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DEVELOPMENT AND VALIDITY OF THE FRONT CRAWL TECHNIQUE ASSESSMENT TOOL: A PILOT STUDY

RAZVOJ IN VELJAVNOST MERSKE LESTVICE ZA OCENJEVANJE KRAVLA: PILOTSKA RAZISKAVA

ABSTRACT

Swim coaches conduct the technique analysis themselves, through observation and qualitative assessment. The latter is based on their own knowledge and experience. They have to identify the technique mistakes and assess them in terms of their impact on the swimmer's performance. Recognizing this, there is a clear need for an assessment tool which can help swimming instructors and coaches in their work with swimmers of different quality levels. The study aimed to first develop and then validate a tool for the front crawl technique assessment (FCTA). Twenty-one experienced swimming instructors and coaches evaluated 48 mistakes most common in the front crawl for their impact on swimming performance. Based on their perceptions, we developed the FCTA tool. By using the FCTA, we numerically evaluated the mistakes that occurred during participants' maximal 50-meter front crawl test. We found a strong correlation between both the times achieved and amounts of numerically evaluated mistakes made by the participants in the swim test. These results indicated that the FCTA could be a valid tool to effectively assess the technical skills of intermediate and advanced level swimmers in front crawl. However, this was a pilot study, so all conclusions are preliminary and require further research.

Keywords: swimming, teaching, qualitative technique assessment

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IZVLEČEK

Plavalni učitelji in trenerji z opazovanjem in kvalitativno oceno analizirajo plavanje učenca. Prepoznati morajo tehnične napake in jih oceniti glede na vpliv na plavalčevo uspešnost. Pri tem sledijo lastnemu znanju in izkušnjam. Ker pa tega običajno ni dovolj, smo z raziskavo želeli ovrednotiti napake pri kravlu, izdelati mersko lestvico za preverjanje znanja plavanja (FCTA) in preveriti njeno uporabnost. Enaindvajset izkušenih učiteljev in trenerjev plavanja je ocenilo 48 napak, ki se najpogosteje pojavljajo pri kravlu. Ocenili so jih glede na njihov vpliv na plavalčevo uspešnost, od tistih z najmanjšim, do tistih z največjim vplivom. Tako smo izdelali FCTA. Z uporabo FCTA smo nato številčno ovrednotili napake, ki so se pojavile pri plavanju 50 metrov kravla maksimalno. Ta test je plavalo dvesto šestintrideset preiskovancev, kandidatov za vpis na študij fakultete za šport. Ugotovili smo močno povezanost med doseženimi časi in vsoto številčno ocenjenih napak, ki so jih preiskovanci naredili v plavalnem testu. Ti rezultati so pokazali, da bi FCTA lahko bilo veljavno orodje za učinkovito ocenjevanje tehničnih znanj kravla pri srednje dobrih in dobrih plavalcih. Vendar je bila to le pilotna študija, zato so vsi sklepi preliminarni in zahtevajo nadaljnje raziskave.

Cljučne besede: plavanje, poučevanje, kvalitativna ocean plavalne tehnike

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INTRODUCTION

Competitive swimming is based on times achieved in a swim distance. Therefore, quantitative analyses are the most widely used method of analysis by swim coaches. Besides measuring swim times, the relevant data are usually obtained by measuring stroke rate, stroke length, stroke index, index of coordination as well as breathing frequency. Moreover, the methods of quantitative analysis could also involve video-based techniques from which kinematics and kinetics can be derived from direct measurements of velocity and force by using various velocities and forces transducing devices (Sanders et al., 2006).

However, in some cases a quantitative approach could not reflect the progress in the athlete's swimming technique. Indeed, the primary tools available to coaches are their observation and perceptions (Coleman 1998; Hynes, O'Grady, & O'Hare, 2013) which are qualitative by nature. The need for feedback on a technique is vitally important for learning future performances (Maslovat, & Franks 2008). Commonly, coaches conduct the technique analysis by themselves, through observation and qualitative assessment using the naked eye and video playback (Lees, 2002; Wilson, 2008). A key advantage of this is low cost and ease of implementation with large numbers of athletes (Mooney et al., 2016).

