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Stroking parameters in top level swimmers with a disability

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ABSTRACT

PELAYO, P., M. SIDNEY, P. MORETTO, F. WILLE, and D. CHOLLET. Stroking parameters in top level swimmers with a disability. *Med. Sci. Sports Exerc.*, Vol. 31, No. 12, pp. 1839-1843, 1999. **Purpose:** The purposes of this study were to analyze velocity (V), stroke length (SL), and stroke rate (SR) values during the 100-m freestyle competitive events in top level male and female swimmers with a disability (DS) according to the international Functional Classification System (FCS) and to compare the results obtained with those of able-bodied swimmers (ABS). **Methods:** DS ($N = 119$) and ABS ($N = 32$) were tested in real competitive conditions during European and French swimming championships in the A finals of the 100-m freestyle. **Results:** V and SL increased significantly ($P < 0.01$) according to the level of ability from class S3 up to S10. SL values were significantly different ($P < 0.01$) between males and females in each class group. On the contrary, SR was not significantly different between genders, between each class group of FCS, and also with ABS. The major result of this study was that stroke length was related to velocity whereas stroke rate was not. The differences in weekly training time between each class of DS were not significantly different and showed that performances seemed to be more related to the various locomotor disabilities than to the training status. **Conclusions:** These findings, which are discussed, showed that stroke index ($SI = V \cdot SL$) could be used as a sensitive criterion to assess the swimmer with a disability in relationship to his classification level. **Key Words:** SWIMMING, STROKING CHARACTERISTICS

The product of stroke length (SL) and stroke rate (SR) is one of the fundamental components of swimming velocity (V) and has been the subject of many investigations of top level swimmers. Different research teams have studied the existence of an optimal SL/SR ratio in top level able-bodied swimmers according to velocity (6,7,9) and the variations introduced by the swimming styles (2,11,17) and the distance of the race (6,9,12,18). These authors have reported that swimming performances are characterized by greater variability in SL than in SR. Besides, Costill et al. (4) have shown that SL and stroke index ($SI = V \cdot SL$) have a good relationship with swimming performance and success. These parameters have also been studied in nonexpert swimmers (20) but never before in individuals with a disability. During competition for swimmers with physical disabilities each participant competes in a class group in relationship to his or her functional ability to swim and according to the international "Functional Classification System." This classification system was designed

to provide swimmers with an equitable starting point. However, there are few published norms in the area of swimming performance for persons with disabilities (8,13). There is also limited information on the stroking parameters used by top level swimmers in competition in regard to different levels of physical disabilities.

The purposes of the present investigation were: 1) to evaluate the influence of the degree of disability according to the Functional Classification System on velocity, stroke length, stroke rate, and stroke index values during the 100-m freestyle competitive events in top level male and female swimmers with a disability; and 2) to compare the results obtained with those of able-bodied swimmers.

MATERIALS AND METHODS

Participants. Top level swimmers (62 males and 57 females) with a disability (DS) were tested in real competitive conditions (in a 50-m pool) during the 1995 European swimming championships in the A finals of the 100-m freestyle. For all participants, groups were compared according to the revised (post-Barcelona Paralympic Games) "Functional Classification System" (FCS) used during the 1996 Paralympic Games and the 1995 European Swimming Championships (Table 1). It integrates the International

TABLE 1. Means (\pm SD) of velocity (V), stroke length (SL), stroke rate (SR), stroke index (SI), weekly training volume (WTV), and weekly training time (WTT) in male and female swimmers with a disability and able-bodied swimmers.

