HOW ELITE SWIMMERS CONTROL THEIR HAND PROPULSIVE FORCE AND ARM COORDINATION WITH INCREASING VELOCITY DURING FRONT CRAWL

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The purpose of this study was to investigate the change in the intensity and timing of the hand propulsive force by using pressure sensor and motion capture systems as increasing velocity during front crawl swimming. Twelve elite swimmers participated in this study. The swimmers swam three different velocity; i.e. 70%, 80% and 90% of maximal velocity. The propulsive force of both hands were recorded by multiple pressure sensors, and whole body kinematics was measured by using motion capture system. The average propulsive force during the pull and push phase, and thus, total stroke cycle increased as increasing swimming velocity. The non-propulsive phase decreased as increasing swimming velocity. Swimmers increase their swimming velocity with both increasing their hand propulsive force and decreasing their arm non-propulsive duration during a stroke cycle of front crawl swimming.

KEY WORD: Swimming, arm coordination, propulsive force

INTRODUCTION: Swimmers control the intensity and timing of their hand propulsive force during swimming from moment to moment. The propulsive and non-propulsive phase during one cycle of front crawl has been estimated (Chollet, Chalies, & Chatard, 2000), and these previous studies found that the elite swimmer decreased the overlapped non-propulsive action of both arms as increasing velocity. However it is unknown that how the elite swimmers manage the intensity and timing of their propulsive force during propulsive phase because the method of monitoring the propulsive force of hands during swimming had been limited. A newly developed and validated system using twelve pressure sensors on both hands (Kudo, Yanai, Wilson, Takagi, & Vennell, 2008) allow us to explore it. The intensity and timing of the hand propulsive force from moment to moment determine the total propulsive force during stroke, and total propulsive force of hand would be a major contributor of swimming velocity as well as total drag during swimming. The purpose of this study was to investigate the relationship between swimming velocity and the intensity and timing of their hand propulsive force during stroke cycle in elite swimmers using the pressure sensor system.

METHODS: Twelve elite competitive swimmers participated in the study. The subjects performed warming up for 15 min in a 25-m pool. After the warming up, 19-mm diameter reflect markers were placed on the landmarks for the subjects. The twelve pressure sensors were attached the palmar and dorsal surfaces of both hands according with the previous study (Kudo et al., 2008) (Figure 1). After that, the subjects performed second warming up for 5 min to adjust to swimming with markers. Then, the subjects swam 25-m at 70%, 80%, and 90% of maximal velocity (V70, V80, V90, respectively).

The trials were recorded by using motion capture system that included 18 underwater cameras and nine land cameras (Qualisys AB, Gothenburg, Sweden). Motion capture and pressure sensors were recorded with a 100Hz sampling rate and synchronized with each other. Motion and pressure sensor were recorded from 15 to 22 m points in the 25-m pool. In the area, the subjects were instructed not to conduct their breath action.

The underwater stroke divided into two phases (pull and push) in accordance with the previous studies (Chollet, et al., 2000). The obtained propulsive force in pull and push phase were averaged and defined as propul_pull and propul_push. The obtained propulsive force in one stroke cycle from both hands was integrated and divided by stroke time and defined as a propul_stroke. Hand velocity in pull and push phase in swimming direction were averaged and defined as handV_pull and handV_push. The relative propulsive force and hand velocity of V90 against V70 were calculated as the ratio of those two values.

