Baltic Journal of Health and Physical Activity

Volume 5 | Issue 3 Article 2

2013

Kinematic analysis as a part of objective method of functional classification in disability swimming – Pilot studies

Alicja K. Dziuba
Department of Biomechanics, University School of Physical Education in Wroclaw, Poland, alicja.dziuba@awf.wroc.pl

Agata Kolodziej
Department of Biomechanics, University School of Physical Education in Wroclaw, Poland

Anna Zurowska
Department of Physiotherapy, Faculty of Health Science, Wroclaw Medical University, Poland

Recommended Citation

Dziuba AK, Kolodziej A, Zurowska A. Kinematic analysis as a part of objective method of functional classification in disability swimming – Pilot studies. Balt J Health Phys Act. 2013; 5(3):176-183. doi: 10.2478/bjha-2013-0016

Kinematic analysis as a part of objective method of functional classification in disability swimming – Pilot studies

Abstract

Background: A new functional classification system (FCS) of disability swimming is based only on functional abilities in water. The aim of this research was to evaluate the possibility of kinematic analysis to supplement the FCS. Material/Methods: The investigations were carried out during the Polish Winter Disability Swimming Championships in 2008 and involved recording the results of the 100 m freestyle swimming event. Participants included 10 women and 11 men aged 21.7 ± 6.6. Results: The averages and standard deviations (SD) of stroke length (SL), stroke rate (SR), clean swimming speed (CSS) and stroke efficiency index (SI) were calculated. There is a strong negative correlation between SL and SR reaching 0.86 ($p < 0.05$) in particular classes. There were no statistically significant correlations between classes in the SL, CSS and SI parameters ($p < 0.01$) and no statistically significant differences were revealed in the Wilcoxon test ($p < 0.01$), which suggests that the division of swimmers into these classes was performed inaccurately and subjectively. Conclusions: Kinematic parameters could support FCS, and it might be an indicator of progress and the effectiveness of training methods for coaches.

Keywords

kinematic parameters, functional classification, swimmers with disability

BALTIC JOURNAL OF HEALTH AND PHYSICAL ACTIVITY
© Gdansk University of Physical Education and Sport in Gdansk, Vol. 5, No. 3, 2013, 176-183
ORIGINAL ARTICLE
DOI: 10.2478/bjha-2013-0016

Kinematic analysis as a part of objective method of functional classification in disability swimming – Pilot studies

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

Alicja K. Dziuba[1 (A, C, D, E, F)], Agata Kolodziej[1 (B, F)], Anna Zurowska[2 (D)]

[1] Dep. of Biomechanics, University School of Physical Education in Wroclaw, Poland
[2] Dep. of Physiotherapy, Faculty of Health Science, Wroclaw Medical University, Poland

Key words: *kinematic parameters, functional classification, swimmers with disability.*

Abstract

Background: *A new functional classification system (FCS) of disability swimming is based only on functional abilities in water. The aim of this research was to evaluate the possibility of kinematic analysis to supplement the FCS.*

Material/Methods: *The investigations were carried out during the Polish Winter Disability Swimming Championships in 2008 and involved recording the results of the 100 m freestyle swimming event. Participants included 10 women and 11 men aged 21.7 ± 6.6.*

Results: *The averages and standard deviations (SD) of stroke length (SL), stroke rate (SR), clean swimming speed (CSS) and stroke efficiency index (SI) were calculated. There is a strong negative correlation between SL and SR reaching 0.86 ($p < 0.05$) in particular classes. There were no statistically significant correlations between classes in the SL, CSS and SI parameters ($p < 0.01$) and no statistically significant differences were revealed in the Wilcoxon test ($p < 0.01$), which suggests that the division of swimmers into these classes was performed inaccurately and subjectively.*

Conclusions: *Kinematic parameters could support FCS, and it might be an indicator of progress and the effectiveness of training methods for coaches.*

Word count: 3,516
Tables: 1
Figures: 3
References: 13

Received: February 2013
Accepted: September 2013
Published: October 2013

Corresponding author:
Dr inż. Alicja Dziuba
Department of Biomechanics, University School of Physical Education
Al. Paderewskiego 35, 51-612 Wrocław, Poland
Phone: +48 71 3473276, fax: +48 71 3473063
E-mail: alicja.dziuba@awf.wroc.pl

