KINETIC CHAIN APPLICATION TO THE DOLPHIN KICK IN BUTTERFLY SWIMMING

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This study examined the difference in underwater dolphin kick movement between elite and non-elite swimmers. Ten elite and ten non-elite swimmers participated in this study. Kinematic data from the sagittal view were collected and analyzed. Significant differences were found in the peak angular velocities of the lower trunk, thigh, and shank between the elite and the non-elite athletes. Additionally, the analyses on the peak angular velocity transfer rate between the connected segments showed a significant interaction between the skill level and the transfer rate. The findings are discussed in relation to the principle of kinetic chains. We conclude that the optimal propulsion during the downbeat part of the dolphin kick is reached when most segments participated in the movement.

KEY WORDS: dolphin kick, butterfly swimming, kinetic chain.

INTRODUCTION: The international rules of competitive swimming permit swimmers in freestyle, backstroke and butterfly races to be completely submerged for a distance up to 15 metres after the start and after each turn. So underwater dolphin kicking has become tremendously popular with most swimmers finding that they can kick underwater faster than they can swim on the surface (Maglischo, 2003). One advantage of doing this is reducing the speed interference of the backwash from the wall. A second advantage is that taking three or four kicks allows swimmers to push off the turn deeper and move toward the surface on a gradual slope.
In the Butterfly swimming style one dolphin kick consists of an upbeat and a downbeat part. The downbeat begins as the legs pass above the body during the preceding upbeat. It begins with a slight amount of hip flexion that starts the thighs downward and allows the water to flex the lower legs and extend the feet in preparation for a whip-like downward extension at the knees that take place soon thereafter. The upbeat motion is performed with straight legs (Figure 1).

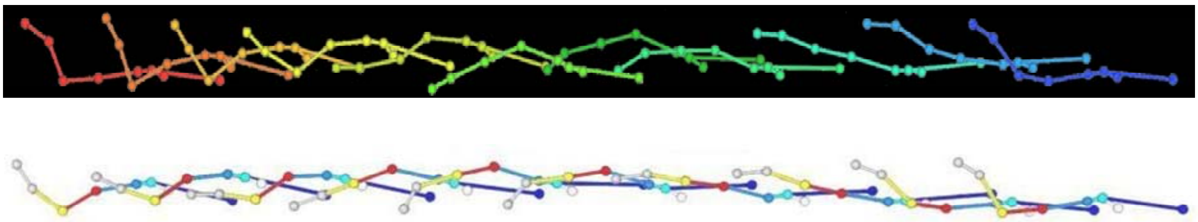

Figure 1. The freeze-frame movement of underwater dolphin kick. There are 10 frames in one stroke from left to right. Each consists foot, shank, thigh, lower trunk, upper trunk, head and arm total 7 segment.

Hahn and Krug (1992) indicated that some body undulation is necessary to translate the downward movements of the legs into forward propulsion. This is accomplished through a mechanism called body shimmy. Maglischo (2003) described the dolphin kick pattern as a whip-like motion that begins with flexion at the hips and continues with extension at the knees. An open question is where the whip-like motion should begin.

METHODS:

Data Collection: Ten elite and ten non-elite swimmers were asked to participate in this study. The basic data of participants were : Age of non-elite swimmers 21 ± 1.8 yr, elite swimmers 22 ± 2 yr. Weight of non-elite swimmers 65 ± 12 kg, elite swimmers 72 ± 6 kg. Height of non-elite swimmers 171±6 m, elite swimmers 171 ± 6 m and training years of non-elite swimmers 3±1 yr, elite swimmers 14 ± 2 yr (mean ± S.D.). All the participants

performed the underwater dolphin kick task for 3 trials, and the movements were videotaped(60Hz) underwater. The calibration object was tied with two pieces of lead at the two ends (each 2.82 kg) to ensure the calibration object was level with the swimming pool.
Data Analysis: Kinematic variables were digitized from videos using Kwon 3D software system. Body segments were divided into five parts: upper-trunk, lower-trunk, thigh, shank and foot, and angle between each segment and horizontal axis were calculated for analyses. Only the fastest trial was selected for analysis from each participant. The rates of change of the maximal angular velocity between each segment (proximal / distal) were derived for analyses. A 3(cycle) X 4 (connection) repeated-measure ANOVA was used on the rate of change of peak angular velocity.

RESULTS: The elite swimmers had significantly faster horizontal velocity, $F(1,18)=14.87$, $p<.05$, and acceleration $F(1,18)=19.21$, $p<.05$, than their non-elite counterpart, confirmed the higher skill level of the elite swimmers (see Table1). The peak angular velocity of upper trunk, lower trunk, thigh, shank and foot were also compared between the two groups. Significantly higher peak angular velocity was found in lower trunk, thigh and shank for the elite swimmers, $F(1,18)=21.01$, $p<.05$, $F(1,18)=14.27$, $p<.05$, $F(1,18)=6.75$, $p<.05$, respectively (see Figure 2). The sequence of the occurrence of each segmental peak angular velocity was examined, and a sample time series of the segmental angular velocity curves from each group was shown in figure 3. The statistical comparisons on these transfer rates of peak angular velocity between every two connected segments showed a significant interaction effect between groups and links, $F(3,48)=5.463$, $p<.05$ (see Figure 4).