Qualitative analysis in swimming comes associated with the detection and analysis of the technical mistakes (Campaniço and Silva, 1998). Technical mistakes are considered as deviations from the most efficient model of performance for given motor skill (Reischle, 1993). In swimming, the technical mistake: (i) decreases the subject's propulsive capacity; (ii) increases drag forces; (iii) or a combination of these two factors (Barbosa et al., 2013). Since swimming velocity and efficiency are the result of the combination of propulsion versus drag, mistakes analysis (observation, identification, and intervention) is a critical factor for a higher quality of the teaching-learning process (Barbosa, 2005). Qualitative assessment is therefore based on the coaches' own knowledge and experience. They have to identify the technique mistakes and remediate them. However, the first step requires an appropriate preparation and a background knowledge, such as understanding: 1.) the ideal form of a movement in each phase, and 2.) the impact of the particular mistake on the technique performance. The presentations of correct form of swimming techniques are well known in written, diagrammatic as well as in pictorial form. Coaching manuals tend to rely on the sequential breaking down of a selected movement into its various phases and templates based on expert performance (Lees, 2002). In this context, it is surprising that the studies by Pion and coworkers (1988) and Stibilj and

coworkers (2020) were, to our knowledge, the only attempt to date to evaluate a swimming technique, i.e., breaststroke and breaststroke, respectively, based on mistakes. Therefore, the aim of the current pilot study was to develop and to validate a tool for the front crawl technique assessment (FCTA). With this in mind, we conducted two studies. In Study 1, we developed the FCTA tool based on perceptions of experienced swimming instructors and coaches regarding common mistakes in front crawl (FC) swimming. In Study 2, we examined the validity of the FCTA tool by using the times of the maximal 50-meter swim test. The institutional review board (Ethics Committee of University of Ljubljana, Faculty of Sport) approved the study protocol. The study was conducted according to the principles expressed in the Declaration of Helsinki.

STUDY 1 – Development of the FCTA Tool

METHODS

Participants

Twenty-one swim coaches (11 males and 10 females; ages 34 ± 11 years) with the certificate of the Slovenian Swimming association participated in the study. They have at least 10 years of experience in teaching and training non-swimmers and swimmers of different ages and genders and at different quality levels. They received written and verbal instructions before the beginning of the study. They provided an informed written consent.

Procedures

A self-administered questionnaire was distributed to all participants. Categories of questions included 1) teaching experiences and 2) the impact of various mistakes on FC performance. The latter category was related to the assessment of a particular mistake in terms of its importance in the learning programme of an advanced swimmer, i.e. a potential competitive swimmer at any level, ranging from the youngest age group to masters swimmers, and in different sports such as triathlon, open water swimming and pool swimming. Participants were asked to mark 48 mistakes that are most common when swimming FC (Maglischo, 2003). Mistakes were grouped according to body position, kicking, stroking, and coordination. Before the data collection, each mistake was presented to participants by using video clips or pictures. Thereafter they evaluated the mistakes on a seven-point scale in regard of their impact on FC swimming performance (Table 1).

Table 1. Table depicting 7-point scale for mistakes evaluation in regard of their impact on FC swimming performance.

SCORE	LEVEL OF IMPACT
1	No impact
2	Minimal impact
3	Lower than moderate impact
4	Moderate impact
5	Higher than moderate impact
6	High impact
7	Severe impact

Statistical analyses

The data presented in the results are descriptive in nature. Statistical analyses were performed using the SPSS package (version 15.0, SPSS Inc., Chicago, USA). Based on participants' evaluation, the median and the interquartile range (IQR) were calculated for each mistake. Thereafter, we arranged the mistakes ranging from no impact to severe impact in order to establish the FCTA tool.

RESULTS

The results of coaches' evaluation of observing FC mistakes are presented in Table 2 and Table 3.

Table 2. Medians (IQR) of FC mistakes scores due to body position and kicking. The mistakes are ranked from those with lower impact to those with severe impact on FC swimming performance.

MISTAKES	MEDIAN (IQR)
BODY POSITION	
The head is too deep	4.5 (3 - 6)
No long-axis rotation	5 (4 - 6)
Too much hip rotation	5 (5 - 6)
Hips are too deep	5 (5 - 6)
Disruption of the lateral alignment	5.5 (5 - 6.75)
Not keeping the whole body in a straight line	6 (5 - 6)
KICKING	
Kicking too high	3.5 (3 - 5)
Kick amplitude too small	4 (2 - 5)
Feet not turned in	4 (3 - 5.75)
Kicking is not rhythmical	4 (3.25 - 5.75)
Extending the ankles too little at the end of kick	4.5 (3 - 6)
Feet not extended	5 (4 - 5)
Kick amplitude too large	5 (3 - 5.75)
Kicking not continuous	5 (3 - 5.75)
Kicking from the hip only	5 (3 - 6)
Kicking too deep	5 (3 - 6)
Crossover kicking	5 (3 - 6)
Kicking from the knee	5.5 (4.25 - 7)
Bicycle kicking	6.5 (5.25 - 7)
Asymmetrical kicking with one leg to the side	7 (6 - 7)
Dorsiflexing the feet	7 (6 - 7)

Table 3. Medians (IQR) of FC mistakes scores due to stroking, breathing and coordination. The mistakes are ranked from those with lower impact to those with severe impact on FC swimming performance.