Introduction

Along with the development of disability sports [1], the need for a reliable classification system has arisen. Initially, the medical classification system was based on medical tests and diagnoses. This system, however, did not take into account the functional abilities of athletes with disability. In the case of swimmers with disability, the new functional classification system (FCS), which has been used until now, was developed in 1980 by Brigitta Blomqiust and her team and was first used during the Paralympic Games in Barcelona in 1992. It is based on functional abilities in water, and swimmers are categorised using three elements of investigation and observation: 1. Bench test – medical test, 2. Water test – functional assessment of the swimmer's skills in water, 3. Observation of a swimmer with disability during competition with an emphasis on their motor abilities – IPC. The system of functional classification categorises women and men into nine classes (S1 to S10) using freestyle, backstroke and butterfly swimming techniques. The class numbers indicate the level of functional abilities of a swimmer, with the lowest classes assigned to swimmers with the lowest level of functional abilities.

Both the system and classification procedures raise doubts because they are subjective. There is therefore an opportunity to use a research method or technique that could complement existing procedures and allow for an objective categorisation of athletes. However, this task is not an easy one. Biomechanical parameters in swimming and their relationships in healthy people have been studied by a number of authors [2]. There are some publications concerning the utilisation of kinematic parameters in healthy persons [3]; however, in the case of swimmers with disability they are rather scarce [4, 5]. Biomechanical analysis in swimming is based on the measurement of kinematic parameters such as stroke length (SL), stroke rate (SR), clean swimming speed (CSS) and stroke index (SI). According to Pelayo et al.[4], one movement cycle in the crawl technique begins at the moment of deepening of the upper limb in water and is completed with another deepening of the fingers of the same hand. The duration of the movement cycle depends on the angular velocity of the arm in relation to the transverse axis of the glenohumeral joint and on the distance covered by the most distal part of the upper limb during movement in and over the water while swimming. Stroke rate – SR [cycles/s] means the number of movement cycles of one upper limb per unit of time. Stroke length – SL [m] is the distance covered by a swimmer in one complete movement cycle. Clean swimming speed – CSS [m/s] means the distance covered per unit time. Stroke index – SI [m2/s] is the product of clean swimming speed (CSS) or cycle length (SL) [4].

A number of studies have investigated dependencies and the effect of individual kinematic parameters during swimming. According to Malone et al. [5], clean swimming speed might be differently reflected by SL and SR depending on individual traits of an athlete. Swimmers use a variety of combinations, such as high SL and low SR, medium values of both parameters or low SL and high SR. Further analysis shows a strong correlation of SL with the results obtained by swimmers in most cases, suggesting that the cycle length is a feature that has a dominating effect on clean swimming speed [6]. This information can be used by coaches for assessment of the swimming technique and for evaluation of the effectiveness of training methods [7].

Both investigations concerning physiology of disability swimming [8] and studies connected with biomechanical aspects of disability swimming [4] open up new opportunities for coaches and athletes. Studies carried out on swimmers with disability [4] confirmed that the stroke length (SL) is connected with clean swimming speed (CSS), contrary to the stroke rate (SR). They found that CSS, SL and SI rise considerably in relation to the growing level of disability from class S3 to S10, whereas SR does not differ much between each class. SL, which maintains a relationship to the level of motor disability, could be one of the parameters used to differentiate between disability categories (from S1 to S10). Actually, the SL is connected with both the propulsive force developed by a swimmer while swimming and with the resistance forces. Hence, a decrease in SL in relation to the degree of motor disability might be explained by the range of motion, force, coordination and limb length [4]. An increase in SI can be linked to changes in swimming efficiency in competitive categories, whereas changes in its value are mainly affected by the degree of disability rather than the total training time or mileage [8]. Therefore, the stroke index (SI) could become a practical, objective and quantitative measure for swimmer assessment during functional categorisation in order to ensure a similar and accurate starting point for all athletes. This criterion should not become the only basis for differentiation of functionality in terms of competitive categories because it is also linked to the training-related status of a swimmer (training experience, number of training sessions per week, training mileage).

As indicated by results from the literature review presented above, biomechanical parameters are a legitimate measure of the swimming technique used for both healthy and disabled people.

The aim of this study is to confirm that kinematic analysis is a necessary, objective and quantitative complement to the process of functional classification of swimmers with disability. In the case of functional classification, one should not consider kinematic parameters separately but in relation to the type of disability, anthropometric traits of a swimmer [9], their functionality in water in a particular swimming stroke, and the athletes' age and training experience.

