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Prescription and control of aerobic training speeds in front crawl swimming.

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KEYWORDS:
Training, Lactate, Heart rate.
Rate of perceived exertion.
Stroke index.

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ABSTRACT

The objectives of this study were twofold: (a) to compare the speeds corresponding to the lactic threshold and the anaerobic threshold intensities assessed through an incremental protocol - 7 x 200m crawl - with those prescribed by the coaches; and (b) to compare the speeds and relevant physiological, psychologic and kinematic swimming variables prescribed from the incremental protocol with those achieved during common training tasks swam in front crawl, identified with the aerobic intensities. Sixteen national and international male swimmers, aged 19.5 (3.6) years old, participated in the study. The main results are as follows: at the lactic threshold intensity, the speed found by the 7 x 200m incremental protocol was 1.43 (0.07) m/s, while the speeds prescribed by the coaches were lower in the two tasks 1.36 (0.05) and 1.39 (0.03) m/s, respectively. In the same intensity zones, the calculated blood lactate concentrations of the incremental protocol were 2.35 (0.54) mmol/l, higher than those found in the other two tasks 1.50 (0.64) and 1.39 (0.25) mmol/l. At the anaerobic threshold, the speed found in the incremental protocol was higher than that prescribed by the coaches 1.50 (0.06) and 1.47 (0.05) m/s. The main conclusion of this study is that coaches tend to prescribe lower aerobic intensity speeds than those determined by a specific incremental protocol.

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Prescrição e controlo da velocidade do treino aeróbio no crawl frontal.

RESUMO

Os objetivos deste estudo foram: (a) comparar as velocidades correspondentes às intensidades do limiar lático e do limiar anaeróbio avaliadas por meio de um protocolo incremental - 7 x 200m crawl - com as velocidades prescritas pelos treinadores; e (b) comparar as velocidades e variáveis fisiológicas, psicológicas e cinemáticas relevantes, prescritas a partir do protocolo incremental com aquelas alcançadas durante tarefas típicas de treino aeróbio realizadas em crol. Participaram do estudo 16 nadadores nacionais e internacionais do sexo masculino, com idade de 19.5 (3.6) anos. Os principais resultados foram os seguintes: na intensidade do limiar lático, a velocidade encontrada pelo protocolo incremental 7 x 200m foi de 1.43 (0.07) m/s, enquanto as velocidades prescritas pelos treinadores foram menores nas duas tarefas 1.36 (0.05) e 1.39 (0.03) m/s. Nas mesmas zonas de intensidade, as concentrações de lactato sanguíneo calculadas do protocolo incremental foram 2.35 (0.54) mmol/l, maiores do que as encontradas nas outras duas tarefas 1.50 (0.64) e 1,39 (0,25) mmol/l. No limiar anaeróbio, a velocidade encontrada no protocolo incremental foi superior à prescrita pelos treinadores, numa das tarefas, 1.50 (0.06) e 1.47 (0.05) m/s, respetivamente. A principal conclusão deste estudo é que os treinadores, em tarefas aeróbias, tendem a prescrever velocidades mais baixas do que aquelas determinadas por um protocolo incremental específico.

PALAVRAS-CHAVE:

Treino. Lactato. Frequência cardíaca.
Perceção de esforço. Índice de nado.

INTRODUCTION

Swimming is an endurance sport, where the contribution of the aerobic metabolism, although variable, is decisive for the energy supply of almost all the competitive events (Figueiredo, Zamparo, Sousa, Vilas-Boas, & Fernandes 2011; Gomes-Pereira, 1992; Rodriguez & Mader, 2011). The use of various physiological, perceptual and kinematic markers is relevant and reliable for assessing swimmers' response to training and predicting performance (Caputo, Lucas, Greco, & Denadai, 2000). Nevertheless, in endurance development in swimming, the importance of the aerobic improvement in getting better results should be emphasized, as well as the appropriate training methods to achieve these improvements (Jones & Carter, 2000).

