DOI: 10.4025/reveducfis.v22i1.8141

ORIGINAL ARTICLE

EFFECTS OF DIFFERENT HAND PADDLE SIZES ON FRONT CRAWL KINEMATICS

EFEITO DE DIFERENTES TAMANHOS DE PALMARES SOBRE A CINEMÁTICA DO NADO CRAWL

Aline Fernandes Gomes de Freitas
Ricardo Peterson Silveira
Marcos Franken
Flávio Antônio de Souza Castro

ABSTRACT
The purpose of the present study was to verify the effects of different hand paddle sizes on kinematics of front crawl performed under perceived exertion, referring to the rating 17 of the Borg Scale. Ten regional level swimmers (age = 17.6 ± 3.7 years) performed twelve 50m trials, with intervals of 20s, in three situations: without hand paddles (WHP), with little hand paddles (LHP; 183cm^2) and with medium hand paddles (MHP; 260cm^2). The use of hand paddles caused increased covered distance per cycle (DC) and reduced frequency of cycles (FC) ($p < 0.001$). Due to the DC increase, in order to maintain the same perception of exertion under different conditions, swimmers adopted a strategy for reducing the FC, which was sufficient for the swimming speed (SP) not to be altered.
Keywords: Swimming. Kinematics Hand paddles.

INTRODUCTION

Sports sciences have been evolving continuously, assisting coaches and athletes in understanding and improving swimming performance. Technique improvement is considered essential for the success of high performance sports, taking more and more time during training sessions (CAPUTO et al., 2000; VILLAS-BOAS et al., 2001). Many resources have been used for this purpose, including integration of various fields, such as physiology, regarding the supply and release of energy, which involve kinematics and biomechanics parameters of swimming that interfere with the drag and propulsion forces ALBERTY; SIDNEY; HUOT-MARCHAND, 2006; JURIMÄE et al., 2007).

It is common to include equipment in training programs, searching for increased loads, technique development and improvement of swimming performance. Hand paddles are equipment used in swimming to increase the surface area of the hand, providing a greater displacement of water mass during the strokes (GOURGOULIS et al. 2006). Thus, the resistance of the water accelerated by the hand becomes superior with the use of this implement, contributing to a greater force application per cycle of strokes (TOUSSAINT; BEEK, 1992). In this context, it is of great importance that the coach be able to determine technical parameters, in order to assess the use of these equipment in an easy way that allow him to monitor the progress of his athletes.

Swimming features, from biomechanical point of view, can be identified by means of kinematic parameters, analyzing swimming average speed (SP), the average frequency of cycles of strokes (FC) and the average distance per cycle of stroke (DC). The SP is dependent on the product between the FC and the DC, variables that are inversely related.

Acutely, increases in the DC cause a reduction in the FC, due to a higher absolute length of the stroke propulsive phase HAY; GUIMARÃES, 1983; MAGLISHO, 2003), besides a greater relative length of the entry and catch phases (CHOLLET et al . 2000). Chatard et al. (1990) believe that skilled swimmers are able to achieve higher SPs through an optimization of the relationship between the DC and the FC, providing a greater motion economy.

The DC is considered an indicator of propulsive efficiency and, consequently, of the technical level of athletes (TOUSSAINT; BEEK, 1992). In cross-sectional analyzes, the DC may indicate acute adaptations of the technique related to the swimmer's momentary physiological state, in response to the demands of the swimming intensity. Chronically, it can be used to assess individual progresses on swimming techniques (CRAIG et al., 1985; CASTRO et al., 2005). These variables (SP, FC and DC) can be obtained with or without using kinematic equipment (CASTRO et al., 2005; MAZZOLA et al., 2008). The latter option is a technique closer to the edge pool technique of the coaches.

Although the use of hand paddles is almost indiscriminate among swimmers of different levels, knowledge of the adaptations that different hand paddle models cause to the swimming technique, particularly in the kinematic variables, is small and little discussed in the literature (GOURGOULIS et al., 2006; GOURGOULIS et al., 2008a), but is useful for coaches and athletes in the training process. Accordingly, the aim of this study was to investigate the effect of different sizes of hand paddles on the kinematics of front crawl performed under intensity relative to the rating 17 of perceived exertion (PE) of the Borg scale.

MATERIAL AND METHODS

Sample

Ten swimmers participated in this study (age: 17.6 ± 3.7 years old; weight: 59.6 ± 7.1; height: 1.72 ± 0.03m, wingspan: 1.77 ± 0.04m), of regional level, with competitive experience of three years, at least, and regular use of hand paddles in their training sessions. This study was approved by the Ethics Committee of the University where it was carried out (number: 2.007.925). All subjects were informed about the objectives, procedures and risks involved in this study, giving their verbal and written consent by signing an informed consent term.

