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Coordinative characterization of front crawl swimmers with Down syndrome

Ana Querido[1], Inês Marques-Aleixo[2], Pedro Figueiredo[1], Luísa Soares-Miranda[2], João Paulo Vilas-Boas[1], Rui Corredeira[1], Ricardo J. Fernandes[1]

[1] University of Porto, Faculty of Sport, Cifi2d, Portugal

[2] University of Porto, Faculty of Sport, CIAFEL, Portugal

Objective: Literature regarding the performance of swimmers with mental disabilities is scarce. Thus, it was purposed to carry out a Down syndrome characterization on front crawl swimming, examining several parameters: velocity, intra-cyclic velocity fluctuation, arm coordination, propelling efficiency and stroke parameters. ***Design:*** Six international level Down syndrome swimmers performed a 20 m maximal intensity front crawl bout. Video analysis was used to assess intra-cyclic velocity fluctuation of the hip, arm coordination and propelling efficiency. ***Results:*** It was observed that velocity, stroke rate, stroke length, index of coordination and propelling efficiency were lower for swimmers with Down syndrome when compared to the literature for swimmers without disabilities, which seems to reflect the lower coordinative development and technical efficiency of people with Down syndrome. However, these swimmers presented a direct relationship between velocity and stroke length ($r=0.83$, $p<0.05$) and between index of coordination and stroke rate ($r=0.90$, $p<0.05$), as is presented in the literature for swimmers without disabilities. Additionally, intra-cyclic velocity fluctuation was higher in swimmers with Down syndrome, evidencing an inability to maintain continuous propulsive actions. This fact is also evidenced by their catch-up coordination mode (negative index of coordination) that is typical for normal young stages of development. ***Conclusion:*** These findings suggest that lower swimming ability is evident in Down syndrome swimmers when compared with swimmers without disability. However, our subjects are involved in a training program and therefore probably more able to better perform activities of daily living when compared with other Down syndrome subjects, since coordination is a requirement for the training program. In addition, coordination is essential to maintain physical independence.

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Key Words: swimming; mental disability; coordination; intra-cyclic velocity fluctuation

INTRODUCTION

Down syndrome is a genetic disorder that occurs when a third copy of human chromosome 21 is present; its incidence is one in 800 newborns (11). It has been reported in specialized literature that individuals with Down syndrome present a combination of physical and cognitive limitations that significantly affect their motor performance and contribute to high motor behaviour variability (9,13). In addition, it has been suggested that persons with Down syndrome show a delay in the development of gross and fine motor skills leading to motor dysfunction (11) as well as exercise intolerance that can lead to a sedentary lifestyle (1). However, recent studies have reported that physical exercise can improve motor function in Down syndrome persons (24). This is particularly important since it is known that impaired motor skills can affect daily living skills and may have a negative impact on quality of life (6). Even so, studies that focus on the specificities of subjects with Down syndrome involved in physical exercise programs, particularly in swimming, are scarce. Since muscle strength, technique, and hydro-
dynamic drag are important swimming performance influencing factors (21-23), coordination studies

Corresponding author:
Ricardo Fernandes: Faculty of Sport, University of Porto, Portugal, Rua Dr. Plácido Costa, 91, 4200-450 Porto, Portugal • Email: ricfer@fade.up.pt

regarding the specific characteristics of swimmers with this specific intellectual disability are also needed.

Regardless of the specificity of the studied population, it is widely accepted that coordinative factors have a significant influence on swimming performance (23). Of these, intra-cyclic velocity fluctuation (dv) and arm coordination are two informative and currently explored coordinative parameters. Intra-cyclic velocity fluctuation is frequently used to characterize swimming performance, being considered an inverse indicator of swimming efficiency (12). Arm coordination has been evaluated through the index of coordination (IdC, proposed for front crawl by Chollet et al., 4), assessing the lag time between left and right arm propulsive phases, and giving temporal information about the organization of arm propulsive actions. However, as the IdC does not provide data about the intensity of the forces acting over the swimmer's body, the combination of dv and IdC seems to be useful: dv gives kinematic data regarding the consequences of propulsive and resistive force combinations, whereas IdC gives temporal information about swimmers' ability to coordinate their propulsive actions (18).