MISTAKES	MEDIAN (IQR)
STROKING	
Keeping fingers too wide apart	3 (2 - 5)
Wrist drop during stroke	5 (3.25 - 5.75)
Finger-tips do not enter the water first	5 (4 - 6)
No hand acceleration during the pull	5 (4 - 6)
Swing arm over the water low and wide	5 (4 - 5.75)
Entering the hand far outside the shoulder line	5 (4 - 6)
Entering the hand across the centre line	5 (4 - 6)
Insweep too short	5 (4.25 - 6)
Insweep too long	5.5 (3.25 - 6)
Wrist drop during entry	6 (5 - 6)
Underreaching during entry	6 (5 - 6.75)
Finishing the armstroke too early	6 (6 - 7)
Elbow drop during entry	7 (6 - 7)
BREATHING AND COORDINATION	
Holding the head unnaturally high	5 (3.25 - 6)
Turning the head too late	5 (4.25 - 6)
Turning the head too soon	5 (5 - 6)
The arm in front glides too long before starting downsweep	5 (2 - 6)
Shallow breathing	5.5 (4 - 6.75)
Pulling the head back and out of alignment	5.5 (5 - 6)
Gliding hand is not extended during inhalation	6 (4 - 6)
Breathing through the nose	6 (4 - 7)
Downsweep started too soon	6 (5 - 6)
Breath holding	6 (4.25 - 7)
Taking a breath twice during each stroke cycle	6 (5 - 7)
Lifting the head forward during inhalation	6 (5 - 7)
Head up swimming	7 (6 - 7)

Based on the mistakes' median scores, we established the FCTA (Table 4) We assigned the points to the mistakes in relation to their impact on FC swimming performance. Despite the scale range spanning from 1 to 7 the coaches evaluated the mistakes mostly with scores ranging from 3 to 7 only (Table 2 and Table 3). Therefore, the points assigned in the FCTA varied from 1 (for mistakes with lower than moderate impact) to 5 (for mistakes with severe impact).

Table 4. The FCTA tool based on FC mistakes in relation to their impact on swimming performance.

	Lower than moderate impact	Moderate impact	Higher than moderate impact	High impact	Severe impact
	1 point	2 points	3 points	4 points	5 points
BODY POSITION		*The head is too deep	*No long-axis rotation, *Too much hip rotation, *Hips are too deep, *Disruption of the lateral alignment	*Not keeping the whole body in a straight line	
KICKING	*Kicking too high	*Kick amplitude too small, *Feet not turned in, *Kicking is not rhythmical, *Extending the ankles too little at the end of kick	*Feet not extended, *Kick amplitude too large, *Kicking not continuous, *Kicking from the hip only, *Kicking too deep, *Crossover kicking, *Kicking from the knee	*Bicycle kicking	*Asymmetrical kicking with one leg to the side, *Dorsiflexing the feet
ARMSTROKING	*Keeping fingers too wide apart		*Wrist drop during stroke, *Finger-tips do not enter the water first, *No acceleration throughout the stroke, *Swing arm over the water low and wide, *Entering the hand far outside the shoulder line, *Entering the hand across the centre line, *Insweep too short, *Insweep too long	*Wrist drop during entry, *Underreaching during entry, *Finishing the armstroke too early	*Elbow drop during entry
BREATHING AND COORDINATION			*Holding the head unnaturally high, *Turning the head too late, *Turning the head too soon, *The arm in front glides too long before starting downsweep, *Shallow breathing, *Pulling the head back and out of alignment	*Gliding hand is not extended during inhalation, *Breathing through the nose, *Downsweep started too soon, *Breath holding, *Taking a breath twice during each stroke cycle, *Lifting the head forward during inhalation	*Head up swimming

STUDY 2 – The FCTA Tool Validation

METHODS

Participants

147 males and 89 females, aged from 18 to 20 years, participated in the study. They were candidates for enrolment in the university study programme at the University of Ljubljana, Faculty of Sport. Therefore, the participants could be classified as intermediate or advanced swimmers. They received written and verbal instructions before the beginning of the study. They provided an informed written consent.