Tests

The tests were performed in a 50m pool (water temperature: 28°C). Three series of twelve 50m trials in front crawl style were performed, with intervals of 20s between trials under the conditions without hand paddles (WHP), with small hand paddle (SHP; area 183 cm^2) and medium hand paddle (MHP; area 260 cm^2) , respecting a minimum interval of 48h between each condition. The performance order of the series was randomized.

Participants were previously acquainted, during the training sessions over two weeks, with the Borg Scale for rating of perceived exertion (Borg, 2000). During the familiarization, the subjects performed the training when they learned to use the perceived exertion scale without any interference with training intensities prescribed by their coaches. Thus, after the weeks of adaptation to the use of the scale, all participants were instructed to perform all trials according to the 16-17 rating of this scale. Although any other physiological variable of exertion has not been measured, it was assumed that this perception is representative of the intensity of anaerobic threshold (WELTMAN, 1995).

Kinematic parameters of path

The kinematic parameters of path were obtained in the first, sixth and twelfth trials of each series, by means of manual timing (SEIKO S143) performed by experienced assessors, similar to the methodology applied by Mazzola et al. (2008). The procedures for data collection are illustrated in Figure 1.

In order to obtain the SP, the assessors recorded the time that swimmers used to cover 20m, between the 20m and 40m of each assessed trial. For this, the head was the reference of the body reference when it crossed the 20m and 40m markings. The SP was measured throughout this 20m distance, considering the time required to perform five complete cycles of strokes, expressed in cycles per second (Hz). The DC can be obtained through the quotient between the values of SP and FC.

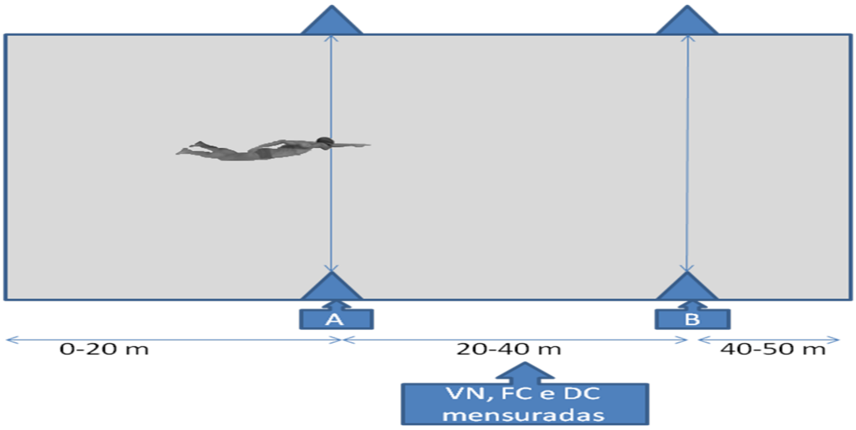

Figure 1 - Markings on the pool for measurement of kinematic variables of path: SP, FC and DC. The distance between A and B points were used to calculate the SP.

Statistical analysis

The mean values, standard deviations and errors for the kinematic parameters were calculated, and the normality (Shapiro-Wilk test) and sphericity of the data (Mauchly test) were verified. The means of the SP, FC and DC values were compared among the WHP, SHP and MHP conditions and, as the same individuals repeated swimming in different conditions, an Analysis of Variance (ANOVA) was applied for repeated measures (one intensity x three conditions). The main effects were observed with a Bonferroni *post hoc* test. All data were processed with SPSS 12.0. The significance level was 5%.

RESULTS

The analyzed swimming conditions presented significant effects on the values of the FC variable. The FC was higher under the condition without hand paddle than under the SHP ($p = 0.004$) and MHP ($p = 0.003$) conditions. No differences were found between the SHP and MHP conditions ($p = 0.352$). Likewise, the use of hand paddles presented effects on the values of DC.

The values of this variable were lower under the condition without hand paddle when compared to the conditions with small hand paddle ($p < 0.001$) and medium hand paddle ($p < 0.001$), however, no differences were observed between the SHP and MHP conditions ($p = 0.248$) . Regarding the SP, this variable was not different among the three assessed conditions.

The results are presented in Table 1.

Table 1 - Means and standard errors of the FC, DC and SP kinematic parameters for each of the conditions (WHP: without hand paddle; SHP: small hand paddle and MHP: medium hand paddle), n=10.

