STROKE INDEX VALUES ACCORDING TO LEVEL, GENDER, SWIMMING STYLE AND EVENT RACE DISTANCE

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The performance of swimmers competing in all events at the First World Short Course Championships and at the XXXVII Winter Spanish Championship were videotaped and analyzed to determine stroke length (SL), stroke rate (SR), average velocity (v) and stroke index (SI); relationships were then taking into account the final time (FT), level, gender, swimming style and event distance. Results revealed significant correlation between SI and FT at both championships in all the butterfly race distances. SI may be used as performance index being significantly greater in male swimmers than female in all the events, independently of their level. The freestyle had the greatest SI followed by the backstroke, butterfly and breaststroke. The general tendency indicates that as the distance of the race increases the SI decreases.

KEY WORDS: swimming, competition analysis, stroke index, kinematic parameters.

INTRODUCTION: The stroke index (SI) was defined by Costill, *et al.* (1985) as the product of average velocity (v) and stroke length (SL), and they considered it a valid indicator of swimming efficiency. McMurray *et al.* (1990) used the definition given by Lavoie *et al.* (1985) who suggested that this index could predict the maximum aerobic power in swimming. To calculate SI, the total number of cycles carried out in a defined distance of swimming was divided by the average velocity from the final time race event; in this way the resulting units were cycles$\cdot(m\cdot s^{-1})^{-1}$ vs. $m^2\cdot(s\cdot cycle)^{-1}$ according to the concept laid down by Costill et al. (1985). These latter units were employed in other research papers (Keskinen *et al.*1989; Wille and Pelayo, 1993; Arellano *et al.*1997). The purpose of the study was to develop the stroke index concept as follows: a) to evaluate the correlation between final time (FT) and SI; b) to compare the SI among swimmers of different levels; c) to examine the differences across several race distances and swimming styles and; d) to compare the differences between sexes.

METHODS: The present study evaluated 313 swimmers at the First World Short Course Championship (WC), 181 men and 313 women, and 420 swimmers at the XXXVII Spanish Championship of Winter (SC), 217 men and 203 women. All the events were recorded with three 8 mm video cameras; the first set covered the start and the first 10 m, the second the middle of the swimming pool and the third the final 10 m at the turning end. Stroke rate (SR) and SL were calculated from the video records. To estimate SR, the time required to perform three stroke cycles was measured and then used to calculate the SR, according to the method used by Sánchez (2000). The v, which was determined by the midsection of the pool, was used in conjunction with the SR data to calculate the SL in each event lap and with this last the SI, as follows:

$$v = l_i \cdot t_i^{-1} \, (m \cdot s^{-1}); \tag{1}$$
$$SL = v \cdot SR^{-1} \, (m \cdot cycle) \tag{2}$$
$$SI = SL \cdot v \, [m^2 \cdot (s \cdot cycle)^{-1}] \tag{3}$$

where l_i = length in meters of midsections of Lap i, and t_i = time in seconds to cover the midsection of Lap i. The FT was obtained from the official swimming results of both championships. For each lap an imaginary line was interpolated between the distance markers of exterior lanes. An electronic flash activated by the starter's gun was switched on, and used to synchronise the video records with the official electronic timing. The swimming times were recorded when the swimmer's head crossed the references. Data from both preliminary and final heats were used in the analysis. For a swimmer who competed in both heats the time of the best performance was used. All the results were calculated with a database program, FileMaker Pro 3.0 by Clarys (1995). The results of the events were

compared by a series of ANOVAs. Scheffe test was subsequently performed to evaluate the differences.

