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Research Article

CHANGES IN CRITICAL VELOCITY AND CRITICAL STROKE RATE DURING A 12 WEEK SWIMMING TRAINING PERIOD: A CASE STUDY

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ABSTRACT

The aim of this study was to analyse the evolution of critical velocity and critical stroke rate during 12 weeks of training in age group swimmers. Fourteen age group male swimmers took part in this investigation. The evaluation took place in two different trials. The first one was conducted at the beginning of the season and the second one after 12 weeks of training. For each subject the critical velocity and the critical stroke rate were determined in both trials. The main result was that critical velocity increased, whereas critical stroke rate decreased between the first and second trials. It seems that technical ability was improved during the 12 weeks of training. The swimmers were able to perform at the same physiological intensity at higher velocities and with less stroke rate. This information could help swimming coaches monitoring their training without expensive instruments.

Key words: Training, Age group swimmers, aerobic capacity, Technique.

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INTRODUCTION

The concept of critical velocity was introduced and adapted for swimming by Wakayoshi et al. (1992), from the original concept of critical power propounded by Monod and Scherrer (1965). Critical velocity was defined as the maximum swim speed that can be maintained during a long period of time without exhaustion (Wakayoshi et al., 1992). Besides the concept of critical velocity which is frequently used by coaches as a method to determine the intensity of swimmers' aerobic capacity, Pelayo et al. (2000) were pioneers in hypothesising the existence of a theoretical stroke rate that could be maintained without exhaustion during a long period of time, defined as critical stroke rate.

Maclaren and Coulson (1999) reported that aerobic training has a positive effect on critical velocity. These authors reported an increase and steady state in critical velocity after an 8 week aerobic training and a 3 week anaerobic training period, respectively. Several studies have illustrated the hyperbolic stroke rate – velocity curve (Dekerle et al., 2005; Wakayoshi et al., 1993a). In fact, when attempting to swim faster, a swimmer will increase his stroke rate. This specific increase will be detrimental to the stroke length above a given sub-maximal intensity (Nomura and Shimoyama, 2002). Consequently, the longer the race is, the lower the speed, and the lower the stroke rate will be. Dekerle et al. (2002) suggested that the stroke rate – time relationship could be modelled using a simple linear regression method. Indeed, critical stroke rate is also represented by the slope of the "number of stroke cycles" – time relationship (Dekerle et al., 2002). One can note that the assessment of critical stroke rate does not require extra-tests to be performed compared to the critical velocity determination. It relies on the record of the stroke rate of each performance. Dekerle et al. (2002) reported a regression line coefficient of 0.99-1.0 when modelling the number of stroke cycles – time relationship. Moreover, Dekerle et al. (2002) found that critical stroke rate was not significantly different and was highly correlated to the mean stroke rate of a 30 min test. Additionally, when swimming at the critical velocity, the subjects spontaneously adopted stroke rate values similar to critical stroke rate and when having to swim at the imposed critical stroke rate, participants swam at the critical velocity. Nevertheless, the number of studies on this thematic of critical stroke rate are very few, specifically in young swimmers (Pelayo et al., 2000; Dekerle et al., 2002). More studies are necessary that incorporate data from training, biomechanics, motor control and physiology in competitive swimmers (Dekerle, 2006).

It seems that critical velocity and critical stroke rate are associated with aerobic performance. However, these two variables are not always linked together during training. On this, it is unclear whether an improvement of the aerobic capacity (e.g. critical velocity) is dependent on bioenergetical and/or biomechanical enhancement (technical efficiency). Therefore, the aim of this study was to analyse the changes of critical velocity and critical stroke rate during 12 weeks of training in a group of young competitive swimmers.

METHODS
Sample

Fourteen age group male swimmers took part in this study. All belonged to a representative Portuguese swimming team. The mean age, height, weight and years of competitive practice were: 13.60 ± 0.21 years old, 1.60 ± 0.10 m, 49.07 ± 13.69 kg, and 4.43 ± 0.51 years, respectively. The participants' parents provided their written informed consent and the procedures were approved by the institutional review board.

Procedures
The evaluations took place in two different trials. The first one was conducted at the beginning of the season (during the first week of October) and the second one after 12 weeks of training (during the last week of December). During this period the subjects performed 70 training units, corresponding to a mean value of 5.83 ± 0.72 training units per week. The swimmers performed 258 km, corresponding to a mean value of 21.50 ± 4.12 km per week and 3.70 ± 0.60 km per training unit. They performed 23.40 km (intensity corresponding to their critical velocity: 2.60 ± 1.02 km per week) and 8.0 km (intensity corresponding to their aerobic power: 1.60 ± 0.28 km per week). The remaining training comprised low aerobic tasks, technical and velocity training. Dry-land training consisted in two sessions per week of 20 minutes of overall physical condition (abs, push ups, spinal erector, and stretching).

