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Race performance analysis of swimmers with Down syndrome.

KEYWORDS:
Trisomy 21. Swimming.
Competition. Freestyle.

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ABSTRACT

Race analysis has been conducted for swimmers with and without disabilities, but competitive swimmers with Down syndrome have not been examined. We assessed male and female elite Down syndrome swimmers final time, clean speed, stroke rate and length, and starting, turning and finishing speed, observed the relationships between variables and analysed the pacing strategies at a middle-distance freestyle event. The 50, 100 and 200m freestyle heat and final races from the 5th World Championships DSISO'2010 were video recorded and the 400m freestyle event splits from the 6th World Swimming Championships DSISO'2012 were analysed. Data showed that: (a) males were faster than females, presenting longer stroke lengths for similar stroke rate values; (b) the swimmers analysed were slower than those without impairments or with minimal physical impairment at the 400m freestyle; (c) pacing strategies most often used in the 400m freestyle were the fast start and negative pacing, with the fastest swimmers using the parabolic strategy. We have concluded that male swimmers with Down syndrome were faster than female counterparts, for similar stroke rates males attain higher stroke lengths and females had more difficulty in starting, turning and finishing. Lastly, there is no apparent advantage to use a specific pacing strategy.

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Análise de performance competitiva em nadadores com síndrome de Down.

RESUMO

Análise de prova é um procedimento avaliativo comumente utilizado em natação pura, mas que não foi ainda aplicado em nadadores com síndrome de Down. Nesse sentido, foram avaliados nadadores masculinos e femininos síndrome de Down relativamente ao tempo final de prova, velocidade de nado, frequência e distância de ciclo, e velocidade de partida, viragem e chegada, tendo sido relacionadas todas as variáveis e caracterizada a tática de uma prova de meio-fundo. As eliminatórias e finais dos 50, 100 e 200m livres dos 5.º Campeonatos do Mundo de Natação DSISO'2010 as e as finais dos 400m livres dos 6.º Campeonatos do Mundo de Natação DSISO'2012 foram filmadas, observando-se que: (a) os nadadores foram mais rápidos que as nadadoras, apresentando maiores distâncias de ciclo para frequências gestuais semelhantes; (b) os nadadores com síndrome de Down foram mais lentos que os nadadores sem deficiência e com deficiência mínima elegível nos 400m livres; (c) as estratégias de nado mais utilizadas nos 400m livres foram as de início rápido e negative pacing, tendo os nadadores mais rápidos utilizado a estratégia parabólica. Os nadadores com síndrome de Down foram mais rápidos que as nadadoras e atingiramm maiores distâncias de ciclo, enquanto as nadadoras apresentaram maiores dificuldades nas fases de partida, viragens e chegadas. Dos dados obtidos parece não existir vantagem na utilização de uma estratégia especifica de ritmo de prova.

PALAVRAS-CHAVE:
Trissomia 21. Natação.
Competição. Livres.

INTRODUCTION

The main goal of a competitive swimmer is to cover the race distance in the shortest time possible. For this reason, understanding swimmers' behaviour in competition through race analysis has been a widely applied procedure (Arellano et al., 2001; Veiga, del Cerro, Rodriguez, Trinidad, & González-Ravé 2021). Since the pioneer work of East (1970), competition analysis has become a regular feature at most international swimming events, with Paralympic events also being recorded for race analysis in Atlanta 1996 (Daly, Malone, Vanlandewijck, & Steadward, 1999). However, research on Down syndrome competitive swimming is very scarce, with a gap of several years compared to monitoring centered on swimmers without disabilities in general and for race analysis in particular (Querido et al., 2012).

Elite male swimmers typically swim faster than females by ~10% (Arellano, Brown, Cappaert, & Nelson, 1994), with pioneer studies (e.g., East, 1970) stating that they had longer stroke length than the latter (for the same stroke rate values), evidencing males greater propulsive force. Arellano, Molina-Sanchez, Navarro, and Aymerich (2003) analysed the 100 m events of all swimming techniques at the 2001 European Youth Olympics and concluded that male swimmers were faster at each race phase and had longer stroke length than female (with similar stroke rate). Furthermore, it is widely accepted that pacing strategy has a significant impact on performance (Abbiss & Laursen, 2008) due to physiological and biomechanical variables management (Oliveira et al., 2019). At the 400, 800 and 1500m freestyle events, highly trained swimmers frequently use the parabolic tactics (Mauger, Neuloh, & Castle 2012; Oliveira et al., 2019), but literature on the topic is scarce especially regarding swimmers with impairments (Taylor, Santi, & Mellalieu, 2016).

