Serbian Journal of Sports Sciences
2009, 3(4): 145-148, www.sjss-sportsacademy.edu.rs
UDC 797.212.015 ISSN 1820-6301
797.212.412.5 ID 171110924

Scientific paper
Received: 03 Feb 2009
Accepted: 16 Jun 2009

THE EFFECT OF LEGWORK ON BIOMECHANICAL PARAMETERS IN DIFFERENT SWIMMING STYLES

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Abstract The purpose of this study was to investigate the effect of leg kicking on different styles of swimming. 17 male swimmers aged 14.64±2.14 participated in this study. The subjects carried out 4 times l00m swims, in each of the four styles (full stroke = crawl, backstroke, butterfly and breaststroke) at their maximum speeds with 15 minute intervals in between. The same procedure was repeated on separate days, (one rest day in between) by swimming stroke with arms only. The velocity (m/sec) and arm-stroke index obtained after swimming. The statistical analyses were performed by using SPSS for Windows. The mean (±) full stroke swimming velocity in crawl was 1.42±0.15 m/sec, in backstroke 1.18±0.1 m/sec and in breaststroke 1.02±0.06 m/sec; the mean (±) arms only swimming velocity in crawl was 1.28±0.15 m/sec, in backstroke 1.07±0.1 m/sec and in breaststroke 0.79±0.14 m/sec. In full stroke swimming the mean (±) arm-stroke index in crawl was 74.46±16.34, in backstroke 79.17±15.75 and in breaststroke 61.03±12.95; and in arms only swimming the mean (±) arm-stroke index in crawl was 89.20±21.12, in backstroke 101.14±21.51 and in breaststroke 130.05±47.18. The velocity while swimming the full stroke (arms and legs) was significantly higher than swimming with arms only ($p<0.01$). In arm-stroke index with arms only was higher than full stroke ($p<0.01$). Leg kicking influenced all parameters positively.

Key words: Propulsion, swimming, leg kicking

INTRODUCTION

Although any swimming coach, starting from his/her daily observations during the kicking drills, would agree to the fact that leg kicking helps propulsion, legs were not believed to be a significant propulsive agent in most competitive strokes way back when the propulsive drag theory was popular. Several studies reported that the arms contributed more to propulsion than the legs in different swimming styles [1, 6]. It was reported by Holmer [7] that the efficiency of swimming with arms only at a constant submaximal velocity was higher than in that with leg kicking. On the other hand, Ogita et al [8] showed that the total energy production during swimming with whole body was lower than that during swimming with arms only. Support for the kick as a propelling agent came from the studies of Watkins & Gordon [11] and Hollander et al [6].

Is kicking the most inefficient part of the crawl swimming movements as Bucher [3] claimed it was? What is the effect of kicking on performance? Most of the research in the literature on the role of legs in swimming propulsion has concentrated on front crawl swimming [1, 11, 6, 9, 10, 8, 5]. In this study, we investigated and compared the effects of leg kicking on swimming efficiency in front crawl, backstroke and breaststroke swimming. Therefore, the aim of this study was to compare normal swimming with swimming with arms only in the context of two biomechanical parameters, namely velocity (V) and arm stroke index (ASI).

MATERIALS AND METHODS

SAMPLES

17 well conditioned, competitive male swimmers aged 14.64±2.14 volunteered to participate in this study. An indoor 50-m long swimming pool with water temperature of 25-26 degrees centigrade was used.

STUDY DESIGN

On the first day of the study, the swimmers were allowed to warm up by swimming at a very slow and steady pace for about 15 minutes and then they were allowed to rest for 15 minutes. Then, they carried out 4 times 100m swims, in each of the four styles (crawl, backstroke, butterfly[1] and breaststroke) at their maximum speeds with 15 minute intervals in between different styles.

The next day, all swimmers rested, and on the third day of the study the first day's procedure was repeated but now swimmers swam with arms only. In order to swim with arms only, pull buoys with ankle ties were used to inactivate the legs. Each category was timed in seconds and the number of strokes was counted and recorded. The swimming velocity (V) was calculated by dividing the total distance swum in meters by the swimming time measured in seconds. The arm stroke index (ASI) is defined as the arm stroke rate over the swimming velocity, or equivalently as the number of strokes necessary to cover a certain distance. In our study, ASI was computed as the number of strokes performed to cover 100 meters.

STATISTICAL ANALYSIS

The statistical analyses of the measured results were performed by using SPSS for Windows. Significance of the data was validated by the Wilcoxon Test for matched pairs. Differences between results obtained for different swimming styles were evaluated through the Friedman Test and Wilcoxon was used as a post-hoc test. Data are presented as Mean ± SD, and 95 percent confidence intervals were calculated for means of differences.

RESULTS

Swimming velocity and ASI measurements obtained during the two-day test procedure described above are presented in Table 1.

Table 1. Mean ± SD of swimming velocity and ASI corresponding to full stroke and to swimming with arms only.