Material and methods

VHS or digital cameras are employed for kinematic investigations of swimmers. This study used a film-based two-dimensional kinematic method of data analysis. The present study utilised a Canon DVD camcorder DC210 located perpendicular to the direction of swimming on a balcony which was ca. 5 meters above the swimming pool, at a distance of between 15 and 25 m from the start line (swimming pool length was 50 m). This camera position provides opportunities for recording swimming without consideration of the start and turning zone.

Errors that resulted from the video recording method were minimised with special camera alignment (perpendicular to the athlete's path), a selection of the distance from the plane of the subject's movement so that at least 10 complete movement cycles could be recorded, and visible markers (points) on both reference plane and the subject recorded.

Two points were marked on the athletes' left and right radiocarpal joints. These are the points that are characterised by high amplitude.

The athlete's motion was recorded using a two-dimensional video-recording method, which involved two stages: video-recording and acquisition of primary data and data derivation using a computer technique.

Video recording

To obtain reliable values of linear and angular displacement in the film-based method, it was essential to ensure proper arrangement and selection of the film set, which comprised the following components: Canon DVD camcorder DC210 with frame f = 100 Hz, which, with the constant position, allowed recording of ten cycles of the subject's motion;

A reference system was provided by the rope that divided the lanes, with alternating 1 m long white and blue lines. The same camera position was used for all the recordings, which was supposed to reproduce actual linear dimensions of the moving object.

Reading and processing of primary data

The film was digitised, and the analysis of data was carried out by means of SIMI Reality Motion Systems (GmbH, Germany) in the Biomechanics Laboratory. Ten full cycles for each swimmer were registered and used for analysis. SIMI software selects points in a semi-automated way and was used to find x and y coordinates of points vs. time, determining the time of a single cycle, and initially preparing the analysed parameters:

One movement cycle begins at the moment of deepening of the wrist in water and is completed by another deepening of the wrist of the same hand.

Stroke length – SL [m] is the distance that is covered by a swimmer in one complete movement cycle, beginning at the moment of deepening of the wrist in water and ending with another deepening of the wrist of the same hand.

Stroke rate – SR [cycles/s] means the number of movement cycles of one upper limb per unit time.

Clean swimming speed – CSS [m/s] means the distance covered per unit time.

Stroke index – SI [m^2/s] is the product of clean swimming speed (CSS) and cycle length (SL).

Using Statistica 8.0 software StatSoft, arithmetic means and standard deviations (SD) for stroke length (SL), stroke rate (SR), clean swimming speed (CSS) and stroke index for each swimmer and each class were calculated (for each subject there were 10 samples, in each group there were at least 40 samples).

Subjects

The study included 21 disabled athletes aged 21.7 ±6.6 from classes S9 and S10 who took part in 100 m freestyle competitions. The athletes included people with several years of training experience who were either disabled since birth or were initially healthy and later became disabled (Table 1).

Table 1. Characteristics of all the swimmers (women and men) participating in the study: initials, age, dysfunction in particular classification classes (S9 and S10)

No.	Initials	Age	Dysfunction
			WOMEN, CLASS S9
1	AB	21	amputation at the level of forearm
2	KB	28	amputation at the level of thigh
3	MZ	18	hand amputation
4	AT	18	arthrogryposis
5	PW	17	amputation at the level of left forearm
			WOMEN, CLASS S10
1	OJ	12	arthrogryposis (stiffness in both ankle joints)
2	AG	28	dysmelia of the right lower limb (lack of fibula and metatarsus)
3	WL	33	lower leg amputation
4	AO	16	lower leg amputation
5	KP	20	cerebral palsy
			MEN, CLASS S9
1	JW	32	left lower limb amputation
2	KN	19	dysmelia in the right upper limb
3	MK	16	dysmelia in upper limb
4	KO	21	osteoporosis
5	KP	23	amputation of the left upper limb at the level of forearm
6	KR	17	amputation of the right lower limb over the knee joint
7	PB	26	amputation of the lower limb at the level of thigh
			MEN, CLASS S10
1	MB	18	dwarfism
2	JB	14	dysmelia in upper limbs
3	TG	37	amputation of a lower leg in half length
4	KD	22	dysmelia in the right lower limb (lack of fibula and foot deformation)

The investigations were carried out during the Polish Winter Championships for the Disabled in a 50-metre swimming pool owned by the Polish Swimming Association in Dębica on March 14th, 2008, in the morning, during the first part of the championships (i.e., 100 m women and men freestyle swimming.) The investigations were approved by the Senate's Bioethical Research at the University School of Physical Education in Wroclaw, Poland. The subjects and their guardians were informed about the procedure for these investigations and gave their written informed consent.