RESULTS AND DISCUSSION: SI correlated for both championships with FT (p<0.01; r>0.75) in all the butterfly race distances; for the rest of the swimming styles, although there was significant correlation, these never reached the value r>0.75, except in the 50 m WC female breaststroke (p<0.01; r=-0.87). We agree with Mason (1999), who only found a high correlation in butterfly. We consider that for the same velocity a swimmer will be more efficient if the SL is higher because the SI will be higher. At both championships for males and females, the freestyle was the most effective stroke, followed by backstroke, butterfly and breaststroke. The SI values in descending order are shown in figure 1. The SI value of 50 m WC freestyle is the highest in all events in both championships. The analysis indicated, without exception, at the WC, significant differences of the SI (p<0.01) for gender and between events, and with the exception of 50 m breaststroke at the SC due to the high SF of women (0.97 ±0.05 cs^{-1}). The v also showed significant differences (p<0.001); however the SF values were not statistically different. The SL values of WC were significantly different (p<0.05) in two events (200 m freestyle and 100 m butterfly). Besides these two events the SC also presented differences in the freestyle 100 m. The values of SI, v and SL in males were higher than these in females in all events. This is probably due to the difference in height between men and women, as it influences the SL. The men showed higher 100 m SL values than the women, 9% at the WC and 11% at the SC. Kennedy *et al.* (1990) obtained similar values (10% approximately) at the 1988 Olympic Games. Arellano *et al.* (1994) established some greater differences of 9% for male freestyle events at the 1992 Olympic Games. We found 10% at the WC and 12% at the SC in the freestyle events. Therefore, our data does not differ from the studies presented before. The SL of WC was significantly higher (p<0.001) than the SL of SC, 5% for men and 3% for women. When t test was calculated with the event distance as a grouping factor at the WC the SI, results were significantly different (p<0.05) in male butterfly and breaststroke, while at the SC (by means of Scheffe test) these differences were in butterfly and male breaststroke (p<0.05) and even between the 200 m with respect to 50 m and 100 m. At the WC, the Scheffe test showed significant differences in male freestyle events between 400 m and the other distances; at the SC they were between 100 m and the rest of distances. For women the SI also decreased at longer distances, and while at the WC there were significant differences (p<0.05) among distances, excepting the 50 m with respect to the 100 m and 200 m, at the SC there were no differences, perhaps due to the very short SL in the 100 m and 200 m events. The backstroke was the style where the event distance had least influence in the SI for both genders; the butterfly was the style where the distance most affected the men, while this influence was very similar in the remaining styles for the women. Table 1 presents the SI percentage found from the highest SI, in both championships, that is the 50 m male freestyle [4.15 m^{2}· (s·cycle)$^{-1}$ is 100%]. As a general tendency, a reduction of the SI value is appreciated when the event distance increases as much in the men as in the women and in both championships from the 100 m events. The SI values of the man's 50 m backstroke and breaststroke events were smaller than the values 200 m in the event; in these events, the increase of the SF was not able to compensate the large reduction of the SL and of this way, although the velocity was higher in these events than in superior distance events the SI was not. At the SC the women did not reduce the SL so much in the 50 m events and their SI is in the second place of the three distances analysed per style, except in the butterfly which reaches the highest value.

CONCLUSIONS: a) SI may be used as an indicator of the performance level because in the international competition swimmers' SI was significantly greater than in the national competition swimmers´ SI. b) Results showed an important correlation between SI and FT at both championships in all the butterfly race distances. c) For swimming styles: front crawl had the greatest SI, followed by the backstroke and butterfly; the breaststroke SI had the smallest value. d) The general tendency indicates that as the distance of the race increases, from 50 to 400 m, SI decreases, excepting breaststroke style. d) In all the events, without exception, SI was significantly greater in male swimmers than female, independently of their levels.
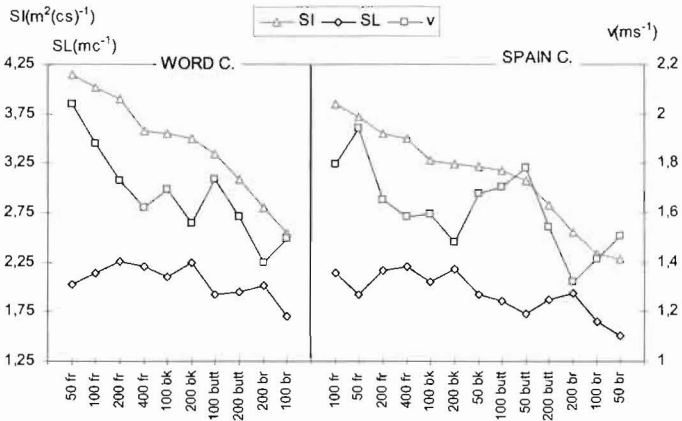
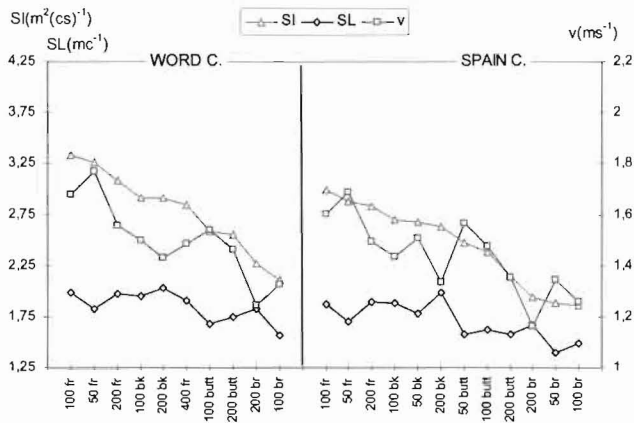**Figure 1**. SI, SL and v at the World and Spain Championships male events.

Figure 2. SI, SL and v at the World and Spain Championships female events.

Table 1. SI, expressed as a percentage of the maximum value obtained, per event, sex and style, at WS and SC.

	Freestyle					Backstroke				Butterfly				Breaststroke			
	50	100	200	400	**Mean**	50	100	200	**Mean**	50	100	200	**Mean**	50	100	200	**Mean**
WC Male	100	97	94	86	94		86	84	85		81	74	77		61	68	64
WC Female	79	80	74	69	76		70	70	70		62	61	62		51	55	53
SC Male	90	93	86	84	88	78	79	78	78	74	77	68	73	55	56	62	58
SC Female	69	72	68		70	65	65	64	64	60	57	52	56	45	45	47	46

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