Since the above parameters, as well as their combination, have not been previously studied in swimmers with Down syndrome involved in a systematic physical exercise training program, we purposed to carry out a Down syndrome characterization on swimming regarding the dv of the hip as well as the IdC in a high intensity front crawl. In addition, to obtain a more detailed coordinative characterization of this specific population, front crawl propelling efficiency (ηp) was assessed and related with the dv and IdC parameters.

MATERIAL AND METHODS

Participants

Six international level swimmers with Down syndrome participated in the present study. The individual and total mean ± SD values of physical and training background characteristics are described in Table 1.

All participants provided informed written consent (parental consent was also obtained) to participate in the study, which was approved by the local ethics committee, in agreement with the Declaration of Helsinki.

Procedures

Subjects performed a 20 m maximal intensity front crawl swim bout. Two digital cameras (Sony® DCR-HC42E) inserted into a sealed housing (SPK - HCB) recorded (50Hz) two complete underwater arm stroke cycles without breathing in the sagittal and frontal planes. The sagittal plane camera was placed laterally at the bottom of the pool, at 2 m depth and 13.5 m from the start wall. The frontal plane camera was placed at 0.5 m depth and aligned with the swimmer. For calibration of the recorded space a bi-dimensional rigid calibration structure (2.10 x 3 m) was used with 13 calibration points. Subsequently, a kinematic analysis was done for each swimmer using the APASystem (Ariel Dynamics Inc., USA), digitizing nine anatomical points (manually and frame by frame): the hip (right femoral condoyle) and the finger tips, wrist, elbow, and shoulder on both sides.

The average swimming horizontal velocity, stroke rate (SR), stroke length (SL), dv and arm coordination were assessed using kinematical data. For the dv assessment the coefficient of variation of the velocity/time curves of the hip in a complete stroke cycle was used. Arm coordination was assessed using the IdC for two complete arm strokes, measuring the lag time between the propulsive phases of each arm, and expressed as the percentage of the overall duration of the stroke cycle (4). Following Chollet et al (4), the propulsive phase begins with the start of the hand's backward movement and ends at the moment where the hand exits from the water (pull and push); the non-propulsive phase initiates with the hand's water release and ends at the beginning of the propulsive phase (recovery, entry and catch). For the front crawl technique, three coordination modes are proposed (cf. 4): (i) catch-up, when a lag time occurs between the propulsive phases of the two arms (IdC < 0%); (ii) opposition, when the propulsive phase of one arm starts as the other arm ends its propulsive phase (IdC= 0%); and (iii) superposition, when the propulsive phases of the two arms overlap (IdC > 0%).

Finally, arm stroke efficiency was calculated according to the model proposed by Zamparo et al. (26), yielding the average efficiency for the underwater phase only (ηF), as indicated in Equation 1:

$$\eta F = [(v.0.9)/2\pi.SR.l)](2/\pi), \quad (1)$$

where v is the mean velocity of the swimmer, SR is expressed in Hz, and l is the average shoulder-to-hand distance (assessed trigonometrically by measuring the upper limb length and the average elbow angle during the insweep of the arm pull). Also in Equation 1, velocity is multiplied by 0.9 to take into account that about 10% of forward propulsion in the front crawl is produced by the legs (8). It was assumed that ηF ~ ηp.

Statistical Analysis

Descriptive statistics (mean and standard deviations)

Table 1. Individual and total mean ± SD values of age, height, body mass, years of previous competitive practice and training units per week for swimmers with Down syndrome in the present study.

