THE RELATIONSHIP BETWEEN FOOT MOVEMENT AND THE COM VELOCITY IN ELITE FEMALE BRESTSTROKE SWIMMERS

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The purpose of this study was to investigate the effect of foot movement on the instantaneous COM velocity changing during kick movement for elite female breaststroke swimmers. Nine elite swimmers swam at their maximal effort in a 25-m pool. The swimming motions were recorded with the motion capture system. The COM velocity generated by kick movement was not related the foot velocity. In contrast, the COM velocity was correlated with the sweepback angle of foot. The swimmers who showed high kick velocity were moved their foot outward during early kick movement. In contrast the swimmer who showed low kick velocity moved their foot backward. These results suggest that the higher increased COM velocity obtained by kick movement would not be related to foot velocity, but foot angle for elite female swimmers.

KEY WORD: Swimming, foot, three dimensional analysis

INTRODUCTION: In breaststroke the internal/external rotation, flexion/extension and abduction/adduction were observed in the hip joint movement. This lower limb movement in breaststroke is more complex than that in other swimming style. The force-production ratio of leg movement to arm movement is larger in the breaststroke than the other swimming styles(Morouço et al., 2011). However it is unknown how the swimmers modify the lower limb movement to improve their swimming performance in breaststroke.
The magnitude of hydrodynamic force is related to the segment velocity and angle relative to the water flow(Schleihauf, 1979). Therefore the relationship swimming performance and velocity and angle of hand (pitch and sweepback angle) was investigated in front crawl(Gourgoulis et al., 2008). To examine the relationship between COM velocity changing during kick movement and the velocity and angle of foot, it would be clear the techniques for improving swimming performance. The purpose of this study was to investigate the effect of foot velocity and angle on the instantaneous COM velocity changing during kick movement for elite female breaststroke swimmers.

METHODS: Nine elite female swimmers in whose several swimmers won the medals in the international championship during the last 2 years participated with this study. Their best time of 200 m breaststroke was 144.61 ± 4.04 s (mean ± SD). The subjects performed warming up for 15 min in a 25-m pool. After the warming up, 19-mm diameter reflective markers were placed on the landmarks for the subjects. After that, the subjects performed second warming up for 5 min to adjust to swimming with the markers. Then, the subjects swam 25-m in their maximal effort. The trials were recorded by using motion capture system that included 18 underwater cameras and nine land cameras (Qualisys AB, Gothenburg, Sweden) with a 200Hz sampling rate. Motions were recorded from 15 to 22 m points in the 25-m pool. The X-axis was defined as the swimming direction, the Y-axis was defined as the lateral direction and the Z -axis was defined as the vertical direction.
⊿V_kick: The COM position was calculated through the weighted average of the COM of each segment. The COM velocity in swimming direction was calculated by differentiating COM positional data. ΔV_kick was defined as the difference between the minimum and maximal COM velocity during kick movement (Fig 1).
Foot velocity: The foot velocity was calculated as the velocity of the midpoint between the second and the fifth metatarsal. The foot velocity in swimming, lateral, vertical direction was defined as V_x, V_y, V_z, respectively.
Sweepback angle: Foot plane was defined by using the markers located on the second and the fifth metatarsal and heel. (Fig 2) The direction of water flow relative to the foot was defined by projecting the foot velocity vector onto the foot plane. Sweepback angle was defined as the leading edge of the right foot relative to water flow.

The beginning of the kick phase was defined as when the foot segment started moving backward. The end of the kick phase was defined as the timing right before the foot started moving forward. The kick phase was divided into two phases (early and late phase) with equal duration.
The foot velocity and sweepback angle were averaged in early and late phase. The relationship between the foot velocity and the sweepback angle in early and late phase and *Δ V_kick* were examined by using Pearson's correlation analysis.