In aerobic training tasks, the main goal should be to swim at predefined optimum speeds that will enable swimmers to achieve superior aerobic capacity without severe acidosis resulting from the accumulation of lactate and associated hydrogen ions (Maglischo, 2003; Sweetenham & Atkinson, 2003). In swimming, Olbrecht (2000) and Maglischo (2003) considered the lactic threshold and the anaerobic threshold (also known as A1 and A2 intensities, respectively) as critical training zones to develop aerobic endurance. However, there are few physiological studies conducted with elite swimmers where the training prescription often used by coaches based on the performance data is compared with the determined by specific swim protocols. The lack of available published research in this domain probably is due to the difficulty in persuading swimmers and their coaches to change their training programs following the scientific interests of researchers (Laursen & Jenkins, 2002).

Therefore, the current study aimed to analyse the relationship between the speeds obtained in usual specific incremental swim protocols (Pyne, Maw, & Goldsmith, 2000) and those prescribed by the coaches. In addition, we have evaluated how swimmers interpret the training tasks typified for training zones A1 and A2. Lastly, we have compared the physiological (blood lactate concentrations and heart rate), perceptual (the rate of perceived of exertion) and kinematical (stroke rate and stroke index) variables assessed, both in the experimental protocol and the typified tasks.

METHOD

SAMPLE

The sample consisted of 16 national and international male swimmers, specialists in 200 m or longer distances, aged 19.5 (3.6) years, 8.8 (2.3) years of training, 659 (89.1) FINA points score in the best race. Their anthropometric data was 178.48 (5.22) cm height, 67.53 (3.16) kg weight and 181.91 (8.16) cm arm span. The sample included several high-level swimmers: one bronze medal in European open water championships, one ranked twelfth in World Championships, one Olympic swimmer, one with participation in the European open water championships and three with international involvement in Junior European championships.

INSTRUMENTS

We used the Arkrey Pro Test Strips and a Lactate Pro LT-1710 portable lactate analyser (Arkray KDK, Kyoto, Japan) for blood lactate assessment. In the anthropometric characterization, a Slim Guide® adipometer, a SECA® scale (model 770, with 100 g accuracy, Bradford, USA), a Bodymeter® brand portable stadiometer (model 208, with an accuracy of 0.1mm, Hamburg, Germany) and a Hoechstmass Rollfix® tape measure (accurate to 0.1mm, GMBH, Germany) were used. Heart rate was monitored using a Polar® S810 series heart rate monitor configured for beat-to-beat (RR) collection (Kimpele, Finland). Rate of perceived exertion was performed using the Borg Cr-10 scale (Borg & Borg, 2001). Swimming times and stroke rate were controlled with Seiko® stopwatches (Tokyo, Japan) with a base 3 function. SI was calculated by v2 · SR-1.

PROCEDURES

The current study took place between the second and fourth training microcycles of the second macrocycle of a training season.

The study design accords with the timeline present in figure 1. Protocol A aimed to determine the speeds and corresponding values of blood lactate concentrations, heart rate, stroke rate, stroke index and rate of perceived of exertion corresponding to the A1 and A2 intensity zones (adapted from Pyne et al., 2000). It consisted of 7 x 200m front crawl, with increasing intensity, starting each repetition always at every 5min. In the initial 200m step, the target time was 35s more than the personal best of each swimmer, being subtracted 5s for each subsequent repetition. The seventh repetition was split at 4 x 50m (with a 10s pause) to ensure an approximate speed to the personal record (cf. Pelayo, Sidney, Kherif, Chollet, & Tourny, 1996).

Immediately after each 200m step, a capillary blood sample was taken from the finger pulp to assess lactate concentration. At the end of the protocol, samples were taken at the first, third, fifth and seventh min or until the value found showed a tendency to decrease (Keskinen, Keskinen, & Mero, 1996). The profile of each lactate curve was calculated using an excel macro Lactate-E (Newell et al., 2007) based on a grade 3 polynomial regression model (Newell et al., 2007; Rama, 2009). The intensity corresponding to A1 was identified by the 1 mmol/l increase in lactate accumulation relative to resting lactate concentrations (Thoden, MacDougall, & Wilson; 1991) and the intensity of A2 was found through D-max (Cheng et al., 1992) method. HR was monitored through a Polar Rs800Cx heart rate monitor (Keskinen, Keskinen, & Poyhonen, 2010).