Results

The mean values for each swimmer's stroke length (SL), clean swimming speed (CSS) and stroke index (SI) for individuals in classes S9 and S10 with the corresponding standard deviations for women and men are presented in Figures 1, 2, and 3.

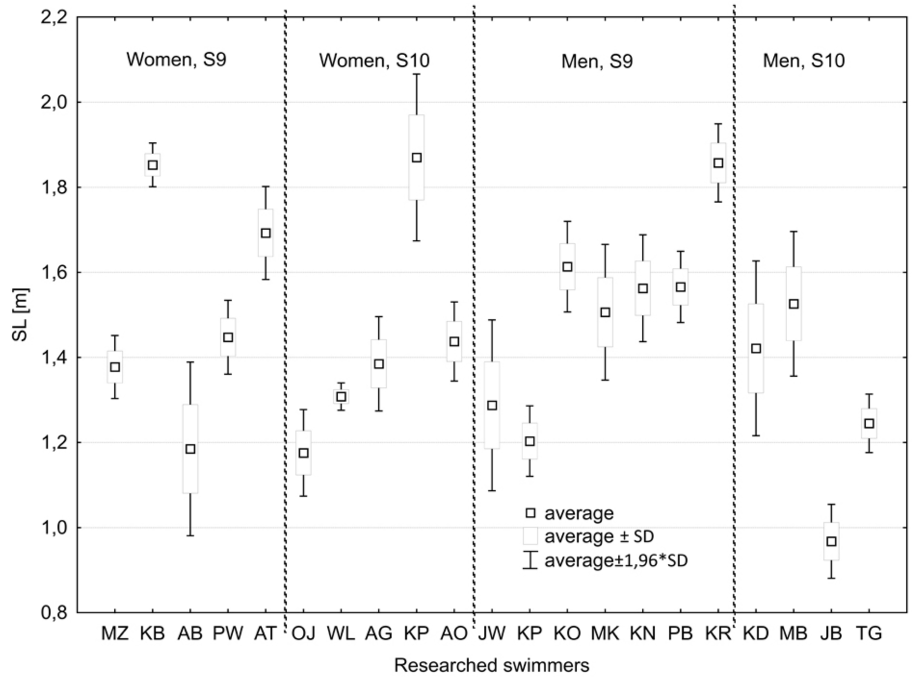

Fig. 1. Average stroke length (SL [m]) with standard deviation (SD) of all the swimmers (women and men) participating in the study. S9 and S10 – classes

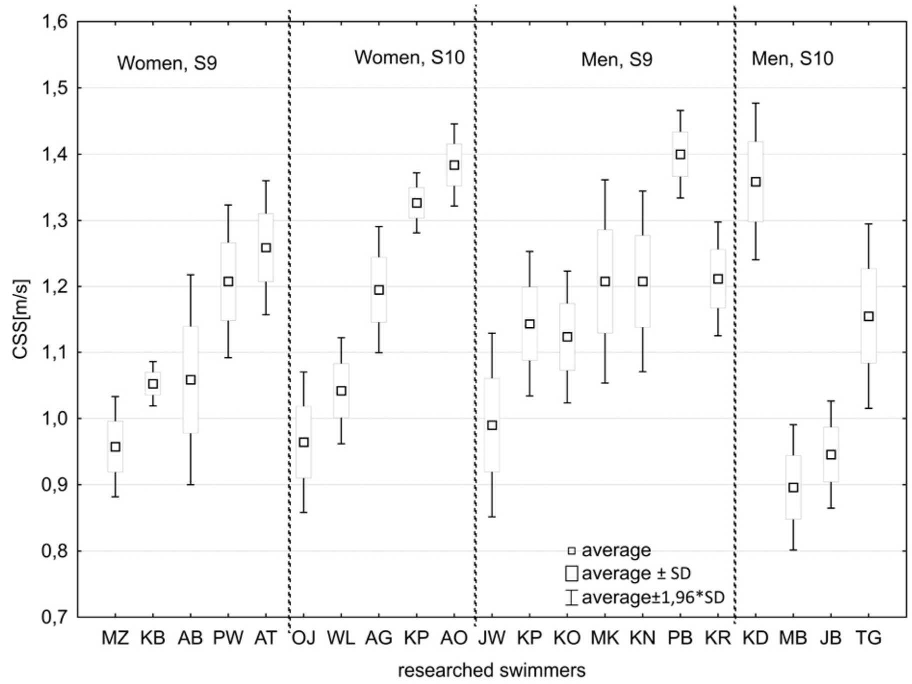

Fig. 2. Average clean swimming speed (CSS [m/s]) with standard deviation (SD) of all the swimmers (women and men) participating in the study. S9 and S10 – classes