Procedures

The participants swam maximal 50-meter FC. The swim test was part of the selection process (test of motor abilities and skills) for the candidates who applied to the study at the University of Ljubljana, Faculty of Sport. The candidates had to swim 50-meter as fast as possible with voluntary start (start from the water or jump from the edge or from starting block), swimming technique and turn. There were no other technical requirements for the test. In this study, we selected the candidates who swam the entire 50-meter distance in FC. The test was conducted in a 25-meter swimming pool with both shallow water (120 cm) and deep water (180 cm) sections, with a water temperature of 28°C, and with eight lanes. Eight participants swam in the same time. We recorded their performances for further technical analyses.

Statistical analyses

Two swim experts identified the mistakes made during participants' swimming. Their professional qualifications provided by Slovenian Swimming Federation were instructors (level two) and had at least ten years of experience in teaching swimming. Additionally, we numerically evaluated the mistakes based on the FCTA tool and made a summary for each participant. Validity of the FCTA tool was determined by examining Pearson correlations between and the amounts of numerically evaluated mistakes made by the participants their times achieved at maximal 50-meter swim test. The data were analysed using SPSS package (version 15.0, SPSS Inc., Chicago, USA).

RESULTS

On the basis of the observations (table 5), the most common mistakes during the maximal 50-meter FC swimming in both groups were: *finishing the armstroke too early, downsweep started too soon, feet not turned in, swing arm over the water low and wide*. These mistakes were made by 50% of participants or more.

Table 5. The most common mistakes made at participants' maximal 50-meter FC swimming. The data are presented in percentage (incidence of the mistake per number of male or female participants, respectively) for each group.

MISTAKES	MALES	FEMALES
BODY POSITION		
Hips are too deep	40	31
Too much hip rotation	32	27
Not keeping the whole body in a straight line	15	15
The head is too deep	2	0
KICKING		
Feet not turned in	61	51
Kicking not continuous	42	30
Kicking too deep	37	33
Bicycle kicking	33	42
Kicking too high	32	34
Kicking is not rhythmical	32	28
Kick amplitude too large	24	24
Kicking from the knee	22	26
Feet not extended	12	6
Dorsiflexing the feet	9	2
ARMSTROKING		
Finishing the armstroke too early	74	63
Swing arm over the water low and wide	51	49
Entering the hand across the centre line	44	49
Underreaching during entry	36	31
Insweep too short	20	24
Wrist drop during entry	19	19
No hand acceleration during the pull	12	20
Elbow drop during entry	10	21
Keeping fingers too wide apart	15	11
BREATHING AND COORDINATION		
Downsweep started too soon	76	60
Pulling the head back and out of alignment	40	31
Lifting the head forward during inhalation	23	19
Head up swimming	18	15

The average time of the maximal 50-meter FC swimming was 41.88 ± 5.79 and 46.67 ± 6.65 seconds for male and female participants, respectively. By using Pearson's correlation coefficient, we confirmed a linear correlation between the times achieved and the amounts of numerically evaluated mistakes made by participants maximal 50-meter swim test (Figures 1 and 2). The correlations between variables were positive, $r(145)=0.74$, $p<0.01$ and $r(87)=0.69$, $p<0.01$, for male and female participants, respectively.

Figure 1. The correlation between the times achieved and the amounts of numerically evaluated mistakes made by male participants at maximal 50-meter swim test.