For each subject the critical velocity and the critical stroke rate were determined in both trials. All swimmers performed two maximal tests in front crawl: 50 m and 400 m. Before the tests, each swimmer performed the same warm-up protocol. The 50 m and the 400 m tests took place with two days interval, starting with the 50 m test. The evaluation process was conducted in a 25 m indoor swimming pool. In both tests in-water starts were used (Fernandes and Vilas-Boas, 1999).

Critical velocity was assessed considering the slope of the distance-time relationship (50 m and 400 m), plotting the swimming performance over time (Figure 1) (Wakayoshi et al., 1992). Critical stroke rate was determined using the slope of the number of stroke cycles-time relationship (50 m and 400 m) (Figure 2). During each test the number of stroke cycles over each 25 m was measured (Marinho et al., 2006).

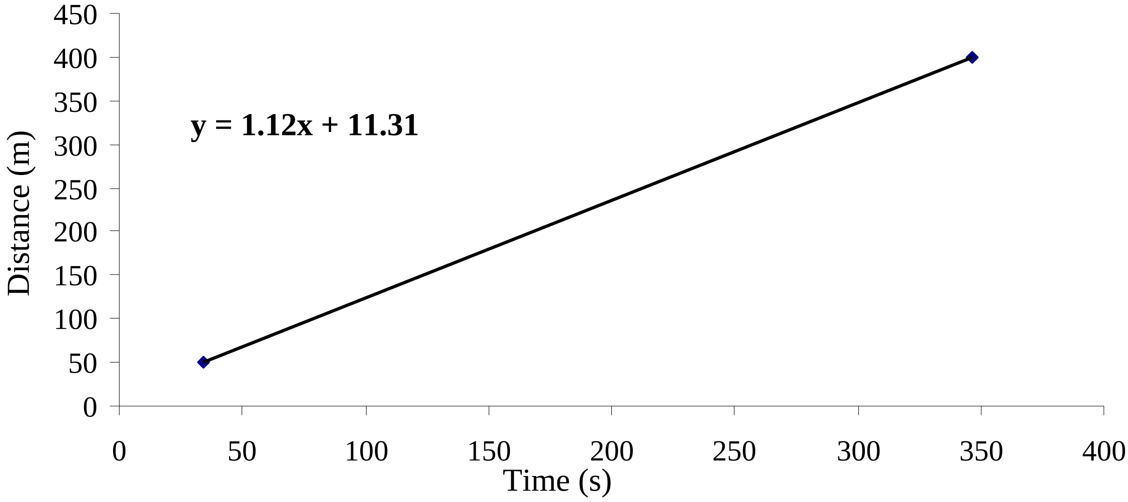

***Figure 1**. An example of the assessment of critical velocity for one swimmer of the sample (critical velocity = 1.12 m/s). The regression equation between the distance and the event time is also presented.*

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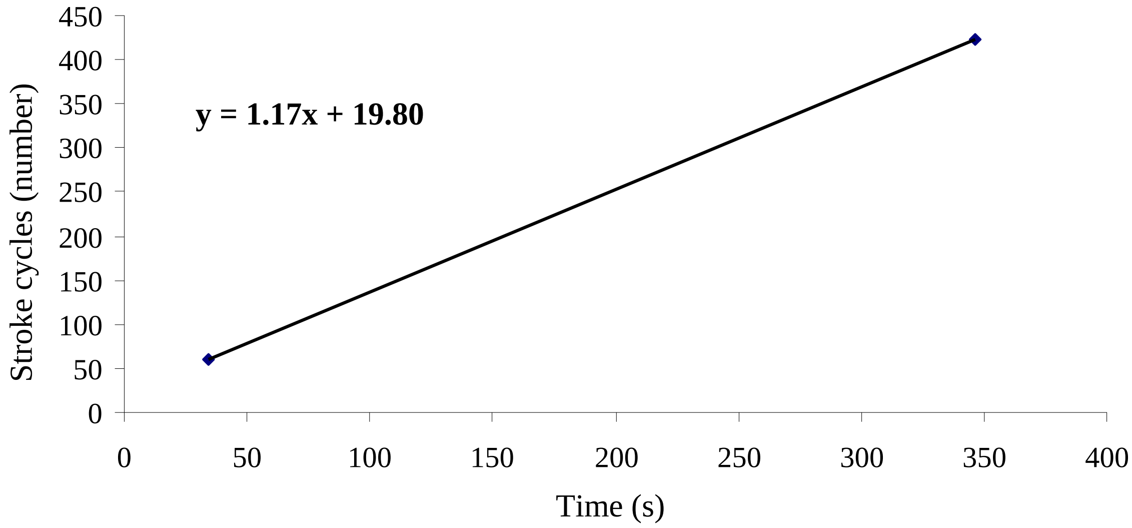