The aims of the current study were to: (a) compare the swimming race components (start, clean swim, turn and finish) of male and female swimmers with Down syndrome, as well as their clean swimming speed, stroke rate and length; (a) examine the relations between the analysed variables for the 50, 100 and 200m freestyle events; and (c) identify these specific swimmers pacing strategies at the 400m freestyle race. We hypothesized that: (a) male swimmers with Down syndrome are faster than females and attain higher stroke rate and length values; (b) swimmers with Down syndrome present similar relationships between race components, stroke rate and length to swimmers without impairment and swimmers with other intellectual impairment than Down syndrome; and (c) elite swimmers with Down syndrome adopt different pacing strategies comparable to other international level swimmers.

MATERIAL AND METHODS

PARTICIPANTS

Seventy-four male and 62 female swimmers participating in the 50, 100 and 200 m freestyle qualifying heats and finals of the Down Syndrome International Swimming Organization (DSISO) 5th World Swimming Championship were included in this study. In addition, 44 swimmers (24 male and 20 female) participating in the 400 m freestyle heats of the DSISO 6th World Swimming Championship were evaluated.

DESIGN AND PROCEDURES

After receiving DSISO approval, the events were videotaped with two side view cameras that were perpendicular to the swimming direction, 6.5m from the start and turn, 2.5m away from and 3m above the edge of lane 8 of the 25m swimming pool. Due to infrastructural constraints, swimmers from lane 8 were not included in the analysis so that the other seven lanes would have better visibility (FIGURE 1). As used for gait analysis (Dobson, Morris, Baker, & Graham, 2007), combined qualitative and quantitative classification methods were used to group the swimmers for pacing strategy at the 400m freestyle race.

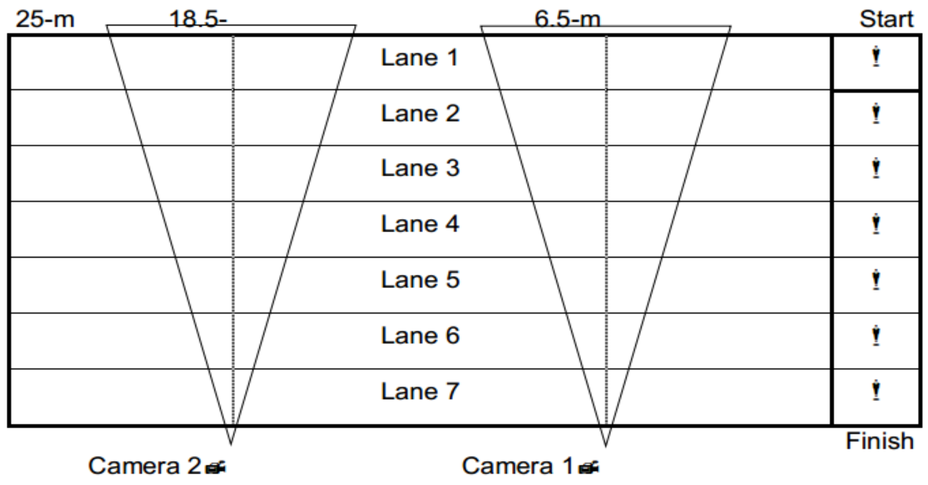

FIGURE 1. Relationships between variables for the 100m freestyle event (significant correlations are identified with an * ($p < .05$).

Video recording began at the referee starting acoustic signal, which was recorded on the soundtrack of both cameras for synchronization purposes. As the race clock was not registered, cameras kept running during the entire race and the frame count was used as a stopwatch. An electronic copy of all official competition results was obtained from the timing equipment server, but only final times were available (lap splits were not obtainable). Adobe Premier 1.5 software was used to analyse the 50, 100 and 200m freestyle races video images, with video footage from both cameras being captured into the computer for the entire race. Then, the video file from camera 1 was imported to the software, allowing forward and backward frame by frame visualization (the soundtrack wave was also visualized and the sound made audible). The start signal frame was identified based on both the sound wave and real audio changes, with this frame number corresponding to the start.