	Disabled Swimmers								Able-Bodied Swimmers
	S 3	S 4	S 5	S 6	S 7	S 8	S 9	S 10	
Males	<i>N</i> = 7	<i>N</i> = 7	<i>N</i> = 8	<i>N</i> = 8	<i>N</i> = 8	<i>N</i> = 8	<i>N</i> = 8	<i>N</i> = 8	<i>N</i> = 16
V (m·s ⁻¹)	0.73 \pm 0.07	0.94 \pm 0.04 ^a	1.03 \pm 0.09 ^a	1.16 \pm 0.11 ^a	1.38 \pm 0.03 ^a	1.46 \pm 0.06 ^a	1.49 \pm 0.03 ^b	1.59 \pm 0.04 ^a	1.83 \pm 0.04 ^a
SL (m·cycle ⁻¹)	1.05 \pm 0.40	1.21 \pm 0.24	1.23 \pm 0.21	1.46 \pm 0.33 ^a	1.52 \pm 0.13 ^b	1.73 \pm 0.22 ^b	1.72 \pm 0.15 ^c	1.82 \pm 0.11 ^c	2.21 \pm 0.13 ^a
SR (cycle·min ⁻¹)	47.35 \pm 18.77	48.34 \pm 10.97	51.21 \pm 9.38	48.87 \pm 8.84	51.46 \pm 4.00	51.33 \pm 5.77	52.39 \pm 4.56	52.47 \pm 2.43	49.80 \pm 3.52
SI (m ² ·s ⁻¹ ·cycle ⁻¹)	0.8 \pm 0.4	1.1 \pm 0.3 ^a	1.3 \pm 0.3 ^b	1.7 \pm 0.5 ^a	2.1 \pm 0.2 ^b	2.4 \pm 0.4 ^b	2.5 \pm 0.3 ^b	2.9 \pm 0.2 ^a	4 \pm 0.2 ^a
WTV (km·wk ⁻¹)	16 \pm 2.1	18.4 \pm 3.3	20.1 \pm 3.9	25.9 \pm 4.7 ^a	30.8 \pm 4.5 ^b	31.9 \pm 6.1 ^b	35.9 \pm 7.8 ^c	37.8 \pm 5 ^c	64 \pm 5 ^a
WTT (h·wk ⁻¹)	9.3 \pm 1	8.7 \pm 1.7	8.7 \pm 1.1	9.2 \pm 2.6	9.4 \pm 2	9.9 \pm 2.7	9.9 \pm 2.5	9.6 \pm 1.6	15.7 \pm 2
Females	<i>N</i> = 5	<i>N</i> = 6	<i>N</i> = 8	<i>N</i> = 8	<i>N</i> = 8	<i>N</i> = 8	<i>N</i> = 8	<i>N</i> = 6	<i>N</i> = 16
V (m·s ⁻¹)	0.53 \pm 0.13 ^a	0.76 \pm 0.16 ^{a*}	0.87 \pm 0.15 ^{a*}	0.99 \pm 0.11 ^{a*}	1.10 \pm 0.06 ^{a*}	1.16 \pm 0.06 ^{a*}	1.27 \pm 0.04 ^{a*}	1.35 \pm 0.12 ^{a*}	1.61 \pm 0.02 ^{a*}
SL (m·cycle ⁻¹)	0.76 \pm 0.25 ^a	0.96 \pm 0.23 ^{a*}	1.20 \pm 0.18 ^{a*}	1.22 \pm 0.18 ^{a*}	1.39 \pm 0.13 ^{a*}	1.44 \pm 0.14 ^{a*}	1.49 \pm 0.07 ^{a*}	1.54 \pm 0.17 ^{a*}	2.00 \pm 0.12 ^{a*}
SR (cycle·min ⁻¹)	46.99 \pm 9.83	48.00 \pm 6.68	46.09 \pm 5.57	49.12 \pm 6.42	48.07 \pm 5.93	48.61 \pm 4.83	52.51 \pm 2.62	52.65 \pm 3.69	48.34 \pm 2.74
SI (m ² ·s ⁻¹ ·cycle ⁻¹)	0.4 \pm 0.2 ^a	0.7 \pm 0.3 ^a	1.2 \pm 0.3 ^{a*}	1.2 \pm 0.3 ^{a*}	1.5 \pm 0.1 ^{a*}	1.7 \pm 0.2 ^{a*}	2.0 \pm 0.1 ^{a*}	2.1 \pm 0.4 ^{a*}	3.2 \pm 0.2 ^{a*}
WTV (km·wk ⁻¹)	11.8 \pm 2.9 ^a	13.8 \pm 1.7 ^a	17.8 \pm 2.4 ^{a*}	23.1 \pm 4.8 ^a	27 \pm 4.9 ^c	29 \pm 5.4 ^c	34.9 \pm 4.8 ^b	36.2 \pm 7 ^c	65 \pm 4.5 ^a
WTT (h·wk ⁻¹)	7.7 \pm 1.4 ^a	8.1 \pm 1.2	8.0 \pm 1.8	9.5 \pm 1.4	9.8 \pm 1.2	9.9 \pm 1.7	10.6 \pm 1.5	10.4 \pm 1	15.9 \pm 2.7

* Significantly different between males and females.