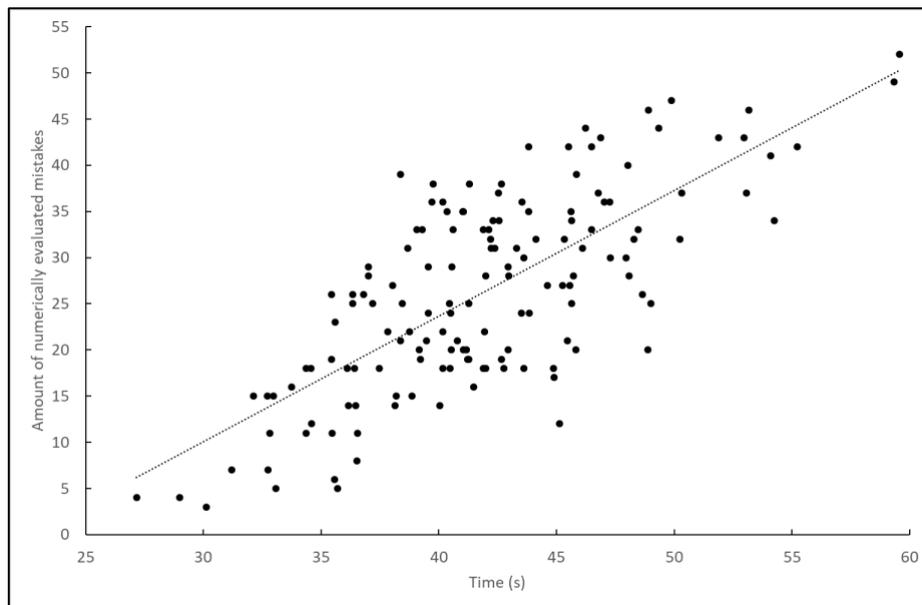
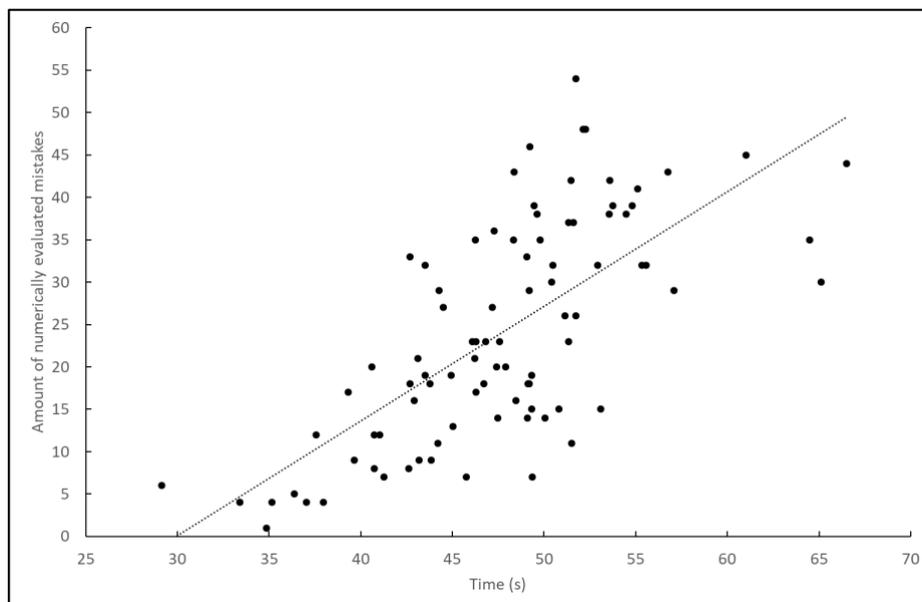


Figure 2. The correlation between the times achieved and the amounts of numerically evaluated mistakes made by female participants at maximal 50-meter swim test.



DISCUSSION

The aim of this pilot study was to develop and to validate the FCTA tool. In the study 48 FC mistakes were evaluated and arranged according to the perceptions of experienced swimming instructors and coaches. Mistakes were ranked on a scale from 1 (for mistakes with lower than moderate impact) to 5 (for mistakes with severe impact). By using the FCTA tool, we numerically evaluated the mistakes that were made during participants' maximal 50-meter swim test. Validity of the FCTA tool was determined by examining Pearson correlations between and the amounts of numerically evaluated mistakes made by the participants their times achieved at maximal 50-meter swim test. We found a strong correlation between these variables. Thus, we believe that the FCTA tool could be useful for the technique assessment of FC performance.

Despite the scale range spanning from 1 to 7 the coaches evaluated the mistakes mostly with scores ranging from 3 to 7 only (Tables 2 and 3). This was expected due to the fact that we have chosen mistakes already discussed in existing literature (Maglischo, 2003). Swimmers can apply a particular swimming technique in a slightly different way. This is known as an individual's style. However, there are specific aspects in each swimming technique performance that are categorically wrong. These were referred to as mistakes in the present study. The technique mistakes that appear during swimming increase drag and consequently energy expenditure of swimmers (Pyne, & Sharp, 2014). Mistakes in the FC body position usually mean that swimmers disturb their horizontal or lateral alignment i.e. *disruption of the lateral alignment and not keeping the whole body in a straight line* (Table 2). Indeed, the swimmers produce less resistance when their bodies are streamlined horizontally and laterally (Maglischo, 1993). The major mistakes that cause a loss of streamlined horizontal alignment were lifting the head up during inhalation or even holding the head completely out of the water during the entire cycle. Both are results of problems concerning breathing during swimming. Indeed, breathing during swimming is one of the most challenging skills that beginner swimmers should learn. The exhalation should be performed against extra hydrostatic pressure exerted by the water and completed when the face is submerged, thus the breathing should be in accordance with stroke technique as well. Due to the short duration of the inhalation phase, i.e. not more than 0.49 seconds (Cardelli, Lerda, & Cholet, 2000), the problems regarding breathing could be expected at FC learning, for example mistakes such as: *shallow breathing, breath holding, lifting the head forward during inhalation and head up swimming* (Table 3). Head position mistakes result in kicking that is too deep whereas the body inclines too far