The Dartfish program was used for the video analysis, allowing a line to be drawn across the swimming pool marks (at 5 and 10m from the starting and opposite end of the pool). Using pictures from camera 1, the frame codes were manually registered when the swimmers head passed the 10 m mark for each race length following the start and going into and out of the turn, and at the beginning and end of two to eight upper limb cycles on turn approach. On the camera 2, the frame count of the start signal was recorded along with the moment the head passed the 5m mark going into and coming out of the turn. Upper limbs cycle count was also taken with this camera when the swimmer was approaching the turn wall. Afterwards, frame counts data entered an Excel sheet that calculated the 10 m start and finish times. Turn times were also calculated, although these differed for the two pool ends (2 x 10m if the swimmer was on the start/finishing side or 2 x 5m if the swimmer was on the opposite swimming pool side).

The mid pool clean swimming speed was calculated for each race length, as well as the time for the measured upper limbs cycle count, that is, stroke rate and stroke length (the ratio between the clean swimming speed and stroke rate; Daly, Djobova, Malone, Vanlandewijck, & Steadward 2003). Thus, the durations of each race segment, when summed, should equal the total race time, with the comparison between accounted and real time being checked and faults corrected. Race variables measured included starting, turning, clean swimming and finishing times, as well as stroke rate, stroke length and clean swimming speed (unaffected by starting, turning or finishing) for each pool length in the race (Daly et al., 2003).

For the 400m freestyle event analysis, a group of five experts conducted a visual inspection analysis of the 44 individual curves calculated by the difference between each 50m lap time and the race mean 50m lap time (derived from the overall race time and expressed as a time deviation). Each expert selected one of the parabolic, even, parabolic/fast start, negative and fast start pacing strategies (Taylor et al., 2016), with the final pacing strategy being attributed based on the higher number of votes. Then, a *k*-means cluster analysis was applied to the data to allow grouping the 44 swimmers in five clusters (Abbiss & Laursen, 2008; Mauger et al., 2012; Taylor et al., 2016). We then compared the pacing strategy given buy the experts to the cluster in which the swimmer was placed.

STATISTICAL ANALYSIS

Descriptive statistics were calculated for all the variables and data were checked for normality and homogeneity of variance. Student t-tests were computed to compare sex groups and correlation analyses were performed between all variables for the 50, 100 and 200 m freestyle (correlation from .00-.49 poor, .50-.69 moderate and .70-1.00 strong). k-means cluster analysis was applied to the 400 m freestyle data to classify swimmers according to pacing strategies. Statistical analyses were conducted using SPSS version 21.0, with the significance level in all analyses set at .05.

RESULTS

Male swimmers are considerably faster in all race components, presenting higher stroke length values than female counterparts (TABLE 1). Regarding the stroke rate values, sex related differences were only observed on the 50m freestyle, with male swimmers attaining higher number of strokes per minute than females. Start, swim, turn and finish times displayed strong direct relationships with the final time in all the female events (TABLES 2-4). Stroke rate was strongly related with speed (50m race), finish time (100m race) and stroke length (100 and 200m races), and moderately related with swim time (50m race), turn time (50 and 100m races), finish time (50 and 200m races) and final time (50 and 100m races). Neither stroke rate nor stroke length were related to speed or final time in the 200m freestyle event. For the 100m event, only stroke rate was inversely related to final time.

TABLE 1. *Mean* ± *SD* of each race component, clean swimming speed, stroke rate and stroke length for the 50, 100 and 200 m freestyle events. Differences between sexes are identified with an * ($p < .05$).

	50M FREESTYLE		100M FREESTYLE		200M FREESTYLE	
	MALE (*n* = 31)	FEMALE (*n* = 26)	MALE (*n* = 25)	FEMALE (*n* = 23)	MALE (*n* = 18)	FEMALE (*n* = 13)
Start time (s)	5.69 ± 0.56*	7.58 ± 0.96	6.07 ± 0.47*	7.37 ± 0.99	6.37 ± 1.01*	7.77 ± 0.88
Swim time (s)	24.58 ± 1.99*	3.86 ± 3.49	34.45 ± 2.90*	44.18 ± 4.49	8.67 ± 6.86*	97.36 ± 9.81
Turn time (s)	7.14 ± 0.62*	9.52 ± 1.02	32.36 ± 2.64*	37.94 ± 3.85	92.03 ± 8.79*	111.25 ± 15.87
Finish time (s)	7.53 ± 0.89*	1.06 ± 1.39	9.08 ± 1.32*	1.25 ± 1.33	1.31 ± 1.71*	11.72 ± 1.81
Clean speed (m/s)	1.26 ± 0.94*	1.01 ± 0.11	1.18 ± 0.09*	.92 ± 0.09	1.01 ± 0.08*	.84 ± 0.08
Stroke rate (strokes/min)	5.44 ± 6.15*	42.03 ± 5.63	43.16 ± 4.87	4.78 ± 5.45	38.06 ± 4.50	36.78 ± 5.10
Stroke length (m)	1.52 ± 0.19*	1.42 ± 0.11	1.65 ± 0.16*	1.38 ± 0.17	1.61 ± 0.17*	1.38 ± 0.17