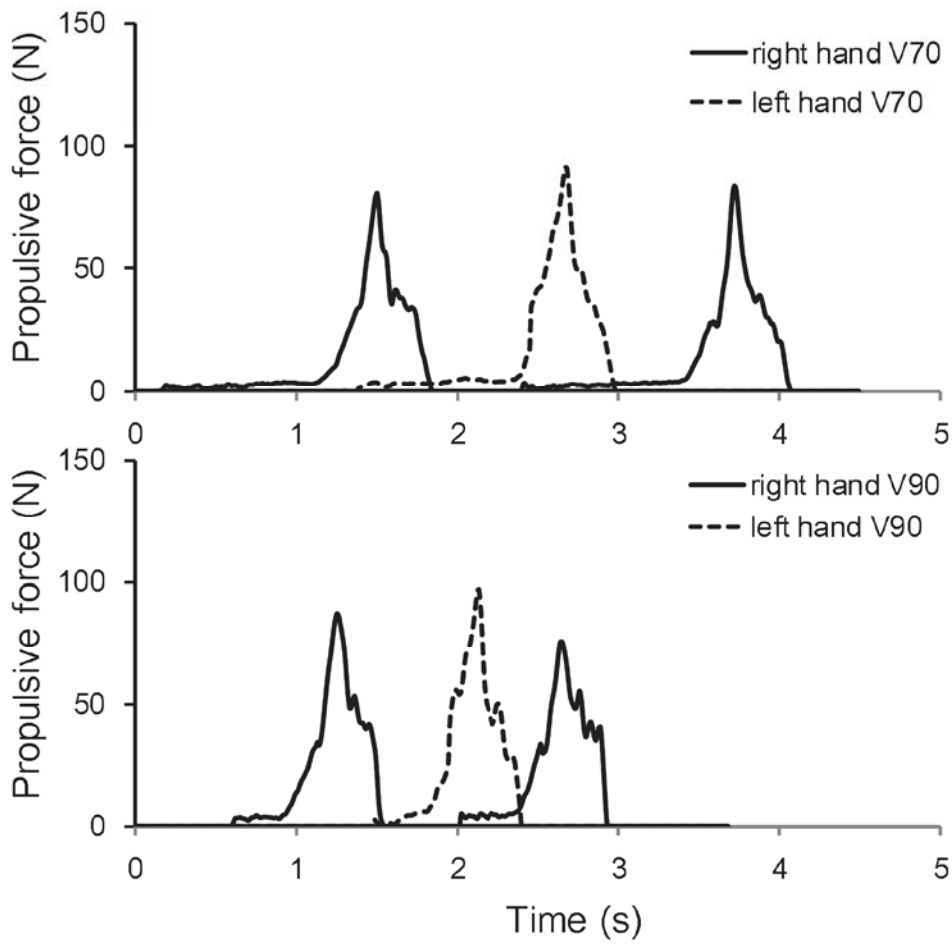

Figure 1: The propulsive force for right and left hand at V70 and V90

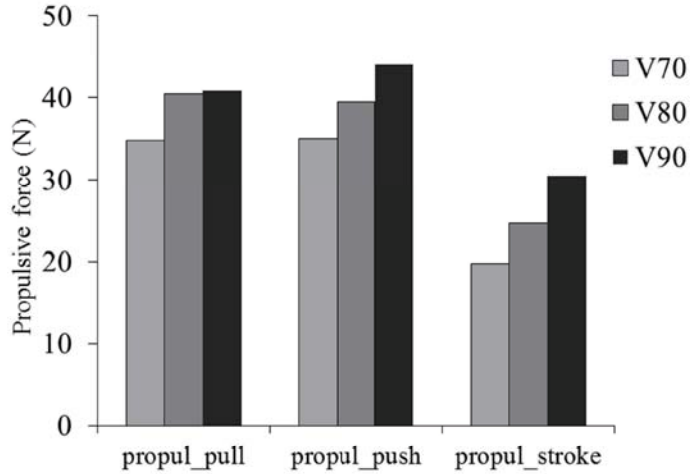

Figure 2: Average propulsive force during pull, push and stroke

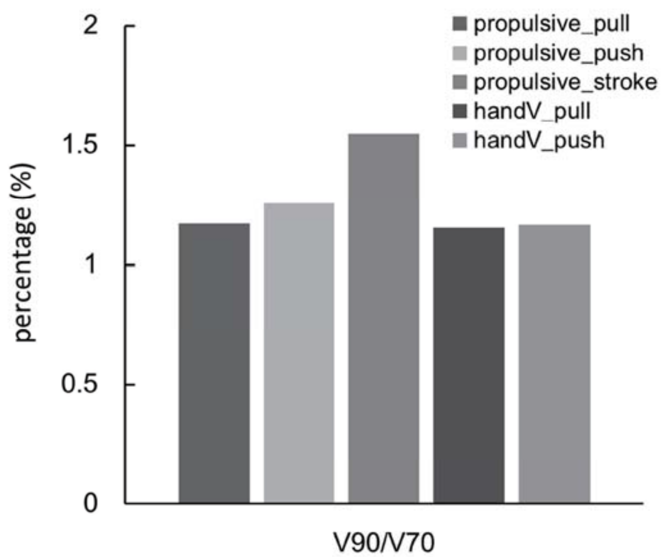

Figure 3: The relative propulsive force of V90 against V70 during pull and push, and whole stroke and the relative hand velocity of V90 against V70 during pull and push phase.

RESULTS AND DISCUSSION

The purpose of this study was to examine the changes in the intensity and timing of the hand propulsive force during front crawl swimming with increasing velocity in elite swimmers using a pressure sensor system on their both hands. To increase swimming velocity, the average propulsive force in a stroke cycle increased. Drag force acts on the swimmer proportionally to the squared swimming velocity. Therefore, increase rate of total propulsive force during one stroke should be higher than that of swimming velocity. Indeed, the current study indicated that the increase rate of total propulsive force during one stroke was 153% from V70 to V90 despite the increase rate of average swimming velocity was 130% from V70 to V90.

The intensity and timing of propulsive force is changed from moment to moment. The average propulsive force during pull and push phase were increased as increasing swimming velocity (Figure1). The average propulsive force during pull at V90 was about 120% of that at V70. The average hand velocity during pull and push phase also increased as increasing swimming velocity. The magnitude of propulsive force is proportional as the square of velocity. Therefore increase in propulsive force during pull and push phase could be related to increase in hand velocity.

The swimmer decreased overlapped non-propulsive phase of arm coordination with increasing swimming velocity (Seifert, Chollet, & Bardy, 2004). In the present study, the overlapped non-propulsive phase was decreased as increasing swimming velocity (19.91 ± 7.1% at 70%, 12.01 ± 4.27% at 90%, $P<0.05$). This result is consistent with the previous studies. During overlapped non-propulsive phase the swimmer could not generate the propulsive force. Decreasing duration of the non-propulsive phase in one stroke cycle contributes to increase in total propulsive force during one stroke cycle.

In additional analysis, we found that swimmers had two different strategies to increase their swimming velocity; increasing the propulsive force in pull and push phase or decreasing the overlapped non-propulsive phase. Both of the two strategies can increase total propulsive force during one stroke cycle.

Conclusion

The present study investigated the relationship between front crawl swimming velocity and the propulsive force, which was obtained by a newly developed and validated pressure sensors and arm coordination in elite swimmers. The obtained propulsive force during pull and push phase increased, and the overlapped non-propulsive phase of both arms decreased with increasing velocity. The strategies induce increasing total propulsive force during one stroke cycle and thus increase swimming velocity.

Reference

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