Swimmer	Age (years)	Height (cm)	Body mass (kg)	Years of previous competitive practice	Training units per week
1	23	160	60.0	3	5
2	20	156	52.3	1	6
3	22	172	78.9	3	5
4	16	156	57.4	1	6
5	13	137	36.4	1	6
6	26	145	65.1	6	3
Mean (±SD)	20.0 (4.8)	154.3 (12.1)	58.4 (14.1)	2.5 (2.0)	5.2 (1.2)

were used to characterize the sample. Spearman Correlation coefficients were obtained to test the significant relationships between variables. The level of significance was set at $P < 0.05$, with data analysed using SPSS version 17.0 (SPSS Inc., Chicago, Illinois, USA).

RESULTS

Mean and standard deviation values for the studied parameters were 0.98 ± 0.15 m.s-1, 0.20 ± 0.07, -11.26 ± 5.25% and 0.28 ± 0.04, for velocity, dv, IdC and ηp, respectively. The IdC value corresponds to catch-up coordination. SR and SL were also assessed, being 41.22 ± 4.07 cycles/min^{-1} and 1.42 ± 0.19 m.cycle-1, respectively. Correlation coefficients computed between all the studied variables are presented in Table 2.

Inverse significant relationships were observed between IdC and SR, while direct significant relationships were observed between velocity and SL. ηp was not related with any of the studied parameters, and IdC and dv were not significantly related.

DISCUSSION

It is well accepted that the mean velocity of front crawl cycles results from the combination of propulsive and drag forces (23). In fact, during a swimming cycle, there are systematic velocity fluctuations due to the modification of the body segments' positions (16). These velocity fluctuations negatively affect swimming performance, in particular due to the swimmer's overcoming of inertia. Therefore, knowing that swimming technique is one of the main determinants of a swimmer's propulsion and resistance, several biomechanical related parameters were assessed during an all-out effort to conduct a coordinative characterization of swimmers with Down syndrome. To the best of our knowledge, this approach has never been tried before. The main findings of the present study evidenced a lower coordinative development of the studied subjects and, therefore, their poorer technical efficiency when compared with swimmers without disabilities.

Firstly, swimmers with Down syndrome presented lower height and arm span than the swimmers without disabilities (cf. 15, 17), reflecting worse anthropometrical characteristics for swimming practice. In fact, slender and taller swimmers have hydrodynamic advantages that reduce drag and increase propulsion. Additionally, a lower arm span implies lower distance traveled by stroke, which justifies their lower SL compared to the normal swimming population (cf. 19). These physical characteristics of Down syndrome have previously been pointed out in sedentary subjects (9, 13).

The 20 m maximum front crawl test was conducted at high intensity to better simulate competition conditions. At near maximum swimming velocities, the dv values obtained in swimmers with Down syndrome were higher than those presented for swimmers with no disabilities who also performed at high exercise intensities (cf. 10, 18). Since the dv is an indicator of a swimmer's technical skill (5), the uniform distribution of the propulsive actions during the cycle represents a fundamental indicator of swimming efficiency, depending not only on the propulsive force but also on global motor synchronization, as well as on the ability to maintain low drag values during non-propulsive phases (7). Therefore, the observed high dv values seem to reflect a low technical efficiency in swimmers with Down syndrome compared with swimmers without disabilities, which seems to be justified by their abnormal muscle control and tone that are linked to motor delays and irregular movement patterns (cf. 2). In fact, since people with Down syndrome have low muscle tone and ligamentous laxity, they will have more difficulty performing the ideal swimming The IdC is also an important indicator of a swimmer's skill, in particular of his or her arm coordination (4). In this

Table 2. Correlation matrix regarding the coefficients between velocity (v), intra-cyclic velocity fluctuation (dv), arm coordination (IdC), propelling efficiency (η_p), stroke rate (SR) and stroke length (SL).