***Figure 2**. An example of the assessment of critical stroke rate for one swimmer of the sample (critical stroke rate = 1.17 cycles/s). The regression equation between the number of stroke cycles and the event time is also presented.*

Statistics

Mean and standard deviations were calculated for all variables. All data were checked for distribution normality with the Shapiro-Wilks test. Pearson correlation coefficient and paired sample and independent student t tests were also applied. The statistical significance was set to $p \leq 0.05$ for all analysis. Data was also divided into two groups, considering the value of critical velocity assessed in the first evaluation. Group 1 corresponded to the seven swimmers who presented the highest values of critical velocity and group 2 corresponded to the seven swimmers who presented the lowest values of critical velocity.

RESULTS

Table 1 shows the mean values of the 50 m and 400 m front crawl for each trial. The present study showed significant increments in swimming performance. These values served to determine the critical velocity and recording the number of stroke cycles of each performance allowed determination of the critical stroke rate (Table 2). One can note that critical velocity increased, whereas critical stroke rate decreased between the first and second trials.

***Table 1**. Mean ± SD values of the 50 m and 400 m front crawl tests in the first and second trial.*

Tests	Evaluation	Mean ± SD	p value
50 m front crawl (s)	1st trial	36.60 ± 4.40	**0.00***
	2nd trial	34.44 ± 3.40	
400 m front crawl (s)	1st trial	367.14 ± 33.21	**0.00***
	2nd trial	353.79 ± 32.80	

** p≤0.05*

Table 2. *Mean ± SD values of the critical velocity and critical stroke rate in the first and second trial.*

Tests	**Evaluation**	**Mean ± SD**	**p value**
Critical velocity (m/s)	1st trial	1.07 ± 0.09	**0.01***
	2nd trial	1.10 ± 0.10	
Critical stroke rate (cycles/s)	1st trial	1.10 ± 0.09	**0.02***
	2nd trial	1.05 ± 0.08	

** p≤0.05*

Additionally, no significant relationship was observed between critical velocity and critical stroke rate in both trials (trial 1: r = 0.04, p = 0.89; and trial 2: r = -0.28, p = 0.34). However, when we divided the sample according to critical velocity value, within the slowest group a significant relationship between critical velocity and critical stroke rate was noted (trial 1: r = 0.766, p = 0.05; trial 2: r = 0.860, p = 0.01). Within the second group no relationship was observed between these two parameters (trial 1: r = 0.16, p = 0.74; trial 2: r = -0.21, p = 0.15).

Figures 3 and 4 showed the differences between group 1 and group 2 for each trial. It is important to emphasize that the seven best swimmers (concerning critical velocity) in the first trail were the same when the second evaluation was conducted. Significant differences were obtained regarding critical velocity and 50 m and 400 m tests. No differences in critical stroke rate were observed.

