Trajectoires des mouvements du bras crawlé des nageurs déficiants physiques: étude préliminaire

Front crawl arm stroke trajectories of physically impaired swimmers: a preliminary study

Short title

Trajectoires des mouvements du bras des nageurs déficiants physiques
Stroke trajectories of physically impaired swimmers

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Trajectoires des mouvements de bras en crawl chez des nageurs déficiants physiques: étude préliminaire

Résumé:

Introduction – Cette étude a eu pour objectif d'évaluer les paramètres tridimensionnels de la cinématique du mouvement crawlé chez des nageurs présentant des limitations fonctionnelles de différents niveaux.

Synthèse des faits et résultats - Huit nageurs de haut niveau (5 hommes et 2 femmes) classés

dans les catégories S5 à S9 du Comité International Paralympique ont réalisé des essais de nage crawlée maximale sur 50m, filmés par six caméras vidéos (4 sous l'eau et 2 au-dessus). Le point le plus distal de l'avant-bras droit a été numérisé à 50Hz pour permettre la reconstruction tridimensionnelle de la trajectoire du bras dans l'eau.

Conclusions - Le mouvement de bras présentait une grande variabilité entre les nageurs, reflétant les caractéristiques individuelles et la gravité de la déficience. Les nageurs qui combinaient un mouvement de bras peu profond et étroit ont réalisé une trajectoire de bras plus courte. Cette étude donne une vue d'ensemble aux nageurs et aux entraîneurs des conséquences des déficiences physiques sur les caractéristiques cinématiques de la nage crawlée.

Mots-clés: natation, paralympique, cinématique, performance

Front crawl arm stroke trajectories of physically impaired swimmers: a preliminary study

Summary

Introduction - This study evaluated three-dimensional kinematic parameters of the front crawl stroke in physically impaired swimmers across a range of functional classification levels.

Facts and Results - Eight highly-trained competitive swimmers (5 male and 3 female) from IPC classes S5 to S9 performed 50m maximal front crawl trials while being video-taped by six cameras (four under- and two above water). The most distal point of the right upper limb was manually digitised at 50 Hz to allow three-dimensional reconstruction of the limb's trajectory through the water.

Conclusion - The stroke presented large inter-swimmer variability, reflecting individual characteristics and severity of the impairment. The swimmers who combined shallow and narrow stroke movements produced a shorter trajectory. This study provides swimmers and coaches with an overview of the kinematic characteristics of a range of physically impaired swimmers.

Key-words: Swimming, paralympic, kinematic, performance.

Introduction

Competitive swimming has caught the public's attention due to the continuous improvement of performance in championships such as the Olympic and Paralympic Games. The means and methods of training are increasingly based on establishing and selecting the most relevant technique factors to improve the performance. Thus, kinematic analysis of swimming movement patterns is becoming increasingly popular as it can be used to produce significant improvements [1, 2] in competitive swimmers' performances through identification and correction of errors.

Due the complexity of swimming environment, two-dimensional analysis has been employed. However, analysis in a single plane compromises the understanding of the multidimensional swimming movements, which require accurate assessment by three-dimensional analysis. The kinematic parameters of able-bodied swimmers' technique have received some attention [3]. However, there is limited information regarding three-dimensional description of the underwater movement patterns of physically impaired swimmers. This information is of utmost importance since physical impairment may limit the range of motion and influence the swimmer´s ability to generate propulsive forces. Thus, this study aimed to quantify some performance-related stroke parameters in elite physically impaired swimmers.

Methods

Eight national or international level of para-swimmers (5 male and 3 female; age 18 ± 3.22 years; mass 54.37 ± 13.75 kg.), ranging from IPC class S5-S9, participated this study. The procedures for the data collection were approved by the Institutional Ethics Committee and participants provided written informed consent.

The swimmers were recorded with four underwater and two above water video cameras (Sony HQ-DNR-1 Bullet Cameras linked to Sony GV-HD700 video recorders and Sony HDR CX700 respectively) synchronized by an LED pulse. Images were sampled at 50 Hz. Each camera focussed on a volume in the middle lane area of a 50 m indoor pool that had been calibrated with a frame (length (y-axis): 3.0 m, width (x-axis): 1.0 m, depth (z-axis): 1.5 m) comprising 48 control points underwater and 36 above water.

After a 20 minute uncontrolled warm-up, each swimmer performed a 50 m maximal effort front crawl swim. Anatomical points of the upper limb (fingertip, wrist and elbow) were digitised manually at 50 Hz, from each camera view (SIMI Reality Motion Systems GmbH, unterschleißheim, Germany, version 7.2). Two dimensional coordinates were filtered at 7 Hz using a low pass Butterworth filter (2nd order) and then converted to three-dimensional real-world coordinates using a DLT algorithm.