^a Significantly different from the next previous class group.

^b Significantly different from the second previous class group.

^c Significantly different from the third previous class group.

Sports Organization for persons with amputations and persons with other conditions, the International Stoke Mandeville Wheelchair Sport Federation for those with spinal paralysis, and the Cerebral Palsy International Sports and Recreation Association for those with nonprogressive motor dysfunction above the foramen magnum, such as cerebral palsy and head injury. In the FCS for freestyle, each competitor with one of the various locomotor disabilities is classified into 1 of 10 classes (referred to as S). The swimmers in class 1 (S1) have the least functional ability to swim and those in class 10 (S10) have the most ability. The Functional Classification System is derived from bench testing which evaluates range of motion, strength, coordination, and limb length, and from a functional swimming analysis which evaluates the swimmer in his or her competitive stroke, dive start, and turns (10). The bench points are calculated and added to the sum of the points for the stroke, dive start, and turn components for the appropriate classification level. Each swimmer is further observed and assessed during the actual competition. Thus the swimmer's classification may be changed during competition if the swimmer's abilities appear to be too functional or not functional enough for his or her classification level.

In addition to this, 16 male and 16 female top level able-bodied swimmers (ABS) were tested during the 1995 French championships in the A and B finals of the 100-m freestyle.

All participants and delegations gave written informed consent to voluntarily participate in the study before the beginning of the competitions. All evaluations in the study were carried out under organizational committee supervision.

Protocol. The procedure for the analysis was that of Pelayo et al. (18) and was very similar to those of Kennedy et al. (11). It consisted of measuring the velocity over a distance of 30-m (V) as well as the SR from a videotape recording of the finals according to the following protocol: two S-VHS video cameras running synchronously, set 30-m apart along the central part of the pool and connected to a

timer, enabled us to assess the value of V. The SR was measured across the length of the 30-m using a Seiko (Japan) frequency meter (base 3, i.e., three stroke cycles) and expressed in cycles per minute (cycles·min⁻¹). The distance per cycle over 30-m (SL) was calculated from the V/SR ratio. One freestyle stroke cycle corresponded to two arm strokes (left and right strokes). During a freestyle event and in swimmers with a disability, the styles used by each swimmer differed according to his or her various locomotor disabilities. Thus, a stroke cycle was defined as follows in this study: the part of the body (head or arm) emerging above the water level during each stroke cycle which could easily be selected on the video film was used to identify the beginning and the end of a stroke cycle. To appreciate the evolution of swimming performance level, the stroke index (SI) was calculated for each class and sex group (4). SI was the result of the product of velocity and stroke length and was expressed in m²·s⁻¹·cycle⁻¹.

A questionnaire given to all the assessed swimmers allowed us to report the average weekly training volume (WTV) and weekly training time (WTT) during the current season.

Statistical analyses. Group means and SD were calculated for all measured parameters. The Mann-Whitney unit test was used to determine the significance of differences for dependent variables (V, SR, SL, WTV, and WTT values) among the class groups and between males and females (independent variable). Simple regressions were performed between SR, SL, and the V mean values observed in the different groups. The level of statistical significance was set at *P* < 0.05.

RESULTS

Velocity (V) and stroking parameters (SL, SR) measured during the 100-m freestyle are shown in Table 1 for male and female swimmers with a disability (DS), as well as for able-bodied ones (ABS). V values increased significantly (*P* < 0.01) according to the level of ability from S3 up to

