Evaluation of technique performances in freestyle swimming

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ABSTRACT

KESKINEN K.L. Evaluation of technique performances in freestyle swimming. *Kinesiology*, Vol. 2. No. 1, pp. 30-38, 1997. This is a review of studies on some methods that have shown to be useful when evaluating the technique performances of swimmers in training conditions. The mean velocity of swimming (v), excluding starts and turns, and independent of the stroke pattern, can be estimated from the product of stroke rate (SR) and siroke length (SL). SL rather than SR have been found to be the determinant factor in a swimmer's average speed so that the decline of v during racing is almost completely accounted for by decreasing SL. Thus one of the best parameters to describe the effectiveness of stroking is to examine the stroke length (SL) at a given swimming velocity. SR was noted to increase with increasing v with only minor differences between the curves of 100-m and 300-m distances. SL decreased when v increased above lactate threshold. The absolute values of SL at a certain speed were distance dependent having the shortest values when the distance was longest. When the stroke parameters were examined between different phases of swimming exercises of 400-m swims it was shown that the basic stroke patterns during the early part of the exercises were not different from those observed in competition. However, the patterns changed with the enhancement of swimming intensity suggesting that the degree of metabolic acidosis may determine the stroke patterns to be used. It is suggested that in order to get more benefit from the technique testing, unfatigued swimming should be compared with those of real competitive nature, where fatigue progresses. Moreover, it was found that best swimmers are superior in maximum velocities, in starting and turning as well in counter movement jump. With respect to the intra-cycle variation of force and velocity in front crawl it was observed that well balanced swimming was characterised by lower velocities in pull phases and higher velocities in push phases for both arms separately, while pulls were performed with higher force than push phases. Finally a one minute all out tethered swimming force in swimmers and triathlonists is discussed.

Key words: SWIMMING TECHNIQUES, FREE STYLE SWIMMING, STROKE PERFORMANCE, STROKE FORCE, INTRA-CYCLE VARIATION, SWIMMING VELOCITY, TETHERED SWIMMING

There are different approaches to evaluate the techniques of the swimmers in competition and practice. On one hand, good performances and good techniques are closely related and thus top level competitive results can be reached when also technique appearances are successful. On the other hand, nice looking and visually beautiful techniques are in the eyes of the spectator and not necessarily related to a first class performance. Therefore, expert systems based on computerised methods have been developed to help practitioners to improve individual techniques towards perfection (e.g. Persyn et al., 1988).

Three basic elements of a competitive swimming performance are starting, turning and stroking. Their relative importance for the whole swimming event depends on the distance to be covered during a race (e.g. Thayer & Hay, 1984). A simple race analysis with measurement of time during different phases of a competitive swimming event provides information about the effectiveness of a swimmer during the different phases of a race (Wakayoshi, 1988; Absalymov et al., 1989; Nelson & al., 1990; Kennedy et al., 1991; Chengalur & Brown, 1992; Wakayoshi et al., 1992; Keskinen, 1994). It has become customary to perform race analyses in international and national championships all over the world. Unfortunately, the protocols have not been fully comparable in terms of measured distances.

The aim of this article is to present and discuss some methods that have shown to be useful when evaluating the technique performances in training conditions.

Stroke Performance. The mean velocity of swimming (v), excluding starts and turns, and independent of the stroke pattern, can be estimated from the product of stroke rate (SR) and stroke length (SL). These factors and their basic relationships have been studied mostly in competitive situations (e.g. East, 1970; Craig & Pendergast, 1979). In these studies the major emphasis have been focused on examining the absolute values of SR and SL in different swimming events and strokes as well as on making comparisons between the genders.