		FC	BA	BR
VELOCITY (m/sec)	***FS***	1.42±0.15	1.18±0.1	1.02±0.06
	AO	1.28±0.15*	1.07±0.1*	0.79±0.14*
ASI	***FS***	74.46±16.34	79.17±15.75	61.03±12.95
	AO	89.20±21.12*	101.14±21.51*	130.05±47.18*

*FC- front crawl; BA- backstroke; BR- breaststroke; FS- full stroke; AO- arms only; ASI- arm stroke index *p<0.01*

The velocity reached while swimming with arms and legs was significantly higher than the velocity reached while swimming with arms only ($p<0.01$). The ASI corresponding to swimming with pull buoys was higher than the ASI corresponding to full stroke ($p<0.01$). It is evident from the data presented in Table 1 that leg kicking affected both velocity and ASI positively.

Percentage changes brought about in velocity and in ASI by leg kicking are summarised in Table 2.

[1] As it turned out to be impossible to prevent leg kicking in the butterfly stroke with pull buoys, results of the butterfly strokes were taken down but they were not taken into account and were not processed statistically.

Table 2. Mean ± SD of the percentage change in swimming velocity and ASI as a result of leg kicking.

	FC	BA	BR
VELOCITY (m/sec)	-11.02±6.08	-9.76±3.86	-24.28±9.11*
ASI	24.05±18.03	28.97±8.43	114.7±43.68*

*FC- front crawl; BA- backstroke; BR- breaststroke; ASI- arm stroke index *p<0.01*

DISCUSSION

In this study leg kicking was found to contribute to swimming performance (as measured by swimming velocity) and to swimming economy (as measured by ASI) significantly. Indeed, swimming velocity was higher and ASI was lower for full stroke swimming in all styles of swimming which were tested.

The net effect of swimming with arms only was to reduce swimming velocity in crawl, back and breaststroke swimming by 11.02±6.08%, 9.76±3.86% and 24.28±9.11% respectively. Although the percentage changes in crawl and backstroke velocities were close, change brought about by leg kicking was much higher in breaststroke swimming. In other words, improvements in crawl and in backstroke swimming due to leg kicking were modest compared to the drastic improvement in breaststroke swimming.

As it is almost a physical necessity to increase the number of arm strokes while swimming with pull buoys, ASI was naturally found to be higher during arms-only swimming than during full stroke swimming. This implies that those with higher ASI did not swim economically. Economical loss was 24.05±18.03% for crawl, 28.97±8.43% for backstroke, and 114.7±43.68% for breaststroke swimming.

To recapitulate, in crawl and backstroke swimming, our results suggest that the contribution of leg kicking to swimming velocity was approximately 10% and to swimming economy it was approximately 25%. The effect of leg kicking on breaststroke swimming was much more pronounced; its contribution to swimming velocity was approximately 25% and to swimming economy it was more than 100%.

Watkins & Gordon [11] found that a group of 73 male and female competitors could only pull at 90% of sprint speed when they were not kicking. The swimmers' legs were supported by pull buoys while they swam the front crawl stroke. Our results are in complete agreement with theirs. In another study by Hollander et al [6], researchers used a measuring active drag system to measure propulsive force while swimming and pulling. They tested 18 swimmers under two different conditions: (i) while swimming full stroke at maximum speed, and (ii) while pulling (arms only) at maximum speed with their legs supported by a pull buoy. The mean force produced during full stroke swimming was, on average, approximately 12 percent greater. They concluded that the additional force was supplied by the kicks because the arms were not capable of stroking any more efficiently. Our results confirm these findings as well.

Adrian et al [1] measured the oxygen consumption of 12 competitive swimmers while they were kicking only, pulling only, and swimming full stroke. The swimmers used nearly four times more oxygen when kicking only as compared to pulling only. These results are supported by the work of other researchers [2, 4, 7], all of whom found kicking causes a considerable increase in energy cost of swimming at medium and long distances.

In our study, ASI was the only criterion used to measure swimming economy. In this slightly simplified model, more strokes require more energy and therefore anything which increases the number of strokes causes, by definition, a loss of economy in swimming. Thus, in the light of our results, which are valid for short distance swimming, we conclude that leg kicking results in enhanced propulsion and more economical swimming. By the same token, we may suggest that leg kicking should be used extensively in sprint races and in the final sprints of medium to long distance competitions.

Backstroke competitions do not exceed 200 meters and therefore, in these short competitions, propulsion from the legs contributes to success considerably. The mechanics of breaststroke swimming are very different from those of crawl and backstroke swimming. In the breaststroke, the leg movements are best described as an outsweep and insweep. On the other hand the ASI in breaststroke swimming (using both arms simultaneously) cannot be compared to the two other strokes. However, in this study, it was found that the contribution of leg kicking to swimming velocity was considerable in breaststroke swimming. The contribution of leg kicking to the breaststroke needs no explanation. This can also be easily seen from the results. Of the three styles studied, the highest impact of leg kicking was on the breaststroke.

CONCLUSIONS

As a result of these findings, the performance impact of leg kicking was found to be important. In crawl and backstroke, the values were found similar; the impact of leg kicking seems especially clear in the breaststroke.

PRACTICAL APPLICATION

The application regarding the importance of increased training should be set with the inclusion of leg kicking. Leg sets should be considered as a form of training rather than recovery. In sprint training, especially in the breaststroke, the leg kicking training should be applied with high importance. In order to develop the leg strength in land and pool training, planning should be done carefully. On the other hand, pull buoy training combined with leg sets should be applied.

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