downward. The need of keeping the head out of water leads to an increase of trunk incline, thus to an increase of frontal area and hydrodynamic resistance (Zamparo, & Falco, 2010). This leads to an increase of energy requirement albeit indirectly by higher heart rate during FC swimming with the head above the water in comparison to the FC with proper head movements (Zamparo, & Falco, 2010). Furthermore, most of the mistakes that disturb lateral alignment are related to armstroke mistakes such as *entering the hand far outside the shoulder line*, *entering the hand across the centre line* and *underreaching during entry* (Table 3).

The mistake with severe impact at FC armstroke is the *elbow drop during entry* (Table 3). The reason for this mistake lies in the fact that swimmers try to apply propulsive force before the arms are oriented backward (Maglischo, 2003). This causes pushing water down, disturbing horizontal and lateral alignment and decreasing forward speed. Additionally, it could put the swimmer in a poor position to use the latissimus dorsi muscle during the stroke (Troup, 1992). Another important (i.e. severe impact) mistake such as *finishing the armstroke too early* (with hand exit before extension) could be a result of beginning the downsweep with the other arm too soon (Maglischo, 2003). This mistake shortens the propulsive phase, i.e. shortens stroke length, which is usually correlated with the decrease of the swimming speed (Hay, & Guimares, 1983). Indeed, Yanai (2003) suggested that swimmers improve their FC performance over a period of training in order to be able to attain a faster speed with an increased stroke length.

The FCTA tool was developed according to the perceptions of experienced swimming instructors and coaches. For the validation of this tool, we deliberately chose the swimming performances of candidates for the enrolment at the University of Ljubljana, Faculty of Sport. There were at least two reasons for choosing these candidates. Firstly, they swam 50-meter as fast as they could because the achieved time was one of the selection criteria for enrolment. Secondly, they were mostly swimmers at intermediate or advanced levels without any experience with competitive swimming. In terms of physical, technical and psychological preparation for the swim test they did all the preparation themselves, most of them without any expert help. In the light of the above, they swam 50-meter FC maximally, however with more or less technical mistakes (Table 5). Great heterogeneity was observed between them regarding swim times and mistakes occurrence (Figures 1 and 2), however, these two variables were related to each other. Regardless to gender, we obtained a positive correlation between the times achieved and the amounts of numerically evaluated mistakes made by the participants at maximal 50-meter swim test. R of 0,69 and 0,74 obtained by female and male participants, respectively, was moderately strong with very high statistical significance ($p < 0,01$) (Akoglu,

2018). This means that candidates with fewer mistakes made achieved faster times, i.e. better results at the swim test. In view of the above, we assumed that the times that the participants achieved at the swim test depended mainly on their FC technical skills and, to a lesser extent, on other factors. We could not exclude the effects of the starting and turning performance (Veiga, & Roig, 2017) as well as the influences of anthropometrical (Rozi, Thanopoulos, Geladas, Soultanaki, & Dopsaj, 2018), physiological (Lätt, et al., 2010), energy (Pyne, & Sharp, 2014) and psychological (Sheard, & Golby, 2006) attributes. It seems that the FCTA tool discriminated the participants due to their degree of technical skills in a similar way as the measured time did.

Limitations and Directions for Further Research

The generalisability of the findings is limited for several reasons. In retrospect, our failure to collect retest data regarding swimming instructors' assessments was a missed opportunity to determine internal consistency of their perceptions of common FC mistakes. Future investigators should redress this omission thus, determine the reliability of the tool. Moreover, we investigated the validity of the FCTA tool using the times of the maximum 50-meter swim test of adult participants. One might suspect that we would obtain different results if we tested younger participants for this validation.

CONCLUSION

In conclusion, these results indicated that the FCTA could be a valid tool to effectively assess the technical skills of intermediate and advanced level swimmers in front crawl. It could help instructors and coaches classify swimmers according to their FC technique performance. However, this was a pilot study, so all conclusions are preliminary and require further research.

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Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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