TABLE 2. Relationships between variables for the 50m freestyle event (significant correlations are identified with an * ($p < .05$).

		START TIME	SWIM TIME	TURN TIME	FINISH TIME	FINAL TIME	SPEED	STROKE RATE
Swim time	Male	.31						
	Female	.74*						
Turn time	Male	.69*	.66*					
	Female	.80*	.94*					
Finish time	Male	.52*	.61*	.72*				
	Female	.74*	.61*	.89*				
Final time	Male	.56*	.90*	.83*	.75*			
	Female	.83*	.98*	.97*	.94*			
Clean speed	Male	-.32	-.97*	-.60*	-.53*	-.84*		
	Female	-.71*	-.98*	-.93*	-.87*	-.96*		
Stroke rate	Male	-.09	-.36*	-.28	-.34	-.42	.36*	
	Female	-.34	-.69*	-.57*	-.51*	-.62*	.72*	
Stroke length	Male	-.07	-.18	-.03	.07	-.02	.19	-.67*
	Female	-.39	-.20	-.31	-.34	-.29	.20	-.39

TABLE 3. Relationships between variables for the 100m freestyle event (significant correlations are identified with an * ($p < .05$).

		START TIME	SWIM TIME	TURN TIME	FINISH TIME	FINAL TIME	SPEED	STROKE RATE
Swim time	Male	.50*						
	Female	.47						
Turn time	Male	.70*	.86*					
	Female	.86*	.73*					
Finish time	Male	.03	.62*	.42				
	Female	.65	.73*	.84*				
Final time	Male	.59*	.97*	.94*	.66*			
	Female	.75*	.91*	.95*	.88*			
Clean speed	Male	-.53*	-.99*	-.86*	-.59*	-.97*		
	Female	-.53*	-.99*	-.78*	-.75*	-.93*		
Stroke rate	Male	-.19	-.51*	-.40	-.50*	-.51*	.50*	
	Female	-.39	-.42	-.61*	-.70*	-.58*	.43	
Stroke length	Male	-.20	-.29*	-.30	.05	-.26	.31	-.67*
	Female	.06	-.23	.07	.20	.05	.22	-.76*

TABLE 4. Relationships between variables for the 200m freestyle event (significant correlations are identified with an * ($p < .05$).

		START TIME	SWIM TIME	TURN TIME	FINISH TIME	FINAL TIME	SPEED	STROKE RATE
Swim time	Male	.50*						
	Female	.47						
Turn time	Male	.70*	.86*					
	Female	.86*	.73*					
Finish time	Male	.03	.62*	.42				
	Female	.65	.73*	.84*				
Final time	Male	.59*	.97*	.94*	.66*			
	Female	.75*	.91*	.95*	.88*			
Clean speed	Male	-.53*	-.99*	-.86*	-.59*	-.97*		
	Female	-.53*	-.99*	-.78*	-.75*	-.93*		
Stroke rate	Male	-.19	-.51*	-.40	-.50*	-.51*	.50*	
	Female	-.39	-.42	-.61*	-.70*	-.58*	.43	
Stroke length	Male	-.20	-.29*	-.30	.05	-.26	.31	-.67*
	Female	.06	-.23	.07	.20	.05	.22	-.76*

For male swimmers (see also TABLES 2-4), the final time is strongly related with swim, turn and finish times (50m race), swim and turn times (100m race) and start, swim and turn times (200m race), and moderately related to start time (50m race) and start and finish times (100m race). Finish time was weakly related to final time (200m race) and stroke rate was moderately inversely related to swim time (100 and 200m races), presenting a weak inverse relationship to the 50m event. Stroke rate also presented moderate correlation values to finish time, final time (inverse relation) and speed for the 100m event, and to final time and speed for the 200m event. Concerning the 50m event, only weak relations between stroke rate and swim time (inverse relation) and speed were found. Stroke rate related moderate and negatively to stroke length at the 50 and 100m events, and strong and negatively to the 200m.