The observations made in international swimming championships have shown that the combination of SR and SL in producing v is highly individualised (e.g. Satori, 1974, 1975, 1976, 1980). In skilled swimmers SL usually increases, while SR and v decrease with the increase in the race distance (Pai et al., 1984; Craig & Pendergast, 1979; Craig et al.,1985). There is a general agreement about how SL, SR and v vary as a race progresses (Letzelter & Freitag, 1982, 1983; Hay & Guimares, 1983; Craig et al., 1985; Pai et al., 1984). Except for finishing bursts in the final 1-2 laps of distance events, SL and v generally decrease throughout the course of a race. No similarly consistent pattern has been found with respect to SR. It may remain constant throughout a race or it may either decrease or increase. However, SL rather than SR have been found to be the determinant factor in a swimmer's average speed so that the decline of v during races (see for example Hay & Guimares, 1983) is almost completely accounted for by decreasing SL. Thus, one of the best parameters to describe the effectiveness of stroking is to examine the stroke length (SL) at a given swimming velocity.

Stroke Performance in exercise conditions. The behavior of SL, SR and speed during exercise conditions has been a topic of a few studies. Craig & Pendergast (1979) examined repeated swims at constant v for 22m distance at speeds varying from slow to maximum. An inverted U curve tor each swimmer was found, implying that there is an optimum SR for each swimmer. Furthermore, it has been demonstrated that when SL and blood lactate concentration (BLa) were related to velocity during exercises using incremental protocols SL could be seen to decrease below initial highest levels along with the increase in BLa (Keskinen & Komi, 1988a). Similar finding was reported by Weiss et al. (1988). When three different groups of swimmers were compared between each other (15 swimmers in each group selected according to competitive performance), the SL versus velocity curves demonstrated that best swimmers could maintain higher SL levels throughout the exercise as compared with their inferior counterparts. SL values started to decrease more rapidly (SL collapse) at the point of lactate threshold in each group (Keskinen & Komi, 1989). These relationships have been applied to indicate the progression of fatique during training conditions (Keskinen, 1993; Keskinen, 1994).

When different swimming distances were compared between each other the combination between v, SR, and SL was observed to change with increasing swimming intensity independent from the distances swum (Keskinen & Komi, 1988b). SR was noted to increase with increasing v with only minor differences between the curves of 100-m and 300-m distances. SL decreased when v increased above lactate threshold. The absolute values of SL at a certain speed were distance dependent having the shortest values when the distance was longest. When the stroke parameters were examined between different phases of swimming exercises of 400-m swims (Keskinen et al., 1993) it was shown that the basic stroke patterns during the early part of the exercises were not different from those observed in competition. However, the patterns changed with the enhancement of swimming intensity suggesting that the degree of metabolic acidosis may determine the stroke patterns to be used. The reduction of SL in lap by lap comparisons at intensities higher than the lactate threshold would be connected to the developing metabolic acidosis, while SR would primarily be determined by the possibility to maintain adequate neural activation. The comparison between the first-lap-SL and the rest of the 400-m swim demonstrated that fatigue may start to accumulate very early in 400-m swimming. While the common technique analyses are based on samples from a physiologically fresh swimmer the results may not correspond to a technique recorded in a situation with a longer duration. It is suggested that in order to get more benefit from the technique testing, unfatigued swimming should be compared with those of real competitive nature, where fatigue progresses.

Swimming force and technique performance. Counsilman's experiments (1977) demonstrated that a close relationship exists between swimming performance and vertical jumping height. A close relationship between strength on dry-land conditions and sprint swimming performance have been demonstrated by e.g. Miyashita (1975), Costill et al. (1980) and Sharp et al. (1982). In addition, Costill et al. (1983) found that small differences in sprinting speed was associated with measurable differences in swimming power and peak force, so that the best swimmers generated markedly greater peak force and power than swimmers with slower sprint times. Furthermore, the mean maximum force during tethered swimming has been shown to correlate positively to both maximum swimming velocity and stroke length (Keskinen et al., 1989). Thus it is of interest to discuss further the interrelationships between performance, technique and propulsive force production during swimming.