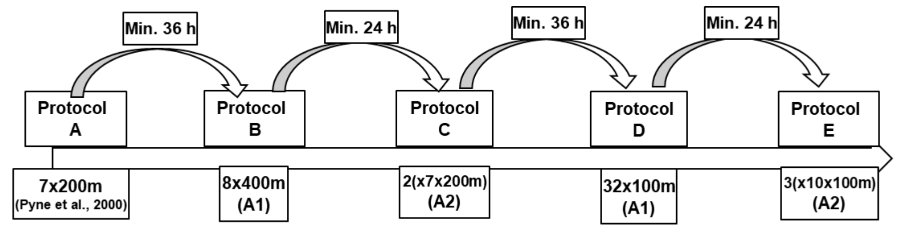

FIGURE 1. Chronological protocols sequence

The other experimental protocols were also conducted using the front crawl technique, as follows: (a) protocol B (task 1) consisted of 8 x 400m 70%, 30s rest (A1); (b) protocol C (task 2) comprised 2 x (7 x 200m 80%, 30s rest) with 3 min intervals between series (A2); (c) protocol D (task 3) consisted of 32 x 100m 65%, 10s rest (A1); and (d) protocol E (task 4) comprised 3 x (10 x 100m 75%, 15s rest) with 3 min intervals between series (A2). In these protocols, each swimmer's performance times were prescribed and controlled manually by the respective coaches, who did not have access to protocol A information.

The blood lactate concentrations values were determined as previously described, immediately after each protocol (and at the third and fifth mins or until the values showed a tendency to regress). The blood lactate control at the C and E protocols was done immediately after the last repetition of each series. Heart rate was monitored for protocols B and D midway and immediately after the end of each task, and for protocols C and E immediately after the end of each series. To determine the rate of perceived of exertion, swimmers identified the perceived effort at the end of each task for protocols B and D, and protocols C and E after the end of each series, using a table with the Borg scale (Borg & Borg, 2001). Stroke rate was controlled by recording three complete stroke cycles performed in the last 15m of every 100m.

The current study was approved by the local ethics committee and was performed according to the Declaration of Helsinki.

STATISTICAL ANALYSIS

The normality and homogeneity of the distribution of the data was verified by the Shapiro–Wilk's and Levenne tests respectively. Mean (*SD*) were calculated for all the variables. We used the Wilcoxon and the Friedman tests to compare paired samples and repeated measures (respectively). For all statistical analyses performed, the degree of significance was defined as $p \leq .05$. In cases where a significant difference was observed, the effect size was determined according to Cohen (1992): small (0.2-0.59), moderate (0.6-1.19), high (> 1.20). All statistical procedures were performed using SPSS 20 and Graphpad (Prisma 7) software for Mac.

RESULTS

Data presented in table 1 shows that the speeds corresponding to the lactic threshold intensity (A1) prescribed by the coaches for both 8 x 400m and 32 x 100m were lower than the speed estimated by the protocol A (with a medium and small ES, respectively). In addition, coaches prescribed a higher speed for the 32 x 100m compared to 8 x 400m (with a small effect size). It should be noted that at A1 intensity, there are no differences between the speed prescribed by the coaches and those performed by the swimmers who fully complied with the instructions in both tasks. Still regarding A1, the blood lactate concentrations and the rate of perceived of exertion values determined from protocol A were higher – 2.35 (0.54) and 3.,25 (0.86) respectively than those obtained in the training tasks 2 and 4, 1.50 (0.64), 2.56 (0.96) and 1.29 (0.35), 2.25 (0.78). Regarding the blood lactate concentrations, the differences between protocol A and the 8 x 400m presented a medium effect size, while when compared to the 32 x 100m, we found a higher effect size. Regarding the rate of perceived of exertion, the differences between protocol A and the 8 x 400m showed a small and a medium effect sizes when compared to the 32 x 100m tasks.

TABLE 1. Mean and standard deviation A1 data: A - 7x200 front crawl incremental protocol (adapted from Pyne et al. 2000), B - speed prescribed by coaches for task 1 (T1) 8 x 400m, C - speed performed by swimmers in T1, D - speed prescribedby coaches for task 3 (T3) 32 x 100m, E - speed performed by the swimmers in T3.