Discrepancies between the 400m freestyle pacing strategies were mostly observed at the end of the race, with the negative pacing strategy presenting the most relevant differences with other strategies (TABLE 5). There were no differences between strategies for the race time, although the parabolic pacing strategy resulted in the fastest overall times. The strategies most frequently adopted by swimmers with Down syndrome were the fast start followed by the negative tactic. Swimmers with Down syndrome presented considerably slower race 400m freestyle event times and 50m splits than able-bodied and elite swimmers with impairment (TABLE 6).

TABLE 5. *Mean ± SD* of the differences between each 50m splits for the 400m freestyle event pacing strategies.

STRATEGIES	50 M SPLIT (S)	100 M SPLIT (S)	150 M SPLIT (S)	200 M SPLIT (S)	250 M SPLIT (S)	300 M SPLIT (S)	350 M SPLIT (S)	400 M SPLIT (S)
Parabolic (*n* = 4)	-7.87 ± 2.06	-2.38 ± 1.13B	0.61 ± 1.17	1.29 ± 0.65	1.56 ± 1.30	1.55 ± 1.71	3.97 ± 2.84AB	1.27 ± 3.38B
Even (*n* = 9)	-7.09 ± 2.17	-0.85 ± 1.59C	1.28 ± 0.70E	1.20 ± 1.34	1.29 ± .087CE	1.82 ± .63C	1.72 ± .72C	0.62 ± 2.07DE
Parabolic/ Fast start (*n* = 4)	-9.28 ± 3.85f	-3.21 ± 2.04F	0.68 ± 0.90	1.91 ± 1.65	3.34 ± 1.46G	3.41 ± 1.30FG	3.7 ± 1.39FG	-0.63 ± 0.59FG
Negative (*n* = 12)	-6.14 ± 1.84h	-0.07 ± 1.19H	1.40 ± 0.63H	1.71 ± 0.99	2.02 ± 1.13	1.89 ± 1.05	1.76 ± .96	-2.60 ± 1.22H
Fast start (*n* = 15)	-8.48 ± 2.11	-1.87 ± 1.15	0.33 ± 1.06	1.12 ± 0.80	1.95 ± 0.53	2.29 ± .61	2.05 ± 1.43	2.70 ± 1.49
TOTAL (*n* = 44)	-7.58 ± 2.39	-1.34 ± 1.64	0.87 ± 0.97	1.38 ± 1.05	1.92 ± 1.05	2.12 ± 1.01	2.23 ± 1.52	0.41 ± 2.68

a, b, c, d, e, f, g, h Differences between parabolic vs. even, parabolic vs. negative, even vs. parabolic/fast start, even vs. negative, even vs. fast start, parabolic/fast start vs. negative, parabolic/fast start vs. fast start and negative vs. fast start strategies

TABLE 6. Descriptive statistics for swimmers with Down syndrome (current study S21), elite able-bodied male and female swimmers, and elite male and female swimmers with an impairment (classes S10 - physical impairment and S13 - visual impairment) (adapted from Taylor et al. [2016])