The improvement of maximum velocity in starts, turns and swimming is a common subject of practice among swimmers. Both the technical skill as well as the ability for muscular force production need to be exercised in order to gain further progress in performance. However, one should be able to recognise which one of the two: technique or capacity for force production, should be more pronounced. The intention of a study by Keskinen et al., 1992 (see also Keskinen 1993) was to examine maximum velocities in starting (SV), turning (TV) and swimming (MV) as indexes of highest technical ability to perform these activities. The consequent maximum velocities were related to indexes of force production capacity obtained either by the measurement of maximum force in tethered swimming (MF) or by the measurement of rise of centre of mass during counter movement jump (CMJ) on dry-land conditions (Komi & Bosco, 1978). Close relationship between MV and MF point out that in order to swim faster the swimmer must produce more propulsive force. The examination of MV versus MF relationship (Figure 1) enables the comparison of the highest technical ability as demonstrated by MV and the swimmer's capacity for muscular force production as shown by MF.

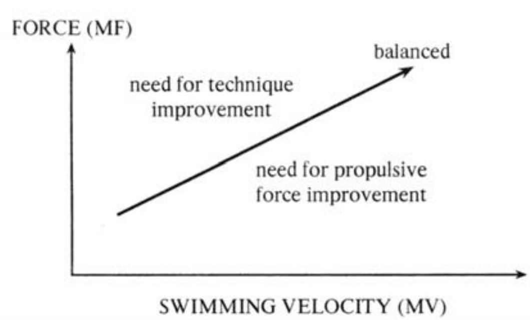

Figure 1. Representation of the relationship between maximum force in tethered swimming and maximum swimming velocity.

Thus, two swimmers with equally high strength level but different MV show remarkable differences in their swimming technique and therefore should be treated differently in their future training. On the other hand, two swimmers with the same MV but different force values should be handled separately when planning their weight training programs. CMJ which demonstrates the explosive power of the lower extremities had a strong positive correlation with SV and TV. CMJ is a very convenient parameter to describe the explosive component of both starting and turning activities. Best swimmers were superior in SV and TV as well as in CMJ. These plots when used in a similar principle as was done with the plots of MV and MF, make it possible to evaluate starting and turning skills in relation to the capacity of leg extensor muscles to produce explosive power (see also Counsilman 1977).

Intracycle variation of force and velocity in front crawl. Intracycle variation during swimming have previously been studied separately in velocity (e.g. Miyashita, 1970; Manley & Atha, 1992) and in tethered swim force (e.g. Yeater et al, 1981). Schleihauf et al. (1983) estimated swimming force, velocity and power by film analysis. Toussaint et al. (1988) registered averaged swimming force and velocity using a specially designed apparatus for measurement of active drag in arm stroke swimming.

The purpose of a paper presented by Keskinen & Komi (1993) was to make comparisons between technique performances of competitive swimmers by measuring intracycle variation of force, velocity and power during maximum intensity swims in front crawl stroke. Twelve male competitive swimmers performed two maximum intensity swims in randomized order: 10-m free swim and 10-s tethered swim. In free swimming an additional 10 m was allowed to increase the speed to maximum before the measurement started. Tethered swimming experiments were organized so that a rope from a belt around the subjects' waist was attached to a strain gauge dynamometer which in turn was attached to the wall of the swimming pool. The swimmers performed 10-s swims against the dynamometer. The force signal was registered on-line with a sample frequency of 50 Hz. The swims in both free and tethered swimming conditions were videotaped underwater (50 frames$\cdot s^{-1}$). The camera was attached on underwater trails on the side of the pool perpendicular to the direction of locomotion. The camera followed the swimmers with a similar speed throughout the swims. In order to synchronize the data from the video with that of the force dynamometer, an electrical signal at fixed intervals was recorded on the microcomputer during the course of force recordings simultaneously with a light signal which was recorded on the videotape. The velocity curves for each subject were analyzed from the videotapes of free swimming experiments. The force curves were drawn from the data stored in the microcomputer. The two different videotapes were used to match the values for velocity and force within the phases of the stroke cycle. Swimming power was calculated according to the equation:

$$\text{Power (W)} = \text{velocity } (m \cdot s^{-1}) \cdot \text{force (N)}$$

The data demonstrated large intra- and interindividual variation in all of the measured variables. On one hand, well balanced swimming was characterized by lower velocities in pull phases and higher velocities in push phases for both arms separately. On the other hand, pulls were performed with higher force than push phases. The best performers obtained relatively high means in velocity, force and power. Highest peaks in velocity and power (2.37 $m \cdot s^{-1}$ and 400 W, respectively) were obtained from a swimmer with highest mean velocity (2.03 $m \cdot s^{-1}$). That swimmer did not, however, reach the highest mean values neither in force (161 N) nor in power (294.7 W). Furthermore, the highest peak force (205 N) was observed from a swimmer with a lesser ability to very high speed swimming. The values for peak power in this study were in many subjects surprisingly high, even 400 W. Generally, the mean values were greater than calculated from the equations presented by Toussaint et al. (1988) or Schleihauf et al. (1983) for arm stroke. The differences were most likely due to differences in swimming conditions, and if the leg work could be accounted the values may be closely the same magnitude. Despite the great heterogenity of the individual curves, the intracycle variations could be used as a tool to evaluate the swimmers' technique performances with the measured parameters. The data agreed with Miyashita's (1970) observation that the fluctuation in intracycle velocities during successive stroke cycles can basically be represented by sine curve. It is therefore suggested that the individual curves should be evaluated in contrast with that observation.

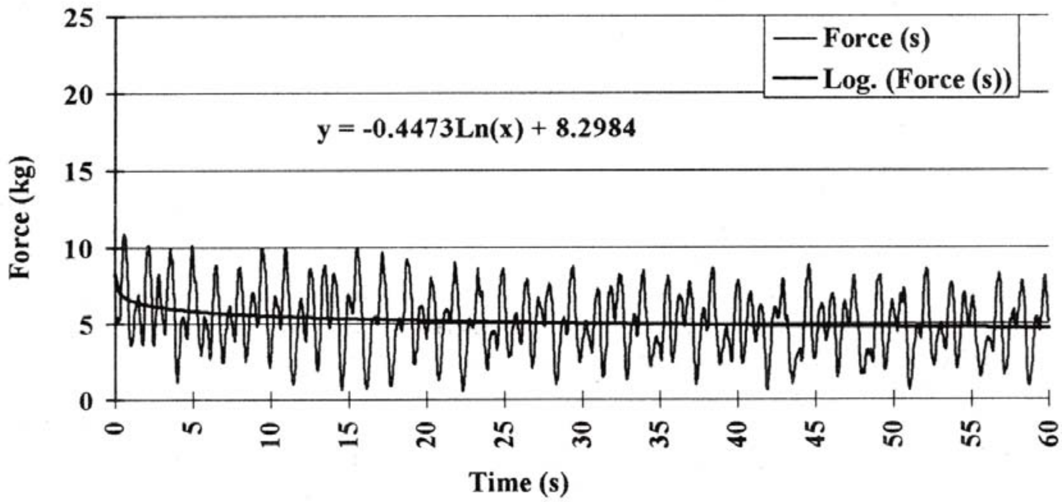

Figure 2. Force versus Time-relationship in 60-s all-out tethered swim for a triathlonist (HeJo).

One-minute all-out tethered swimming force in swimmers and triathlonists. Force production during tethered swimming have been shown to decrease in relation to time spent in stroking (e.g. Magel, 1970; Yeater et al., 1981). The studies, however, have been dealing merely with case materials, and consequently the results cannot be generalised for training purposes as such. Therefore, it was the aim of Keskinen et al. (1995) to examine the forces exerted during a single all-out 60-s tethered swim to gain further information about the relationships between force generation and continuous stroking. Eight swimmers and eight triathlonists volunteered to serve as subjects (Table 1). Tethered swimming experiments were performed as described earlier by Keskinen & Komi (1993).

In stroke by stroke comparisons the swimmers were found to generate significantly more force in the water as compared to triathlonists in the cycle means, maximum and minimum peaks as well as in left and right arms separately. However, the force reduction was similar between swimmers and triathletes during the 60-s swims. This is in a good agreement with previous findings of e.g. Magel (1970) and Yeater et al. (1981). The swimmers were found superior as compared with triathlonists in swimming force in the early phase of the trial but at the end of swims the difference was diminished. It seems that the swimmers, although significantly younger and less mature, have been more accustomed to high speed swimming.

