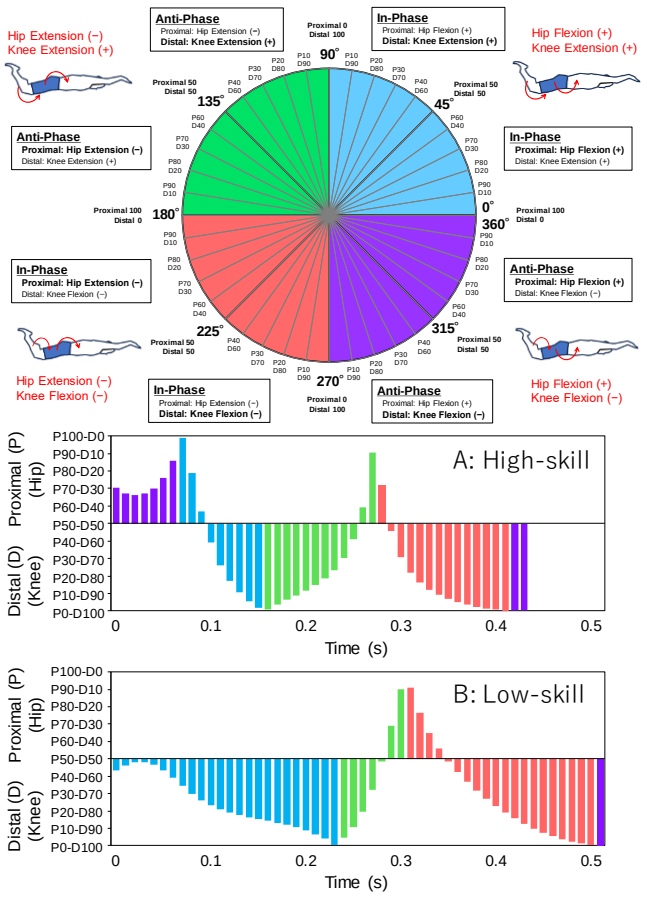


**Figure 1**: Inter-jointed coordination patterns between hip and knee.

## Conclusions

A higher skill level participant showed higher swimming velocity and higher kick frequency, suggesting the importance of anti-phase as a preparatory motion.

## Acknowledgments

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## References

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