CLASS	DESCRIPTIVE STATISTICS	50 M SPLIT (S)	100 M SPLIT (S)	150 M SPLIT (S)	200 M SPLIT (S)	250 M SPLIT (S)	300 M SPLIT (S)	350 M SPLIT (S)	400 M SPLIT (S)	RACE TIME
S21	MEAN TIME (S)	46.35	52.58	54.79	55.31	55.85	56.04	56.16	54.33	431.38
	LOWER LIMIT (S)	44.23	5.21	52.45	53.08	53.50	53.62	53.79	51.79	413.08
	UPPER LIMIT (S)	48.46	54.96	57.14	57.53	58.19	58.49	58.53	56.86	449.68
S10M	MEAN TIME (S)	3.01	32.77	33.41	33.82	33.79	34.05	34.06	33.34	265.25
	LOWER LIMIT (S)	29.46	32.22	32.78	33.18	33.07	33.32	33.35	32.56	26.45
	UPPER LIMIT (S)	3.55	33.33	34.04	34.45	34.51	34.77	34.77	34.12	27.04
S10F	MEAN TIME (S)	33.64	36.87	37.96	38.28	38.34	38.45	38.29	37.19	299.03
	LOWER LIMIT (S)	32.89	35.88	36.89	37.17	37.24	37.35	37.24	36.24	291.21
	UPPER LIMIT (S)	34.40	37.86	39.03	39.40	39.45	39.55	39.34	38.15	306.84
S13M	MEAN TIME (S)	29.71	33.17	34.11	34.74	34.70	35.11	34.97	33.81	27.33
	LOWER LIMIT (S)	29.02	32.40	33.27	33.87	33.74	34.15	33.93	32.87	263.91
	UPPER LIMIT (S)	3.40	33.94	34.94	35.62	35.67	36.08	36.01	34.75	276.75
S13F	MEAN TIME (S)	33.30	36.87	37.76	38.20	38.21	38.33	38.41	36.88	297.96
	LOWER LIMIT (S)	32.55	35.97	36.72	37.18	37.18	37.27	37.27	35.86	29.34
	UPPER LIMIT (S)	34.04	37.77	38.79	39.23	39.24	39.39	39.56	37.89	305.58
A-BM	MEAN TIME (S)	27.33	29.56	3.03	3.29	3.24	3.47	3.34	29.53	237.80
	LOWER LIMIT (S)	26.80	28.86	29.22	29.40	29.31	29.50	29.37	28.59	231.28
	UPPER LIMIT (S)	27.87	3.25	3.84	31.17	31.17	31.45	31.32	3.48	244.32
A-BF	MEAN TIME (S)	29.48	31.57	32.04	32.30	32.23	32.49	32.43	31.70	254.24
	LOWER LIMIT (S)	29.12	31.10	31.51	31.74	31.64	31.86	31.79	31.04	25.06
	UPPER LIMIT (S)	29.85	32.04	32.56	32.86	32.86	32.82	33.07	32.36	258.43

Classification (class), Down syndrome class (S21), male and female with minimal physical impairment class (S10M and S10F), male and female with minimal visual impairment (S13M and S13F), male and female able-bodied swimmers (A-BM and A-BF), and lower and upper 95% confidence limits (lower limit and upper limit).

DISCUSSION

The first purpose of the current study was to compare male and female Down syndrome swimmers with respect to swimming race components, clean swimming speed, stroke rate and stroke length. We have observed that males are faster than females in all 50, 100 and 200m freestyle race components and clean swimming speed. In the 100 and 200m events males attained higher stroke length for similar stroke rate values and in the 50m event males reached higher stroke rate values. The physical differences between male and female swimmers can help explaining the differences in final time and race components since they are important contributors to overall swimming performance.

In fact, male adults with Down syndrome attained significantly better results in strength, endurance, coordination, balance and functional tests than female counterparts (Terblanche & Boer, 2013), in accordance with studies performed in swimmers without disabilities. Fifty years ago, East (1970) found that male swimmers had longer stroke length than females (but that stroke rate values were similar), concluding that this was most likely the result of male swimmers greater propulsive force. Furthermore, Arellano et al. (1994) pointed out that elite male swimmers typically swim 10% faster than their female counterparts. Data from the current study confirm our hypothesis (with the exception for the 100 and 200m stroke rate values that did not differed between sexes).

In the current study we also aimed to examine the relationships between the analysed variables for the 50, 100 and 200m freestyle events. The observed strong relationships between start, swim, turn and finish times with the final event time indicates the importance of all these race components for those specific events (especially for female swimmers). For male swimmers it was observed higher variability and the relatively low relationship between finish time and final time/speed (direct/inverse relationships, respectively) might indicate an inefficiency on swimming as fast as possible at the end of the race. As the current study male swimmers present faster starts, turns and swim times than females, they might get more fatigued at the end of the race, which might impact their ability to reduce stroke rate and improve stroke length to swim faster at the finish of the race.

Another problem concerning swimmers with Down syndrome seems to be the pacing strategy. Therefore, we aimed to identify their tactics in a middle-distance swimming event (the 400m freestyle race) and compare them to the literature. The ability to follow a strict race strategy might be a potential problem for persons with an intellectual impairment and this is an important ability for optimal performance (Querido, Corredeira, Vilas-Boas, Daly, & Fernandes, 2014). In a previous 100m freestyle race analysis for swimmers with Down syndrome there were differences in speed and stroke rate from the first to the second race length and from the second to the third race length (Querido et al., 2012), meaning that swimmers with Down syndrome might have difficulties in pacing correctly in competitive conditions.