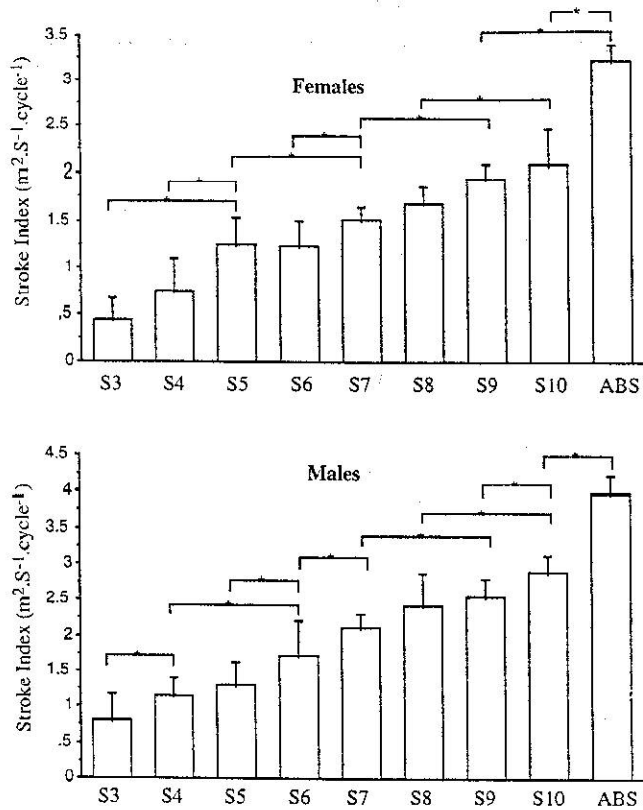


Figure 1—Evolution and comparison of stroke index (SI) in class groups of swimmers with a disability (DS, from S3 up to S10) and able-bodied swimmers (ABS). * Significant differences at $P < 0.05$ between each class group of swimmers (DS and ABS).

S10 and ABS. In DS the mean differences in velocities were $18.4 \pm 4.1\%$ and ranged from 27.3% in S3 to 14.7 and 15.1% in S9 and S10, respectively. In contrast, the difference between male and female able-bodied swimmers recorded in this study was $12 \pm 1.1\%$.

SL and SI values increased significantly ($P < 0.01$) according to the level of ability from S3 up to S10 (Table 1 and Fig. 1, respectively). In DS, mean stroke length values were significantly related ($P < 0.01$) to mean velocity values in male and female swimmers ($r = 0.98$ and $r = 0.99$, respectively). SL and SI values were significantly higher ($P < 0.01$) in males than in females in each class group and also in able-bodied swimmers.

SR values were not significantly different between each class group for those with a disability and for the able-bodied swimmers (Table 1). Mean stroke rate values were not significantly related to mean velocity values in male and female swimmers. No significant difference was noticed in SR values between genders.

Weekly training volume (WTV) and weekly training time (WTT) are also presented in Table 1 for male and female DS as well as for the able-bodied swimmers. From S3 up to S10, the average weekly training volume (WTV) of the season reported for each class group increased significantly ($P < 0.01$) from 14.2 ± 3.2 up to 37.1 ± 5.8 $\text{km}\cdot\text{wk}^{-1}$, respectively, whereas the able-bodied WTV was also significantly higher (64 ± 5.3 $\text{km}\cdot\text{wk}^{-1}$, $P < 0.01$). Significant differences ($P < 0.05$) were noticed between male and female

swimmers only in S3, S4, and S5. However, the differences in weekly training time (WTT) were not significantly different among the DS groups. Only significant differences ($P < 0.01$) were found between DS and ABS for weekly training time values (9.1 ± 2 vs 15.8 ± 1.8 $\text{h}\cdot\text{wk}^{-1}$, respectively). No significant difference was noticed in WTT between genders except in S3 where WTT was higher in men than in women.

DISCUSSION

Significantly different swimming velocity values for swimmers with a disability from S3 up to S10 and for able-bodied swimmers support the assumption that speed increases as the level of ability increases (Table 1). Swimming velocities were significantly different between genders. These differences were higher in DS than in ABS (18.4% vs 12%, respectively) and can be explained by the highest differences recorded in class S3 (27.3%) which included subjects with important disabilities such as tetraplegia and quadriplegia. A difference of 18% has also been reported in paraplegic male and female swimmers by Gehlsen and Karpurk (10). As in the top level swimmers of the present study or previous studies (1,6,9,12,18), the difference in velocity between males and females primarily reflects the differences in stroke length. There was no significant difference in SR between male and female swimmers and between each class group. Therefore, SL seems to be the main contributor to the higher velocity of male swimmers. The gender difference in SL and V could be explained by both strength and body size. According to the results obtained by Toussaint et al. (21) in an investigation between two groups at different levels, the difference in stroke length between male and female swimmers may reflect general differences in muscle mass and body size. Nevertheless, additional reasons such as training habits can be put forth to explain the higher differences observed between gender in swimmers with a disability. Indeed, weekly training volume was significantly higher in males than in females for S3, S4, and S5, as well as weekly training time in S3. More investigations in training intensity or cultural differences could also explain these differences between genders. Moreover, in a study of paraplegic and tetraplegic track records, Coutts and Schutz (5) reported that the differences between classes with males compared with those with females is likely to be a reflection of lower incidence of spinal cord injuries in females and the lower number of female finalists.