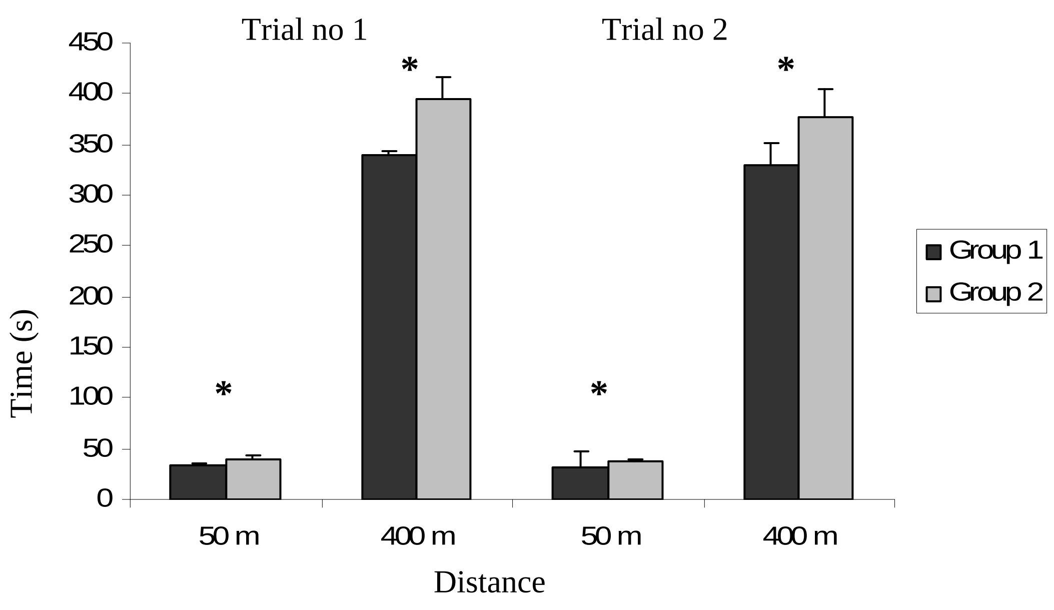

Figure 3. *Comparison between groups 1 and 2 concerning the 50 m and 400 m front crawl tests in the first and second trials. Group 1 corresponds to the 7 swimmers who presented the highest critical velocity in the first evaluation and group 2 corresponds to the 7 swimmers who presented the lowest critical velocity in the first evaluation.* p≤0.05.*

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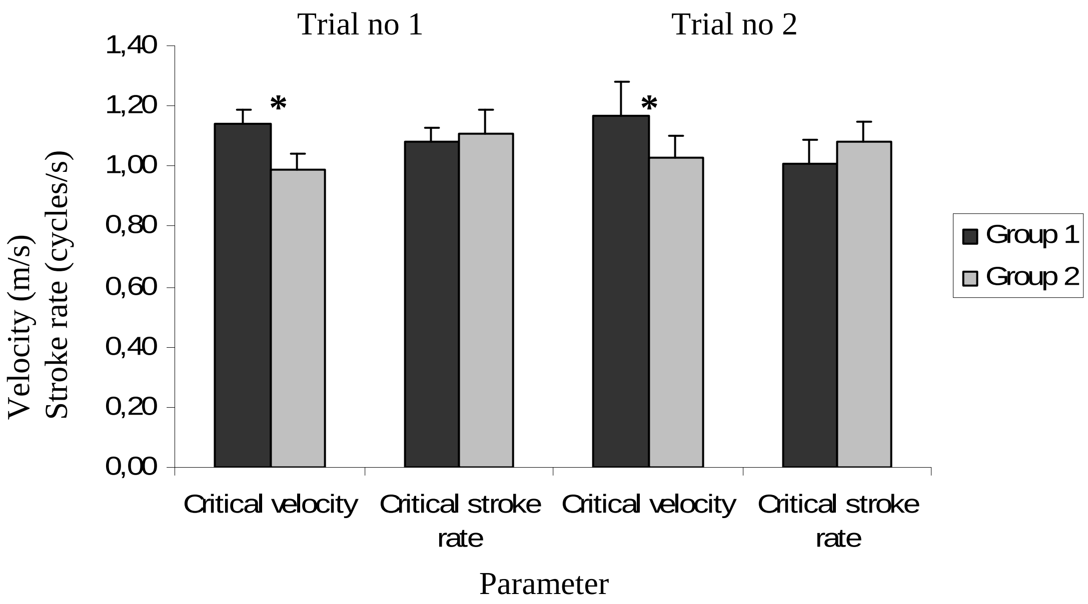

Figure 4. *Comparison between groups 1 and 2 concerning critical velocity and critical stroke rate in the first and second trials. Group 1 corresponds to the 7 swimmers who presented the highest critical velocity in the first evaluation and group 2 corresponds to the 7 swimmers who presented the lowest critical velocity in the first evaluation.* p≤0.05.*

Nevertheless, the performance in 50 m and 400 m tests and the value of critical velocity increased in both groups (Figures 5 and 6) but the value of critical stroke rate increased only in group 1.