	A	B	C	D	E	*p*	EFFECT SIZE (COHEN'S *d*)	
	INCREMENTAL PROTOCOL	T1 PRESCR	T1 PERF	T3 PRESCR	T3 PERF			
V (m.s^{-1})	1.43 (0.07)	1.35 (0.06)	1.36 (0.05)	1.38 (0.05)	1.39 (0.03)	< .001 A-B < .001 A-D and B-D	0.87 0.59 0.53	medium small small
BLa (mmol.L^{-1})	2.35 (0.54)	---	1.50 (0.64)	---	1.29 (0.35)	< .001 A-C <.001 A-E	1.02 1.68	medium large
HR (b.min^{-1})	147 (7.04)	---	142 (18.9)	---	120 (60.3)	---	0.86 0.54	medium small
RPE (CR-10)	3.25 (0.86)	---	2.56 (0.96)	---	2.25 (0.78)	< .01 A-E < .05 A-C		
SR (cycles.min^{-1})	31.1 (2.81)	---	30.1 (6.45)	---	29.0 (2.55)	---		
SI (m2.c-1.s^{-1})	4.01 (0.47)	---	3.82 (0.66)	---	4.04 (0.46)	---		

Speed (V), blood lactate concentrations (BLa), heart rate (HR), rate of perceived exertion (RPE), stroke rate (SR) and stroke index (SI)l, prescribed (PRESCR), performed (PERF)

Table 2 presents the data for A2 intensity level.

TABLE 2. Mean and standard deviation A2 data: A - 7x200 front crawl incremental protocol (adapted from Pyne et al. 2000), B - speed prescribed by coaches for task 2 (T2) 2 x (7 x 200) m, C - speed performed by swimmers in T2 first set, D - speed performed by swimmers in T2 second set, E - speed prescribed by coaches for task 4 (T4) 3 x (10 x 100 m), F - speed performed by swimmers in T4 first set, G - speed performed by swimmers in T4 second set and H - speed performed by swimmers in T4 third set.

	A	B	C	D	E	F	G	H	p	EFFECT SIZE (COHEN'S d)	
	INCREMENTAL PROTOCOL	T2 PRESCRIBED	T2 FIRST SET PERFORMED	T2 SECOND SET PERFORMED	T4 PRESCRIBED	T4 FIRST SET PERFORMED	T4 SECOND SET PERFORMED	T4 THIRD SET PERFORMED			
V (m.s-1)	1.50 (0.06)	1.47 (0.05)	1.47 (0.04)	1.48 (0.04)	1.49 (0.05)	1.47 (0.05)	1.49 (0.05)	1.49 (0.05)	< .05 A-B, A-C, A-D, A-F, B-D, C-D, F-G and F-H	[0.16-0.42]	small
BLa (mmol.L-1)	3.56 (0.53)	---	3.39 (2.07)	3.98 (2.65)	---	2.56 (1.00)	2.46 (1.61)	2.99 (1.84)	< .01 A-G < .05 A-F	0.73 0.92	medium medium
HR (b.min-1)	161 (7.96)	---	165 (12.6)	165 (12.0)	---	166 (12.0)	169 (11.9)	173 (11.3)	< .001 A-H < .01 F-H	0.88 0.43	medium small
RPE (CR-10)	4.69 (0.95)	---	4.94 (1.24)	5.19 (1.16)	---	4.31 (0.95)	4.69 (1.20)	5.13 (1.67)			
SR (cycles.min-1)	33.2 (2.41)	---	32.0 (3.00)	32.5 (2.58)	---	33.0 (3.00)	33.6 (2.90)	34.3 (2.70)	< .05 F-H	0.32	small
SI (m2.c-1.s-1)	4.07 (0.41)	---	4.09 (0.48)	4.06 (0.45)	---	3.98 (0.52)	3.97 (0.48)	3.92 (0.49)			

Speed (V), blood lactate concentrations (BLa), heart rate (HR), rate of perceived exertion (RPE),stroke rate (SR) and stroke index (SI).