	FC (Hz)	DC (m)	SP (m·s-1)
WHP	0.70 ± 0.20	1.9 ± 0.6	1.31 ± 0.03
SHP	0.65 ± 0.17[a]	2,1 ± 0.7[a]	1.32 ± 0.04
MHP	0.64 ± 0.2[a]	2,1 ± 0.6[a]	1.36 ± 0.04
Effect of the condition	*F2, 18= 8.166*	*F2, 18= 21.178*	*F2, 18= 2.925*
ETA^2	*0.587*	*0.702*	*0.245*
Observed power	*0.990*	*1.000*	*0.499*
Significance	*p<0.001*	*p<0.001*	*p=0.079*

[a]There was a difference with the condition without hand paddle (WHP) for p<0.05.

DISCUSSION

The aim of this study was to investigate the effects of using different sizes of hand paddles on the kinematic variables of path of the front crawl performed according to the rating 17 of PE of the Borg scale (BORG, 2000). In general, there was a decrease of the FC when comparing the condition without hand paddle with the SHP and MHP conditions. Gourgoulis et al. (2008a) found similar results, with a reduction in the FC proportional to the increase in size of the implement. Kjendlie et al. (2004) analyzed the behavior of the FC within a group of adults, a group of children and within a third group that used two sizes of hand paddles, and observed a reduction in the FC when comparing swimming performed with and without hand paddles.

The use of both sizes of hand paddles led to an increase in the DC compared to the WHP condition. According to Payton and Lauder (1995); Gourgoulis et al. (2008a, 2008b), the largest surface area of the hand increases the total length of the stroke and decreases the speed of the hand during the propulsive phase of the stroke. Even at a constant FC, Gourgoulis et al. (2006) observed increases in the DC and a lower displacement speed of the hand during the underwater phase of the stroke, which is related to a greater efficiency and application of propulsive force (Keskinen et al., 1989; TOUSSAINT et al., 1991) .

Caputo et al. (2000) and Kjendlie et al. (2004) suggest that the DC increase at a certain SP is representative of a higher propulsive efficiency. Toussaint et al. (1989) verified an increase of 7.8% in the propulsive efficiency in swimming with hand paddles compared to swimming without hand paddles. In the same study, this behavior was related to increased DC and decreased FC, results similar to those of the present study.

According to Maglischo (2003), the use of hand paddles is effective only when there are concomitant increases in the SP and DC, while the FC values remain close to the competition values. Given that SP increases also increase the hydrodynamic drag, this could lead to a concomitant increase of energy cost, considering that the energy cost increases proportionally to the cube of the swimming speed MILLET; CANDAU, 2002).

No differences were found in the SP among the different conditions, whose intensities were controlled by perceived exertion. Studies in which tests were performed at maximal exertion (GOURGOULIS et al., 2008a, 2008b; KJENDLIE et al., 2004; PAYTON; LAUDER, 1995; TOUSSAINT et al., 1991) or with the FC control (GOURGOULIS et al. , 2006) presented increases in the SP when using large hand paddles in comparison to swimming without hand paddles, which suggests that increasing the surface area of the hand provides a greater propulsive force application, generating not only an increase of the DC but also increases in the SP.

It is speculated that, with a greater force application in SHP and MHP conditions, there may be a greater demand for energy, leading the swimmer to adopt a decrease in the FC sufficient for the SP to remain stable, as an anticipatory mechanism to maintain the proposed perception of exertion (TUCKER, 2009). This theory considers that physical activity is controlled by a central government and that the human body works as a complex system during exercise, based on an mechanism of anticipatory regulation in response to afferent signals different from the concept of central fatigue, as described by Ament and Verkerke (2009).

CONCLUSION

With the use of hand paddles, there was an increase in the average distance covered per cycle of stroke. To maintain the same perceived exertion under conditions without hand paddles, with small hand paddles and medium hand paddles, swimmers adopted a strategy of reduction in the FC enough for the average speed of stroke not to be altered. It is suggested that different sizes of hand paddles can be used as overload for training of the swimmers, since there were no acute differences in swimming kinematic variables among the analyzed sizes. However, it is not possible to state that prolonged use of this equipment causes adaptations in swimming technique. Thus, longitudinal studies should be conducted in order to verify the effects of long term use of hand paddles.

REFERENCES

ALBERTY, M.; SIDNEY, M.; HUOT-MARCHAND, F. Reproducibility of performance in three types of training tests in swimming. **International Journal of Sports Medicine**, Suttgart, v. 27, p. 623-628, 2006.

AMENT, W.; VERKERKE, G. J. Exercise and fatigue. **Sports Medicine**, Auckland, v. 39, no. 5, p. 389-422, 2009.

BORG, G. A. V. **Escalas de Borg para a dor e esforço percebido**. São Paulo: Manole, 2000.

CAPUTO, F. et al. Características da braçada em diferentes distâncias no estilo crawl e correlações com a performance. **Revista Brasileira de Ciência e Movimento**, Brasília, DF, v. 8, n. 3, p. 7-13, 2000.