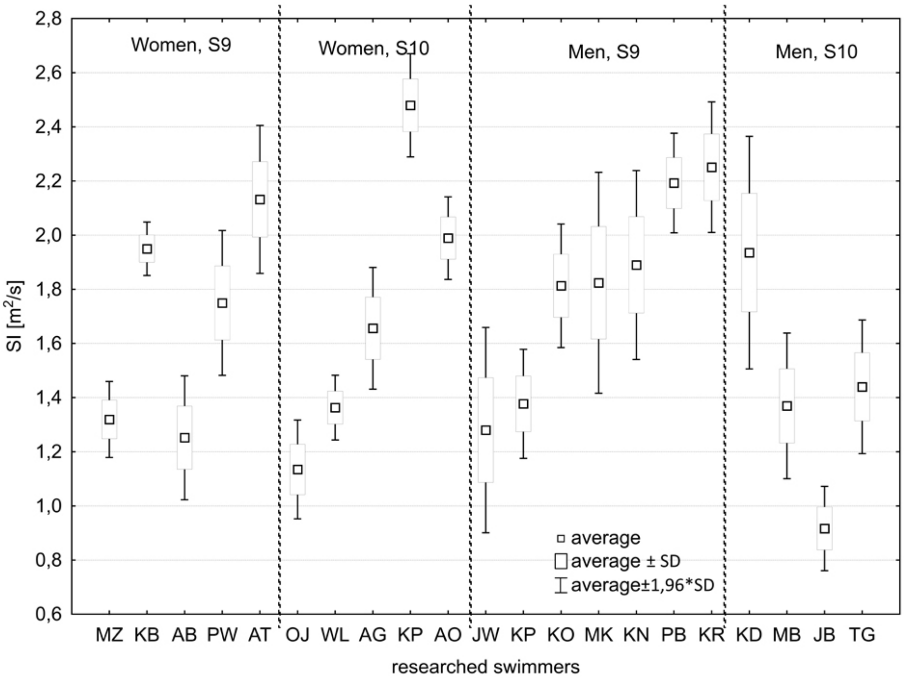

Fig. 3. Average stroke index (SI [m2/s]) with standard deviation (SD) of all the swimmers (women and men) participating in the study. S9 and S10 – classes

Discussion

Application of multiple cameras during a swimming competition is often impossible. However, measurements in a single plane are sometimes insufficient. Kennedy et al. [6] used three video cameras placed over the stands at the side of swimming facilities, which covered the whole length of a fifty-meter swimming pool. Pelayo et al. [4] utilised two cameras located at a distance of 30 m from each other along one of the sides of a swimming pool. In the investigations carried out by Malone et al. [5], only one camera was set at a distance of 25 m from the start line (half of the length of the swimming pool), perpendicular to the direction of swimming, at the bottom of the stands in front of the first row of seats.

The main findings of the present study indicate that a higher class does not reflect a higher functional level of a competitor. This is contrary to the assumption of the system FCS. This relationship occurred only in the case of mean CSS and SI in women.

Women: The lowest value of SL (1.19 m) in class S9 was observed for athlete AB, whereas the highest one was 1.85 m, observed in KB, although both swam with the same average CSS = 1.05 m/s. Differences in these values can be explained by the competitors' age [2], 21 and 28 years, respectively, training experience and competitive experience in both swimmers. KB is a former Paralympics swimmer. The type of dysfunction is also important [6]. AB and MZ showed the lowest value of SL (1.19 m and 1.38 m) in class S9 because they are characterised by a disability of the upper limbs, which, with the heavy reliance on the upper limbs for generating propulsive forces in the crawl technique, is of fundamental importance. KB, whose disability in the area of lower limbs does not considerably affect the level of SL in the crawl technique, could reach a much higher value of this parameter.