Table 1.The results of elite and non-elite swimmers in one dolphin kick trial

	Elite swimmers	**Non-elite swimmers**
Every stroke velocity (m/s)	3.34±0.51	2.1±1.22
Every stroke acceleration(m/s^2)	10.7±2.31	4.9±2.56

Elite swimmers N=10 and non-elite swimmers N=10；Mean ± S.D.；p<.05

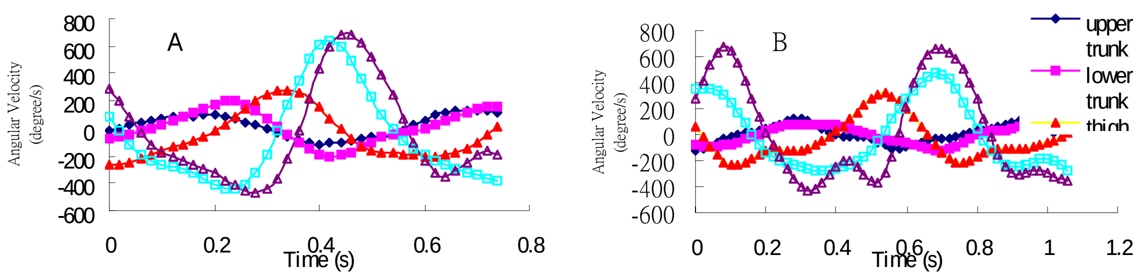

Figure 2. sample time series of segmental angular velocity from the 2 groups. Panel A is from one of the elite swimmers and panel B is from one of the non-elite swimmers.

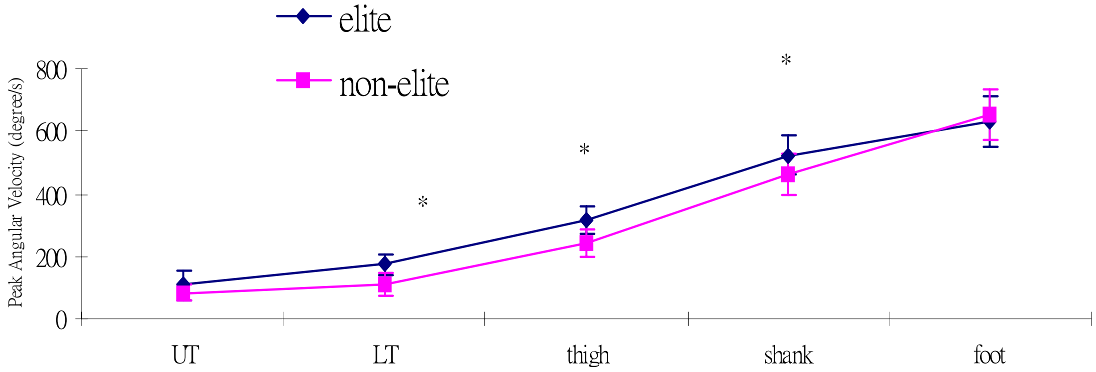

Figure 3. Comparisons of segmental peak angular velocity between elite and non-elite swimmers.
* denotes a significant difference between skill levels.

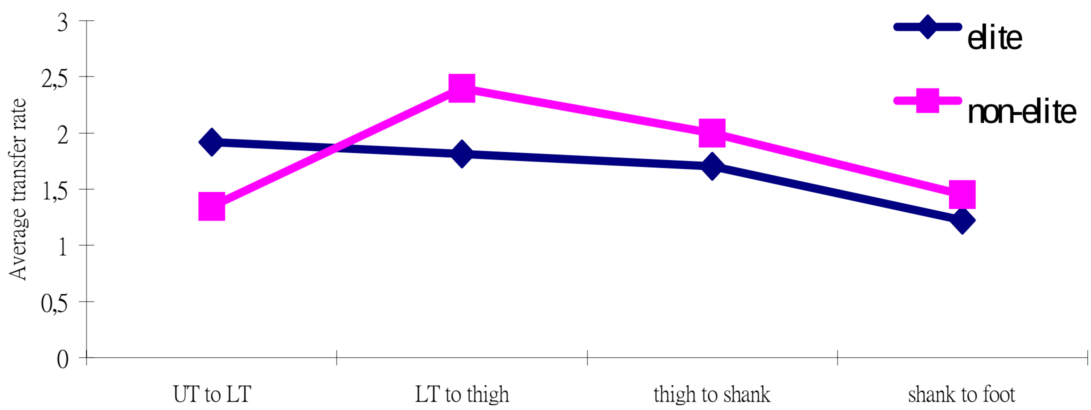

Figure 4. The comparison of the transfer rates of the segmental peak angular velocity between every 2 connected segments, including upper trunk (UT) to lower trunk (LT), lower trunk to thigh, thigh to shank and shank to foot in elite and non-elite swimmers.

DISCUSSION: When segmental peak angular velocity was examined, the results from the foremost upper trunk and the foot were not significantly different between elite and non-elite swimmers. However, the overall forward speed of the dolphin kicks indicated the superior performance from the elite swimmers. Because the lower trunk, thigh, and shank showed higher peak angular velocity for the elite than the non-elite swimmers, a logical inference is drawn that the faster forward speed might come from the movements of the 3 segments. Although text book guide lines suggest a straight (no movement) trunk position during underwater kicks (Maglischo, 2003), the evidence that the elite swimmers who had faster swimming speed also demonstrated a higher peak angular velocity of the lower trunk indicating the whip-like movement began at the trunk. Furthermore, the observation of more than 2 fold increment in the peak angular velocity of thigh in the non-elite group may suggest an active muscle contraction was involved at the thigh in addition to the angular momentum transferred from the lower trunk. The additional muscular activity in the middle of the kinetic chaining sequence may cause perturbation in transferring angular momentum, therefore impeding the build up of forward speed.

CONCLUSION: Butterfly swimming consists of more coordination than any other stroke because the whip-like movement (Hickman, 1999). From the finding of this study, we suggest that the principle of kinetic chain may be applied to the whip-like movement of underwater dolphin kick and the optimal propulsion is reached when most of the segments participated in the motion.

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