The full stroke cycle of the right pulling arm was divided into four phases:

Glide: from hand entry to the most lateral position of the hand.

Insweep: from the end of the glide to the most medial position of the hand.

Upsweep: from the end of the insweep to hand exit.

Recovery: from the end of the upsweep to next hand entry.

Stroke phase boundaries are illustrated in Figure 2. The following variables were used to describe the kinematics of the pulling arm: swimming speed (product of stroke length and stroke rate), *stroke rate* (defined by number of stroke cycles per minute), *stroke length* (distance per stroke cycle, i.e. distance travelled by the body during entry of a hand into the water until next entry of the same hand.), *stroke width* (medial: x-axis displacement of the hand during the insweep), *stroke depth* (vertical: z-axis displacement of the hand from entry to the deepest point), *trajectory length* (the path of the hand extremity during underwater phase), *underwater phase* (percentage time from water entry to water exit of the hand of the pulling arm), *recovery* *phase* (percentage time from water exit to water entry of the hand) and *overlap* (percentage time of stroke superposition in propulsive phase).

FIGURE 1 - ABOUT HERE

Statistics

Standard descriptive statistics (mean and standard) were determined. The small sample size (n=8) and variety of the classifications did not allow other multivariate analysis. The statistical analyses were performed using specific software (Statistic, version 7, Statsoft).

Results

Table 1 presents the front crawl stroke parameters for each participant. The swimming speed ranged from 1.09 to 1.49 $m.s^{-1}$ (mean speed 1.29 $m.s^{-1}$). There was considerable inter-swimmer variability in the dimensions of the underwater arm stroke, with the width ranging from 0.20 to 0.46 m and the depth ranging from 0.40 to 0.80 m. The stroke length ranged from 1.20 to 2.06 m. On average, swimmers spent three-quarters of the stroke cycle time in the underwater phase and one-quarter of it in the recovery phase with an average overlap of 24.5 ± 7%.

Table 1 - ABOUT HERE

Discussion and Implication

This study evaluated three-dimensional kinematic parameters of the front crawl in physically impaired swimmers. The large variability that was observed between participants regarding the arm stroke parameters may explain the large differences in performance observed between and within IPC classifications. This large variation may be a reflection of individual characteristics of the impairment [1], training status and ability of the swimmers.

The more impaired swimmers presented the shortest stroke lengths and highest stroke rates. Emphasize in stroke rate has been identified as strategy adopted by lower class swimmers in order to obtain maximal speed [2]. The use of this compensatory mechanism may explain why swimmers classified as more impaired swam at comparable speeds with swimmers classified as less impaired in the present study. This finding must be viewed with caution due to the small number of participants and range of impairments.

The relative phase durations and the timings used during the stroke cycle (i.e., underwater phase, recovery phase and overlap) were very variable between the participants, but in line with the findings of elite able swimmers [3]. Indeed, the longer is the underwater phase the larger are the propulsive forces generated by the swimmer. However, it is interesting to observe that the swimmer who presented the shortest duration of the underwater phase was also able to show a considerably high swimming speed. On the other hand, his stroke rate was approximately 20% faster than the average swimmers.

The results showed that the mean stroke depth and width were lower than that observed in elite able swimmers [3]. These differences may be explained by anthropometric profile or by the limited range of motion that is generally present as a consequence of the impairment. It is tempting to conclude that the greater the swimmer's impairment, the shorter would be the stroke trajectory due to the combined effect of shallower and narrower movements. It is reasonable to speculate that lower propulsive impulse can be generated in shorter stroke trajectories than when the propulsive forces can be applied more efficiently over a longer time since impulses are calculated by integrating the force-time curve of the stroke [4]. Nevertheless stroke parameters should be normalized with respect to arm length to confirm this hypothesis

This preliminary study included a small sample size. Further studies including a greater population more homogenous in term of impaired, sex and swimming level are warranted. The results of this study provide swimmers and coaches with an overview of the kinematic characteristics of some highly-trained para-swimmers during the front crawl stroke. As in able-bodied swimmers, monitoring stroke parameters of impaired swimmers seems to be useful to optimize performances and training status.

Disclosure of interest

The authors declare that they have no competing interest.