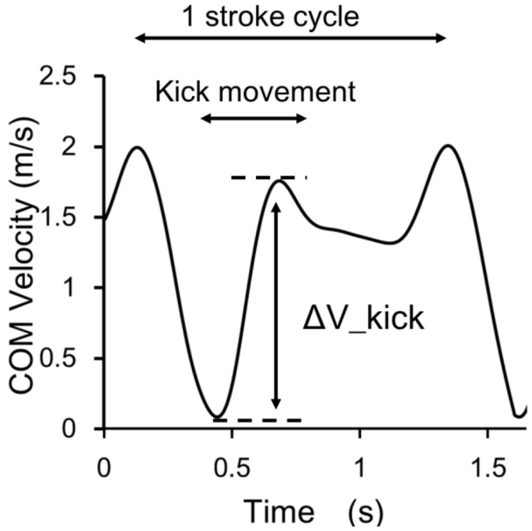

Figure 1: ΔV_kick in breaststroke

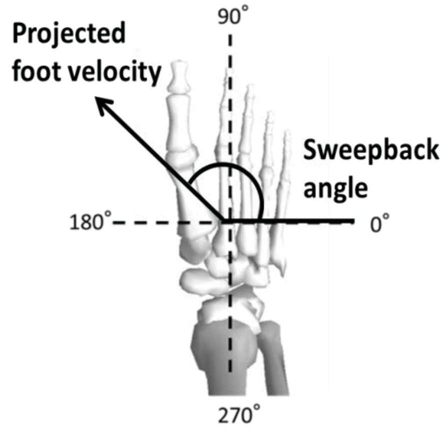

Figure 2: The definition of sweepback angle of foot

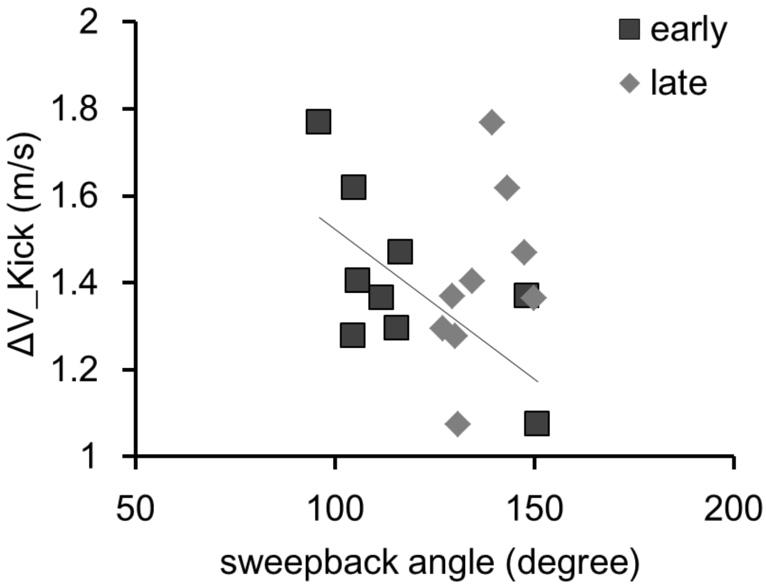

Figure 3: The relationship between kick velocity and sweepback angle

Table 1
The correlation coefficients between ΔV_kick and the all components of the foot velocity

		V_x_early	V_x_late	V_y_early	V_y_late	V_z_early	V_z_late
ΔV_kick	r	-0.251	-0.277	-0.367	0.013	-0.260	-0.036
	p	0.516	0.471	0.332	0.974	0.500	0.927

RESULTS AND DISCUSSION: In the present study ΔV_kick was defined as the change in velocity between maximal and minimum values during the kick movement. In the present

study it was confirmed that the swimmers did not move their both arm during kick movement. This result was consistent with the previous study(Oxford et al., 2016). Therefore the ΔV_kick could be evaluated as the change in velocity obtained by only the kick movement.
Increasing segmental velocity is advantageous for increasing swimming velocity, since the propulsive force is proportionate to square of the segment velocity(Berger, 1999). The result in the present study showed that the all components of the foot velocity were not correlated with ΔV_kick in both early and late phase (Table 1). In the present study the subjects were elite swimmers and relatively homogenous, therefore in the further study the relationship between foot velocity and kick velocity should be investigated for heterogeneous swimmers.
ΔV_kick was significantly correlated with the sweepback angle of foot in early kick movement ($r = -0.705$, $p < 0.05$). The sweepback angle for swimmers who showed high ΔV_kick was about 90 degree which means the foot was moved to tiptoe direction in early kick phase(Fig 3). They moved their foot to outward during early kick phase (Fig 4). In contrast the swimmer who showed low ΔV_kick moved their foot to backward in the early kick movement. This movement would include the some advantageous for the breaststroke kick movement. However in the present study the velocity and angle of foot were measured, but not hydrodynamic force generated by foot movement. Therefore it is unclear that how the sweepback angle of the swimmer who obtained higher COM velocity by kick movement contributes to increase in propulsive force and/or swimming velocity. Further study should be investigated the relationship between sweepback angle and the propulsive force.

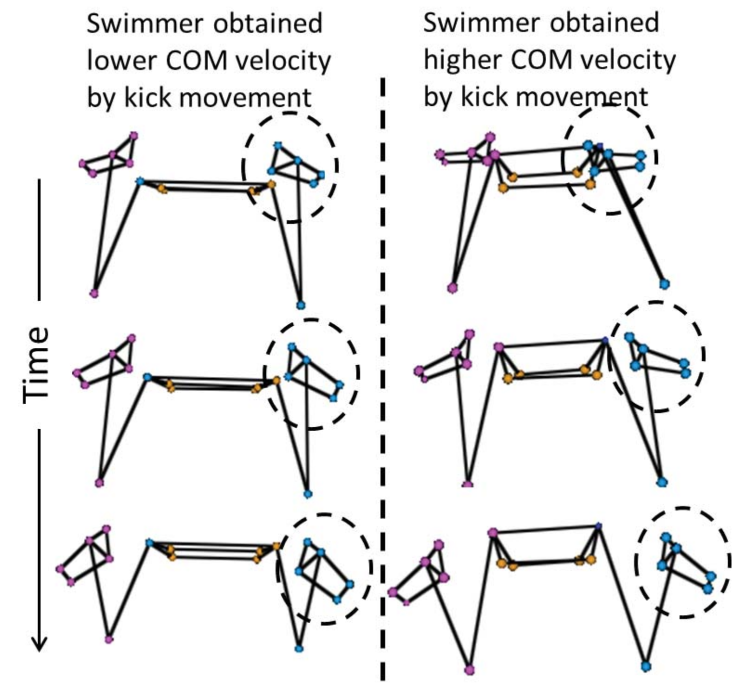

Figure 4: The foot movement in early kick phase for two swimmers who obtained higher or lower COM velocity by kick movement

CONCLUSION

The purpose of this study was to investigate the effect of foot velocity and angle on the COM velocity for elite female breaststroke swimmers. Results showed that the COM velocity obtained by kick movement would not be related to foot velocity but sweepback angle. The swimmers who obtained higher velocity by kick movement were moved their foot to outward during early kick movement. In contrast, the swimmers who obtained lower velocity moved their foot to backward.

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