Differences were found between the speed estimate by protocol A and the 2 x (7 x 200m 80%, 30s rest) prescribed by the coaches. In this task, differences in the speed were found comparing the first and second sets. The speed of the first set is in accordance with the prescribed by the coaches, while in the second set a higher speed was observed than prescribed. In both comparisons, a small ES was observed. Between protocol A and 2 x (7 x 200m 80%, 30s rest) no differences were found for the remaining variables: blood lactate concentrations, heart rate, rate of perceived exertion, stroke rate and swimming index. No differences were found in speed between protocol A and the coaches' prescription for the 3 x (10 x 100m). However, in the first set of this task, the swimmers performed at a lower speed than the one determined in the protocol A; of course, the first set was held at a slower speed when compared to the second and third sets, in which the swimmers achieved the prescribed speed. In turn, in the first and second sets of tasks 3 x (10 x 100 m), the lactate concentration was, respectively, 2.56 (1.00) and 2.46 (1.61), that is lower than that was found in the incremental protocol – 3.56 (0.53).

DISCUSSION

The current study showed that, globally, coaches prescribe swimming aerobic tasks with lower demand than those estimated from a specific evaluation protocol (A). The exception was found in 3 x (10 x 100m) for A2 training intensity, in which coaches prescribe speeds similar to those obtained with the referred protocol. However, if we compare the speed determined by the coaches with the prescriptive methodology proposed by swimming reference authors (e.g., Sweetenham & Atkinson, 2003), we find a remarkable coincidence of values. When comparing the heart rate values of the present study with those proposed by Sweetenham and Atkinson (2003), we found similar values in A1 and slightly higher in both A2 tasks. When comparing the current study heart rate data with those proposed by another author (Maglischo, 2003), we found an absolute coincidence of these values depending on the prescribed speed.

Regarding the blood lactate concentrations, all the values of the present study and those referenced by Maglischo (2003) are confirmed to be equivalent in A1. Interestingly in A2, when speed was correctly prescribed (3 x 10 x 100m), the values of this variable were lower than those proposed by the same author (3-7 mmol/l). In the task (2 x 7 x 200m), where the prescribed speed was lower than that determined in protocol A, the blood lactate concentrations presented values like those proposed by Maglischo (2003). Regarding rate of perceived of exertion, and although different scales were used, the values found in the current study is coincided with those proposed by Maglischo (2003) for both aerobic intensity zones. Thus, the prescriptions made by coaches fit the models proposed by referenced authors (Maglischo, 2003; Sweetenham & Atkinson, 2003), but the values determined by the 7 x 200m protocol, in most cases, point to a higher speed than those prescribed by the coaches in A1 and A2 intensity zones, except for the 3 x (10 x 100m) task.

In endurance sports like swimming a basic endurance-built form with high training volumes may be a central requirement to promote a positive response to a significant increase in training intensity (Seiler, 2012). Under ideal circumstances, training development will translate into maximal physiological adjustments and optimal performance potential. Lowering the stimulus in the training program may result in unwanted situations such as underperformance (Mujika, Halson, Burke, Balagué, & Farrow 2018). Some authors proposed that 70 to 80% of the swimming training volume should be performed at a speed corresponding to A1 (Maglischo, 2003; Seiller, 2010). Supposing that the speed prescribed by the coaches is lower than those determined from a specific swimming evaluation protocol, in that case, this could mean that 70-80% of the training volume of the swimmers in the sample will be performed at speed lower than desired, which may have negative implications on adaptive processes and, consequently, eventual repercussions on competitive results.

In most situations, swimmers correctly interpreted the speed prescribed by the coaches. However, in the second set of the 2 x (7 x 200m), in A2, the speed performed by the swimmers was higher than the speed established by the coaches, still lower than that determined by the protocol. Interestingly, in the only situation in which the coaches prescribed in line with the values determined by protocol A, the swimmers did not fully perform the task as defined but were slower in the first set of the task 3 x (10 x 100m), where they might have opted for an energy-saving strategy for the two subsequent series that were met at the defined speed (TABLE 2). That is, in the only situation assessed where the intensity was prescribed according to data from the specific protocol, the swimmers did not fully correspond to the request. If this situation is repeated systematically in the training process, it will reduce by about one third the expected volume for this intensity zone.

Bentley et al. (2005), evaluating eight national level swimmers (aged 18.4   1.8 years), compared two training tasks (16 x 100 and 4 x 400m) of similar maximal oxygen uptake intensities (1.42   0.06m·s-1) and with intervals proportional to the base distance. No differences were found between these tasks in speed, oxygen uptake, blood lactate concentrations, heart rate and rate of perceived of exertion. Complementarily, the biomechanical data is similar to the present study except for the third set of the 3 x (10 x 100m), where the heart rate and stroke rate values were higher, as well as the speed values in the comparison between the first and second sets, despite the remaining variables showed no differences.