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Figure Captions

FIGURE 1 – Representation of the stroke phase boundaries

Figure 1

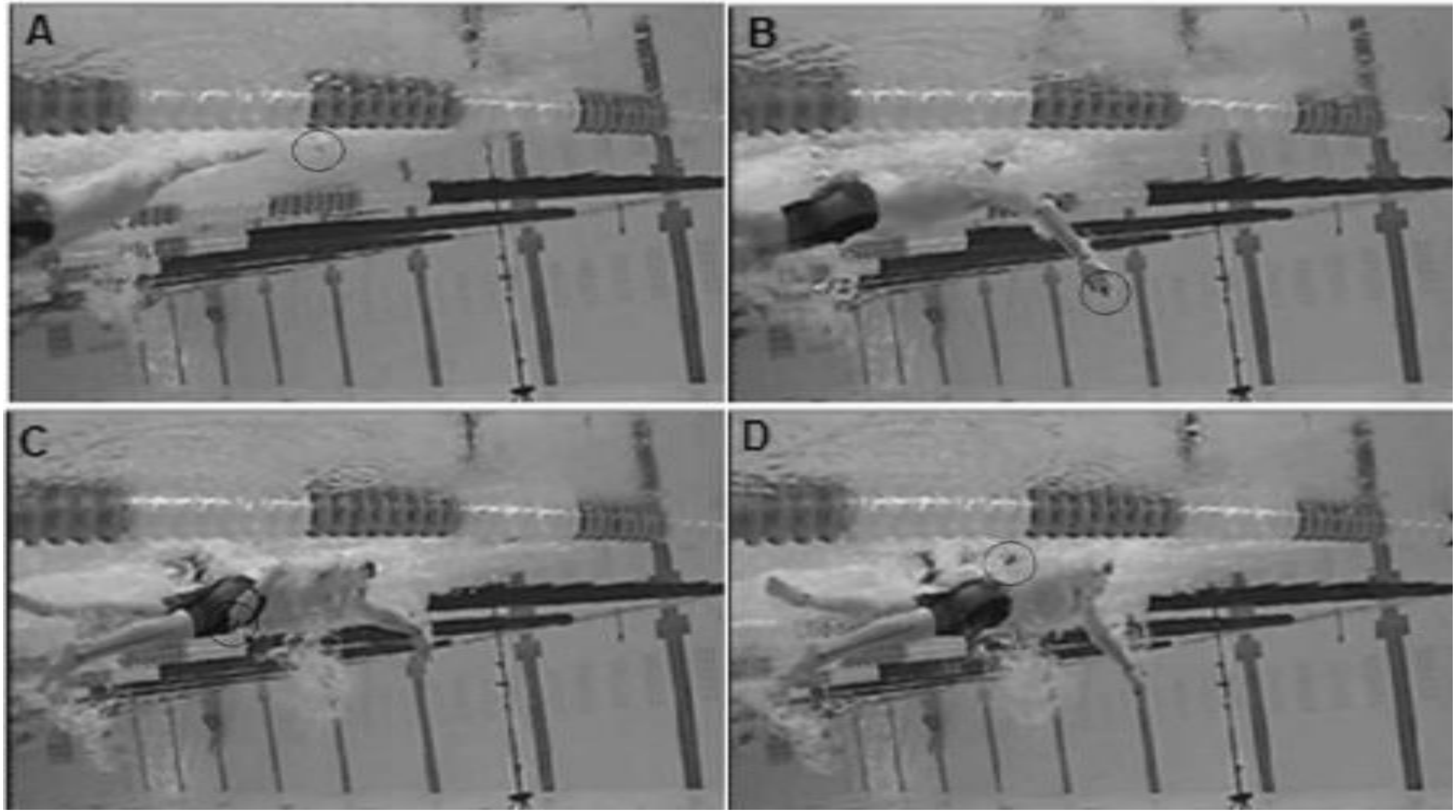

TABLE 1 – Front crawl stroke parameters of impaired swimmers according to their IPC classification.

Classification/ Sex	S9 ♀	S9 ♂	S8 ♀	S8 ♂	S7 ♂	S6 ♂	S6 ♀	S5 ♂	**Mean**	**sd**
Speed ($m.s^{-1}$)	1.28	1.09	1.43	1.31	1.49	1.34	1.18	1.18	1.29	0.13
SL (m)	1.59	1.33	1.69	1.44	1.55	1.20	1.18	1.25	1.41	0.19
SR (cycles/min)	48.39	49.18	50.85	54.55	57.69	66.67	60.00	56.60	55.49	6.14
Width (m)	0.25	0.46	0.37	0.29	0.39	0.31	0.20	0.41	0.34	0.09
Length (m)	1.71	1.61	2.06	1.94	1.72	1.28	1.20	1.25	1.60	0.33
Depth (m)	0.66	0.73	0.80	0.70	0.54	0.44	0.46	0.40	0.59	0.15
Trajectory length (m)	3.53	3.95	4.59	3.70	3.83	2.56	2.62	3.04	3.48	0.70
Underwater phase(%)	75.81	80.33	74.58	72.73	76.92	62.22	80.00	84.91	75.94	6.73
Recovery phase (%)	24.19	19.67	25.42	27.27	23.08	37.78	20.00	15.09	24.06	6.73
Overlap (%)	19.35	27.87	25.42	12.73	26.92	20.00	28.00	35.85	24.52	7.01