The solutions adopted by these top level swimmers with a disability have shown that the difference in velocity between each class group and able-bodied swimmers primarily reflects the differences in stroke length. Indeed, no significant differences in SR values were found between each class group and also with the able-bodied swimmer values. Moreover, SL was significantly related to V ($r = 0.99$) whereas SR was not. The stroke length values which are in relationship with the level of disabilities, could be one of the means of distinguishing the different class groups with a disability

from each other and also from able-bodied swimmers. Indeed, the magnitude of the stroke length is related to the propulsive forces that a swimmer exerts while stroking, and to water drag forces. Thus, the decrease in SL values could be explained by the range of motion, strength, coordination, or limb length according to the degree of physical disability. Furthermore, Chatard et al. (3) have shown in swimmers with a disability that passive drag, which is a gliding factor, is correlated to swimming speed and decreases with the ability level. They have also noticed that the ratio mass/height without amyotrophy (i.e., reduced volume of inactive muscles) is a major determinant of the passive drag. Chatard et al. (3) have concluded that the degree of disability strongly influences performances and gliding factors of swimmers with disabilities. Thus, this could explain the increase of SL according to the degree of functional ability in DS.

The increase of stroke index values from S3 up to S10 and able-bodied swimmers could be linked with the variations of swimming efficiency as indicated by Pelayo et al. (19) in swimmers with cerebral palsy. Their data and the SI values calculated in the present study indicate that the practical level was much higher in ABS than in DS and could be explained by the degree of physical disabilities in DS but also, to a certain extent, by their relatively lower training state (Table 1). Indeed, in the present study, the average weekly training volume of the season reported for each class group partly confirms this second explanation. From S3 up to S10, it increased significantly ($P < 0.01$) and gradually from 14.2 ± 3.2 up to 37.1 ± 5.8 km \cdot wk $^{-1}$, respectively, whereas the able-bodied swimmers swam 64 ± 5.3 km \cdot wk $^{-1}$. Nevertheless, the differences of weekly training time between each class with a disability (i.e., when the distance swam weekly is related to swimming velocity in each group class) were not significantly different. Only significant differences were found between DS and ABS for weekly training time values (9.1 ± 2 vs 15.8 ± 1.8 h \cdot wk $^{-1}$, respectively). This point showed that the swimming performance level seemed to be more related to the level of disability than to the training status in this population of top level swimmers with a disability. Since the Functional Clas-

sification System is derived from bench testing but also from a functional swimming analysis before and during the competition (10), the measure of SI could be used as a practical criterion for referees to assess the swimmer if he appears to be too functional or not functional enough for his or her classification level. This practical criterion could thus be used to complement the subjective assessment of the referees during the functional swimming analysis to provide DS with an equitable starting point. Nevertheless, it must be stressed that this criterion cannot be the sole means of distinguishing the different class groups because it is also linked to the training status (16). Indeed, McMurray et al. (16) have indicated that SI may be a sensitive indicator of training and stroke proficiency. In the same way, it could be suggested that the measurement of SI can be easily introduced by coaches and swimmers with a disability into their training programs as a viable indicator to monitor seasonal progress.

CONCLUSION

The results showed that SR and SL chosen in the 100-m freestyle event in swimmers with a disability has specific characteristics according to the various locomotor disabilities. The velocity and stroking parameters in freestyle also depend on the sex of the swimmer. The SR observed in DS was close to those of ABS. The lower velocities of the DS can be explained by lower SL values. The major result of this study was that SL and not SR was related to velocity as in able-bodied swimmers. Therefore, as in able-bodied swimmers, it could be interesting to regularly evaluate stroking characteristics such as SL or SI to optimize performances of swimmers with a disability in relation with their abilities and training status during the training season.

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