In class S10, the highest values of SL, CSS and SI were observed in athlete OJ, whereas the lowest ones were seen in KP. OJ is only 12 and her body build in terms of anthropometric parameters is characterised by lower values compared to other competitors [2, 8]. KP suffers from cerebral palsy, which does not affect either of the limbs but affects the overall level of motor coordination [6]. Lower and similar values of SL were obtained by WL, AG and AO. The type of disability was important here: lack (amputation) or considerable underdevelopment (dysmelia) in the lower limb. However, CSS and SI in the listed three athletes differ considerably from each other. The average cycle length SLS9 in class S9 amounts to 1.51 m and is 0.06 m higher than in S10. Mean CSS S9 in S9 = 1.11 m/s and is lower than in S10 (1.18 m/s). Stroke index (SI S9) in S9 is 1.68 m2/s and is also lower than S10 (1.72 m^2/s). More efficiency is observed in the competitors from the S10 class at the paradoxically lower stroke length value of SL S10 = 1.44 m compared to S9, where stroke length SL = 1.51 m. Hence, the value of SR seems to be essential because its higher value in S10 (SR S10 = 0.82 cycles/s), compared with a lower value of SL in class S9 (SR S9 = 0.74 cycles/s), gives in effect a higher value of the stroke index in class S10.

Men: Among men, differences in the values of the studied parameters were more noticeable than in the case of women in similar classification classes. The differences were revealed both within and between the two classes. The highest value of SL was obtained by a competitor in the S9 group, KR, with SL = 1.86 m, whereas the lowest one was observed in a S10 class competitor, JB, with SL = 0.97 m. As with the female swimmers, discrepancies in these values can be explained by the type of disability [5]. The dysfunction of motor organs in the case of KR (S9) affects a lower limb, whereas in a competitor from class S10 (JB) it involves both upper limbs. In the crawl technique, which was used by all the competitors, stronger propulsion is generated by upper rather than lower limbs, and thus, the level of disability of upper limbs is more significant. The lowest value of the stroke length in class S9 was observed in KP, SL = 1.20 m, with dysfunction of the upper limb, whereas the highest value for class S10 was demonstrated by athlete MB (SL = 1.53 m) with dwarfism, who has both lower and upper limbs. Mean stroke length in both classes differed noticeably and amounted to SL = 1.52 m for S9 and SL = 1.29 m for class S10.

An analysis of mean swimming speed for men revealed that higher speeds were obtained by S9 class competitors (CSSS9 = 1.18 m/s) compared to S10 class swimmers (CSSS10 = 1.09 m/s).

Mean values of the stroke index in both classes amounted to SIS9 =1.81 m^2/s for S9 and SIS10 = 1.41 m^2/s for S10. These data show that the competitors classified under S10 turned out to be less efficient than those classified under S9. Stroke rate in class S10 equals SRS10 = 0.84 cycles/s. This value in the case of the more efficient swimmers in class S9 was relatively lower, SRS9 = 0.78 cycles/s.

An analysis of mean swimming speed for men revealed that higher speeds were obtained by S9 class competitors (CSS S9 = 1.18 m/s) compared to S10 class swimmers (CSS S10 = 1.09 m/s). The results confirm a positive correlation of SL and CSS (0.58, $p < 0.1$) reported by other researchers [4] and the average value of SL in the present study was higher in class S9. The lower value of both SL and CSS in the highest competitive class of S10 (the best level of functional) can be explained by a lower athletic level of the athletes.

The present study confirmed a strong negative correlation between SL and SR, equals to 0.86 ($p < 0.05$), which demonstrates that the swimmers with disability also use a different combination of these parameters [12].

Seifert et al. [10] in able-bodied swimmers found that high speed swimmers were characterized by higher and more stable SL. The gender effect was greater SL in males than in females. It has not been proved in the case of the disabled group described in this paper, which is another evidence that the groups were badly matched. Cycle length is a feature that should have a dominating effect on clean swimming speed [6]. Barbosa stated that lower speed fluctuation causes a higher stroke length [11]. Some authors argue that the most important contribution to studies in swimmers is a correct practical tool for objective evaluation of swimming performance and they suggest [13] the inertial sensor with water proofing box placed on the sacrum.