	v	*dv*	*IdC*	η_p	*SR*	*SL*
v	1					
dv	-0.14	1				
IdC	0.26	0.43	1			
η_p	0.03	-0.14	0.03	1		
SR	0.12	0.58	0.90*	-0.23	1	
SL	0.83*	-0.54	-0.09	0.29	-0.29	1

*P<0.05

study, the observed mean IdC value was lower in people with Down syndrome than for swimmers with no disability, even when compared with non-elite swimmers at national and regional levels (4, 19, 20). In fact, swimmers without disabilities tend to change their arm coordination from catch-up to opposition or superposition modes as velocity increases (54, 19). Thus, the catch-up mode is adopted for slow velocities and by less skilled swimmers, which evidences that swimmers with Down syndrome resemble non-proficient normal subjects.

Typical Down syndrome characteristics could indirectly influence coordination: swimmers with this syndrome present higher hydrodynamic drag as a result of a higher percentage of body fat and anthropometric traits (9, 13) which, in addition to deficiencies in muscle strength (2), can contribute to an increased lag time between propulsive phases (resulting in an even more negative IdC value). This difficulty in overcoming high hydrodynamic resistance can also compromise velocity and stroking parameters, as observed by the lower values of SR and SL in the present study compared to studies conducted with elite swimmers with no disabilities (cf. 17, 18, 19, 22). However, when comparisons are made with less expert swimmers, the differences are not so evident, even at high velocities (cf. 3).

It has been suggested that the IdC increase with swimming velocity could be a strategy adopted by high-level swimmers to maintain a constant dv despite increases in both propulsive and drag forces (18). Indeed, an increase in both SR and propulsive impulse is expected when a swimmer swims faster, but this also leads to a quadratic increase in total drag (12). Thus, if no changes occur in the coordination pattern, a greater dv is expected. As the obtained IdC values in the present study are significantly negative, it suggests that these swimmers were not able to reach more “continuous” coordination modes at maximal velocities, which can also explain the high dv values observed. In fact, the correlation coefficient between IdC and dv was moderate (although non-significant from the statistical point of view). Moreover, according to Lerda and Cardelli (14), IdC values seem to decrease in inspiratory cycles due to higher discontinuity in the arm actions linked to breathing. This should be taken into account in future studies by observing whether breathing laterality will impose any difference in the lag time between the propulsive actions of right and left arms.

Furthermore, the ηp values found for swimmers with Down syndrome are lower than for elite swimmers without disabilities (cf. 26). However, when compared to pre-pubertal or older groups of swimmers (45-54 years old), similar results can be found (cf. 25). Zamparo (25) reported that ηp depends essentially on the distance covered per stroke (reinforced in the present study by the strong relation between v and SL), whereas anthropometric characteristics play a minor role in ηp determination. Indeed, the low values of ηp in the present study can indicate that most of the swimming power output is wasted in giving water un-useful kinetic energy, revealing a technical inefficiency of the swimmers with Down syndrome (as already suggested by the dv and IdC values). Additionally, Down syndrome swimmers—similarly to elderly swimmers—have a decline in muscle strength and power that play a major role in development of SL and, hence, of ηp (25).

The obtained results in the current study are unique and indicate that lower swimming ability is shown in Down syndrome swimmers when compared with swimmers without disabilities. This finding was expected since Down syndrome is characterized by impaired motor coordination. However, these Down syndrome subjects are involved in a training program, being more capable of performing activities of daily living when compared with other Down syndrome subjects, since coordination is required to do so. It is possible to speculate that the Down syndrome subjects in this study have better motor skills than their sedentary matches and are therefore more able to perform daily activities (e.g., eating, dressing and walking), leading them and their families to be more independent and to have a better quality of life. Thus, future studies comparing trained Down syndrome persons with sedentary Down syndrome persons are needed to analyse the impact of exercise on the health and daily living of Down syndrome persons and their families.

DEDICATORY

We dedicate this study to our beloved colleague, Professor Maria Adília Silva.

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