Table 1. Physical characteristics for eight swimmers and eight triathionists (Keskinen et al., 1995).

Subjects (N=16)		Age (y)	Stature (m)	Mass (kg)	Weight in water (kg)	BMI (kg/m^2)	Time (s)	100m
Swimmers	mean	15.1	1.724	60.41	3.44	20.3	59.79	
(n=8)	S.D.	±0.9	±0.086	±7.52	±0.63	±1.1	±2.54	
Triathlonists	mean	28.71	1.788	73.09	4.17	22.9	71.49	
(n=8)	S.D.	±3.6	±0.059	±5.83	±0.59	±1.4	±4.91	

On the other hand, the reduction of force was less with triathlonists being more accustomed to long distance low pace training. It is evident that the propulsive efficiency of the swimmers might be much higher as compared with triathlonists (see also Toussaint, 1990). It is suggested that the one-minute all-out tethered swims could be used to estimate the swimmers capacity for high intensity work as well as for endurance.

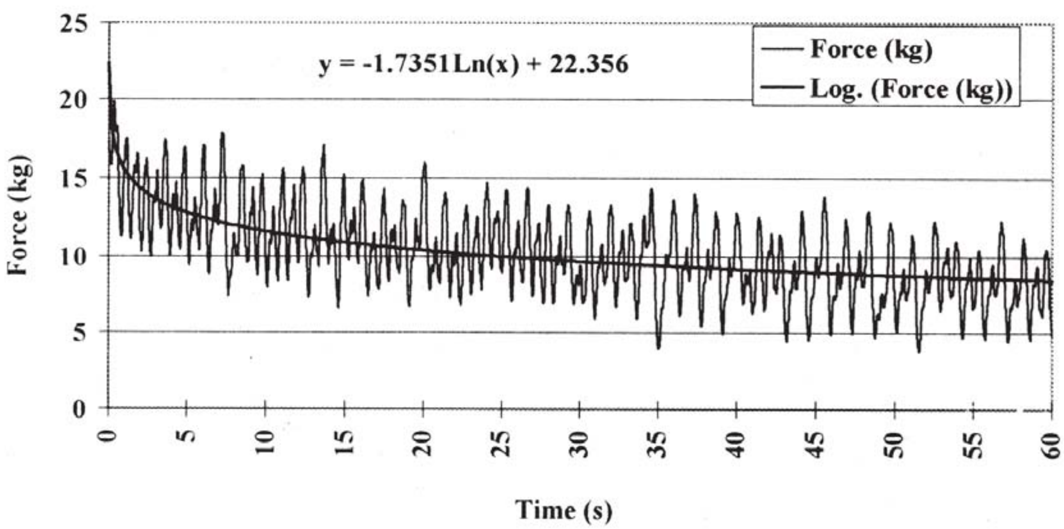

Figure 3. Force versus Time-relationship in 60-s all-out tethered swim for a swimmer (JeHa).

The force analysis in tethered swimming experiments seem to be one of the tools to estimate the techniques of the swimmers in training conditions. And, although not completely similar to free swimming, tethered swimming can be used to define the swimmers potential for muscular force production in the water. This seems to be far better means of testing than dry-land testing protocols as demonstrated by good correlation between average maximum force and swimming velocity and stroke length. However, the force curves are highly individualized and two swimmers with equal performances in competition may show remarkably different force curves. Therefore, the technique malfunction can be recognized only on individual basis. This can be done e.g. by comparing the balances between the left and right arms, as well as by looking for disturbances caused by arm, leg and breathing activities. Large variation between maximum and minimum force peaks seems to be one of the factors that should be avoided in order to obtain well balanced stroking. Finally more information is necessary to demonstrate the effects of fatigue in a situation of major importance; i.e. final phases of competition.

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