Swimmers with Down syndrome front crawl biomechanical characteristics are different than those of experienced and less experienced able-bodied swimmers (Marques-Aleixo et al., 2013). Both drag and propulsion are affected in these swimmers (more than can be expected only from lack of swimming training), suggesting that technique breakdown is most likely a result of the inability to maintain a grip on the water, as reflected by the reduced stroke length at the end of race (Wakayoshi, D'Aquisto, Cappaert, & Troup, 1996). The lack of strength can also be a contributing factor, with swimmers not being able to maintain a correct arm, forearm and hand positioning (Marques-Aleixo et al., 2013). The lower coordinative development of swimmers with Down syndrome was also already described explaining a poorer technical efficiency when compared with swimmers without disabilities (Querido et al., 2010). Moreover, individuals with Down syndrome have a body shape and morphology described as shorter in stature, shorter limbs-to-torso ratio and muscle hypotonia (Mysliwiec et al., 2015), factors that also can negatively impact their swimming performance.

As for the prevalence of the pacing strategies, the current study showed that the strategy most often adopted by swimmers with Down syndrome was the fast start, followed by the negative tactic. A similar study from Taylor et al. (2016) referred that even and negative pacing strategies were prominent in all swimming groups (able-bodied, minimal physical impairment – S10 and minimal visual impairment – S13), while the fast start strategy was used only by able-bodied swimmers, the parabolic fast start was only employed by swimmers with impairments and the parabolic strategy adopted by able-bodied and S10 females. Interestingly, those authors found that the parabolic pacing strategy was mainly used by able-bodied swimmers although the quickest times were attained with the negative strategy. Also, the parabolic strategy was indicated as the most used in longer distance competitions (Mauger et al., 2012; Oliveira et al., 2019) and by elite swimmers, but the even pacing strategy was found to be the most adopted strategy by half-ironman triathletes in the swimming segment (Wu et al., 2015).

Swimmers with Down syndrome from the current study presented 400m freestyle final race times that did not differ between pacing strategies, meaning that these may not be sufficiently dissimilar to promote a quickest/slowest race time or that these swimmers did not take advantage of using the optimal pacing strategy. These results are in accordance with Mauger et al. (2012) who reported that race time was not influenced in a significant way by any single pacing strategy, although they reported fast start and parabolic as the most frequently tactics used by elite 400m freestyle swimmers. Naturally, the adoption of a pacing strategy is likely to be based upon physiological, biomechanical and psychological factors (Mauger et al., 2012; Thompson, 2015) and for swimmers with Down syndrome the question about the consciousness of these choices arises.

There seems to be a tendency for a fast start in swimmers with Down syndrome, but more research is needed to understand if this tendency is a conscious choice or not. Persons with intellectual impairment have been shown to have some underdeveloped cognitive skills (such as visual-spatial skills, reaction time, memory and self-regulation) that could negatively impact sports performance (Burns, 2015). Persons with Down syndrome have a condition that is accompanied with intellectual impairment and additionally to their phenotypic consequences (caused by genes overexpression; Epstein, 1990) swimmers with Down syndrome (as others athletes with intellectual impairment) can experience improvement from practice but at a slower rate than those without disabilities. Swimmers with Down syndrome also display a more variable performance (Burns, 2015), which could explain the greater variability observed for these swimmers compared to physically impaired concerning pacing strategies. Therefore, the third hypothesis of the current study was confirmed, since swimmers with Down syndrome do not seem to make a conscious choice of a specific pacing strategy and are therefore unable to take advantage of an optimal race strategy.

CONCLUSIONS

Male swimmers with Down syndrome are considerably faster than female counterparts. For similar stroke rate male can attain higher stroke length than females, and females seem to have more difficulties in performing starts, finishes and, especially, turns. Swimmers with Down syndrome are considerably slower than able-bodied and minimally impaired swimmers in the 400m freestyle race. The most frequently used pacing strategies for swimmers with Down syndrome were the fast start and negative pacing, and the fastest was the parabolic strategy. Finally, the pacing strategies do not seem to differ significantly in effectiveness since the corresponding race times were similar.

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