CASTRO, F. A. S. et al. Cinemática do nado "crawl" sob diferentes intensidades e condições de respiração de nadadores e triatletas. **Revista Brasileira de Educação Física e Esporte**, Campinas, SP, v. 19, n. 3, p. 223-232, 2005.

CHATARD, J. C. et al. Analysis of determinants of swimming economy in front crawl. **European Journal Applied Physiology**, Berlin, v. 61, no. 1-2, p. 88-92, 1990.

CHOLLET, D. et al. A new index of coordination for the crawl: description and usefulness. **International Journal of Sports Medicine**, Stuttgart, v. 21, no. 1, p. 54-59, 2000.

CRAIG, A. B. et al. Velocity, stroke rate and distance per stroke during elite swimming competition. **Medicine and Science in Sports and Exercise**, Hagerstown, v. 17, no. 6, p. 625-634, 1985.

GOURGOULIS, V. et al. Effect of two different sized hand paddles on front crawl stroke kinematics. **Journal of Sports Medicine and Physical Fitness**, Torino, v. 46, p. 232–237, 2006.

GOURGOULIS, V. et al. Estimation of hand forces and propelling efficiency during front crawl swimming GOURGOULIS, V. et al with hand paddles. **Journal of Biomechanics**, New York, v. 41, p. 208-215, 2008b.

GOURGOULIS, V. et al. Hand orientation in hand paddles swimming. **International Journal of Sports Medicine**, Stuttgart, v. 29, p. 429-434, 2008a.

HAY, J. G.; GUIMARÃES, A. C. S. A quantitative look at swimming biomechanics. **Swimming Technique**, Los Angeles, v. 20, no. 2, p. 11-17, 1983.

JURIMÄE, J. et al. Analysis of swimming performance from physical, pysiological, and bomechanical parameters in young swimmers. **Pediatric Exercise Science**, Champaign, v. 19, p. 70-81, 2007.

KESKINEN, K. L. et al. Maximum velocity swimming: interrelationships of stroking characteristics, force production and anthropometric variables. **Scandinavian Journal of Sports Sciences**, Helsinki, v. 11, no. 2, p. 87, 1989.

KJENDLIE, P. L. et al. Adults have lower stroke rate during submaximal front crawl swimming than children. **European Journal of Applied Physiology**, Berlin, v. 91, p. 649-655, 2004.

MAGLISCHO, E. W. **Swimming fastest**. United States of America: Human Kinetics, 2003.
MAZZOLA, P. N. et al. Cinemática do nado *crawl* de nadadores não-competitivos. **Revista Brasileira de Ciência e Movimento**, Brasília, DF, v. 16, n. 3, p. 8, 2008.
MILLET, G. P.; CANDAU, R. Facteurs mécaniques du coût énergétiquedans trois locomotions humaines. **Science & Sports**, Paris, v. 17, p. 166-176, 2002.
PAYTON, C. J.; LAUDER, M. A. The influence of hand paddles on the kinematics of front crawl swimming. **Journal of Human Movement Studies**, London, v. 28, p. 175–192, 1995.
TOUSSAINT, H. M. et al. Effects of propelling surface size on the mechanics and energetics of front crawl swimming. **Journal of Biomechanics**, New York, v. 24, p. 205–211, 1991.
TOUSSAINT, H. M. et al. The influence of paddles on propulsion. **Swimming Technique**, Los Angeles, v. 26, p. 28–32, 1989.
TOUSSAINT, H. M.; BEEK, P. J. Biomechanics of competitive front crawl swimming. **Sports Medicine**, Auckland, v. 13, p. 8-24, 1992.
TUCKER, R. The anticipatory regulation of performance: the physiological basis for pacing strategies and the development of a perception-based model for exercise performance. **British Journal of Sports Medicine**, Loughborough, v. 43, p. 392-400, 2009.
VILAS-BOAS, J. P. et al. Estudo cinemático 3D da afectação da técnica de nado pela fadiga específica da prova de 200 m livre. In: CONGRESSO
BRASILEIRO DE BIOMECÂNICA, 9., 2001, Gramado. **Anais**... Gramado: UFRGS, 2001. p. 31-41.
WELTMAN, A. **The blood lactate response to exercise**. Champaign: Human Kinetics, 1995.

Received in 04/09/2009
Revised in 27/05/2010
Accepted in 03/06/2010

Mailing address: Ricardo Peterson Silveira. Escola de Educação Física, Laboratório de Pesquisa do Exercício, Sala 212, Rua Felizardo 750, CEP: 90690-200, Porto Alegre – RS, Brasil. E-mail: ricardopetersons@yahoo.com.br