In a study by Barroso, Salgueiro, Carmo, and Nakamura (2015), with regional level swimmers, for tasks corresponding to the critical speed, the responsible coach assigned (on the Borg CR-10 scale) rate of perceived of exertion level 3 to the 10 x 100m task and level 4 to the 20 x 100m task, which coincided with the values selected by swimmers. In the same study, in tasks 20 x 100m, 10 x 200m and 5 x 400m, for a rate of perceived of exertion the coach assigned levels 4, 5 and 6, respectively. In the last two tasks the values reported by swimmers were significantly lower than those prescribed by coaches. The results of the study by Barroso et al. (2015) have similarities with the present study for similar intensities (critical speed is close to A2 intensity) given that, for base distances of 100 m - protocol E, 3 x (10 x 100m) - the coaches prescribed the intensity appropriately, in accordance with the values found in the 7 x 200m incremental protocol (TABLE 2). In turn, when the repeated distance was 200m – protocol C, 2 x (7 x 200m) - the intensity prescribed by the coaches was lower than that defined by the incremental protocol (TABLE 2). This situation had already been found in the prescription of tasks in A1, where there were differences in the intensity prescribed between 8 x 400m and 32 x 100m (TABLE 1).

Also, in a study by Wallace, Coutts, Bell, Simpson, and Slattery (2008), with 12 national level swimmers and two coaches, the coaches' rate of perceived exertion values was higher than those of swimmers in high intensity training tasks and the opposite being true at low intensities. Thus, we can infer that, in the prescription of interval training in predominantly aerobic zones, an increase in the base distance seems to be considered as an increase in the load by the coaches. This fact seems to be confirmed by Dekerle, Brickley, Alberty, and Pelayo (2010), in a study with swimmers performing at speeds corresponding to the slope of the distance-time curve in a continuous test until exhaustion, the rate of perceived exertion values increased between the 10th min and the conclusion of the trial, respectively, 5.8 (1.1) and 7.6 (1.3) on the Borg Cr-10 scale. The same happened with the values of blood lactate concentrations, for the same period, with increases from 7.0 (3.1) and 8.4 (3.3). In the same study, in the continuous test at speeds corresponding to the slope of the distance-time curve, the time to exhaustion was 24.3 (7.7) min while the 10 x 400m (40s rest) at the same intensity - total ~50 min -, was accomplished with a metabolic balance of the blood lactate concentrations, despite the referred increments of the rate of perceived exertion. Still in the referred study in the 10 x 400m task (40s rest), differences in the rate of perceived exertion were also found between the first and sixth, seventh, eighth, ninth and tenth repetitions, where the average of the first repetition stood at 3.3 and the 10th at 6.9. However, the values of blood lactate concentrations remained stable (Dekerle et al., 2010).

Regarding the observed values of rate of perceived exertion for the intensity corresponding to A2 in the present study, no differences were found between the values of protocol A and those corresponding to the two different tasks. However, the speed was higher in the task where each repetition distance was shorter – 3 x (10 x 100m) - which is in line with the results of Barroso et al. (2015) where the rate of perceived of exertion values, identified by the coaches, were higher at longer base distances (despite speed remaining unchanged). Regarding the evaluated biomechanical variables, for the four tasks evaluated, there were only differences in the stroke rate between the first and the third series of the task 3 x (10 x 100m), with a small effect size, which may be the reason for a corresponding increase in the speed between these sets, with a small effect size (TABLE 2). In consequence, we suggest that coaches should pay careful attention to the aerobic endurance interval training task, avoiding the apparent trend to prescribe lower intensities than the swimmers might perform, especially when the repetition distances are longer.

CONCLUSIONS

The current data allowed us to conclude that coaches tend to prescribe lower speeds than those defined through a specific swimming incremental evaluation protocol. Swimmers, in most situations, comply with the intensities prescribed by the coaches. However, in an A1 task, the swimmers performed speeds faster than prescribed but slower than that defined in the incremental protocol.

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