The results of the study showed that the length of the swimming cycle is uneven throughout classification in classes S9 and S10. The stroke length in both women and men was differentiated within and between the classes. These results differ from those reported by Pelayo et al. [4], where SL rose with a higher functional class. These results confirm the fact that an objective and quantitative kinematic method could become a solid complement of FCS [8]. CSS also pointed to differentiation in classes S9 and S10 among women and men. Despite what would seem to be obvious, CSS in women turned out to be higher in class S10, while this value in men was higher in class S9. However, Pelayo et al. [4] argued that CSS should increase with the level of class, which was confirmed here for women, whereas opposite values of CSS were obtained among men. This fact confirms that classes S9 and S10 for men were improperly selected in terms of athletes' functional capabilities. The value of SI, a binding kinematic parameter that explains other values of kinematic parameters, differs either within or between both classes. In women, the stroke index showed a higher value in class S10, in agreement with what was reported by Pelayo at al. [4], pointing to higher swimming efficiency in this class. However, this high efficiency was reached in S10 not because of a higher stroke length but due to a higher stroke rate, which, unfortunately, does not confirm, in general terms, higher swimming economy and efficiency [8]. The value of SI in men was higher in class S9, which clearly points to a higher efficiency of competitors in class S9. This observation can be explained by the fact that higher values of this parameters, unlike in class S10, were obtained through a longer stroke length and a lower stroke rate.

Conclusions

The results of the investigations revealed differences in kinematic parameters within classes and their relationships with a variety of other factors. A higher class reflects a higher functional level of a competitor. This relationship occurred only in the case of mean CSS and SI in women. In the case of other kinematic parameters, both in women and men, the parameters studied found a better functional level in athletes from group S9 rather than S10, suggesting that there are other factors influencing the result of functional classification. The inclusion of kinematic parameters in the FCS, studies on larger samples and development of additional guidelines could potentially decrease the error in the future. Kinematic parameters are reliable and credible measurements that are used more and more frequently among healthy swimmers and could also be successfully introduced in disability swimming. Use of these parameters to evaluate swimming technique could become a critical indicator of the competitive progress and effectiveness of the training methods utilised by coaches during swimming season.

References

1. Jones C, Wilson C. Defining advantage and athletic performance: The case of Oscar Pistorius. Eur J Sport Sci. 2009;9:125-131.
2. Knechtle B, Baumann B, Knechtle P, Rosemann T. What influences race performance in male open-water ultra-endurance swimmers: anthropometry or training? Human Movement. 2010;11: 5-10.
3. Aschenbrenner P, Lipinska P, Erdmann W. Application of the AS-4 software in research on players' kinematics on a large area in 3D coordinates as an alternative to commercial programs. Baltic Journal of Health and Physical Activity. 2012;4(3):172-179.
4. Pelayo P, Sidney M, Moretto P, Wille F, Chollet D. Stroking parameters in top level swimmers with a disability. Med Sci Sport Exer. 1999;31:1839-1843.
5. Malone LA, Sanders RH, Schiltz JH, Steadward RD. Effects of visual impairment on stroke parameters in Paralympic swimmers. Med Sci Sport Exer. 2001;33:2098-2103.
6. Kennedy P, Brown P, Chengalur SN, Nelson RC. Analysis of Male and female Olympic swimmers in the 100 meter events. Int J Sport Biomech. 1990;6:187-197.
7. Smith DJ, Norris SR, Hogg JM. Performance evaluation of swimmers: scientific tools. Sports Med. 2002;32:539-54.
8. Pelayo P, Moretto P, Robin H. Adaptation of maximal aerobic and anaerobic tests for disabled swimmers. Eur J Appl Physiol O. 1995;71:512-517.
9. Taiar R, Lodini A, Rouard A, Toshev Y. Estimation of swimmers anthropometric parameters and surface areas in real swimming conditions. Acta Bioeng Biomech. 2005;7:85-95.
10. Seifert L, Chollet D, Chatard JC. Kinematic changes during a 100-m front crawl: effects of performance level and gender. Med Sci Sport Exer. 2007;39:1784-1793.
11. Barbosa TM, Bragada JA, Reis VM, Marinho DA, Carvalho C, Silva AJ. Energetics and biomechanics as determining factors of swimming performance: Updating the state of the art. J Sci Med Sport. 2010;13: 262-269.
12. Costa M, Bragada J, Mejias J. Tracking the performance, energetics and biomechanics of international versus national level swimmers during a competitive season. Eur J Appl Physiol. 2012;112:811-820.
13. Dadashi F, Crettenand F, Millet GP, Aminian A. Front-crawl instantaneous velocity estimation using a wearable inertial measurement unit. Sensors. 2012;12:12927-12939.