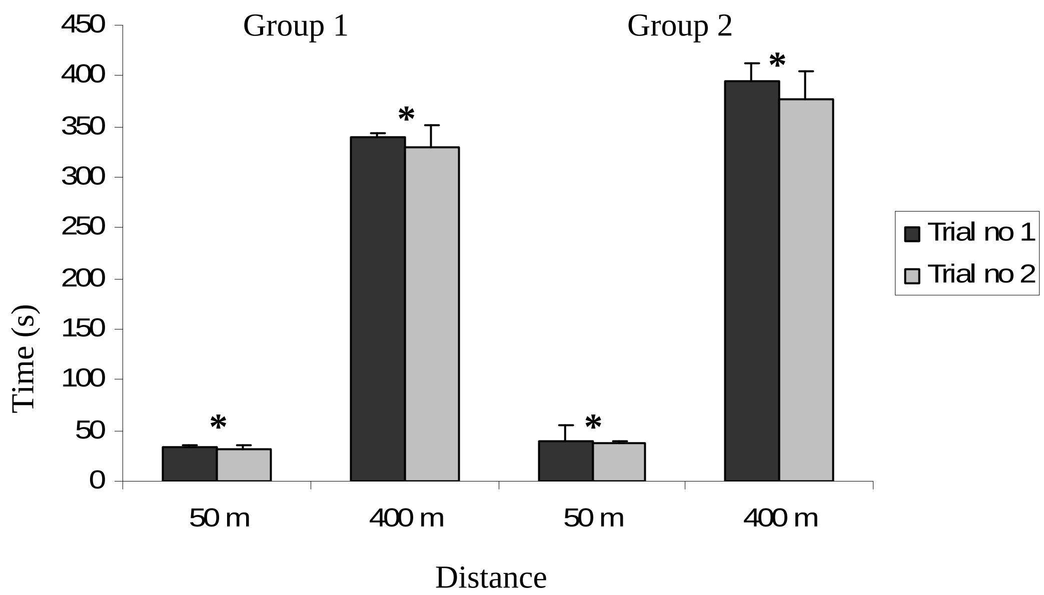

Figure 5. *Comparison between the first and second trials concerning the 50 m and 400 m front crawl tests in groups 1 and 2. Group 1 corresponds to the 7 swimmers who presented the highest critical velocity in the first evaluation and group 2 corresponds to the 7 swimmers who presented the lowest critical velocity in the first evaluation.* p≤0.05.*

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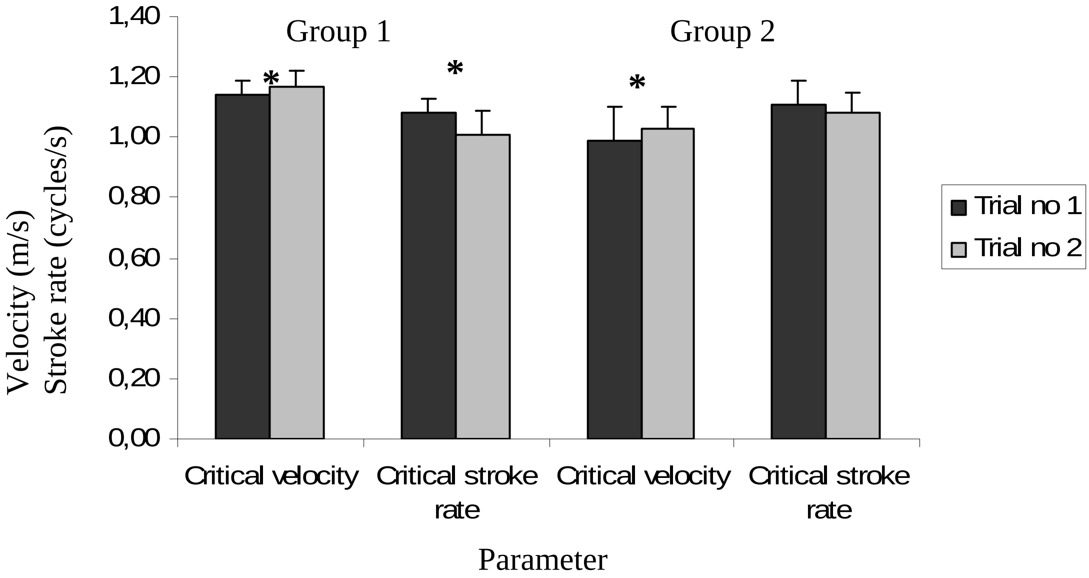

***Figure 6**. Comparison between the first and second trials concerning critical velocity and critical stroke rate in groups 1 and 2. Group 1 corresponds to the 7 swimmers who presented the highest critical velocity in the first evaluation and group 2 corresponds to the 7 swimmers who presented the lowest critical velocity in the first evaluation.* $p \leq 0.05$.*

DISCUSSION

The aim of this study was to analyse the changes of critical velocity and critical stroke rate during 12 weeks of training in age group swimmers. The main finding of this study was that critical velocity and critical stroke rate increased after 12 weeks of training in a sample of young competitive swimmers.

As expected, after 12 weeks of training the swimmers increased their aerobic capacity. The same results were reported by other researchers (e.g. Wakayoshi et al., 1993b; Maclaren and Coulson, 1999). However, the cause of this improvement in aerobic capacity is not always clear. It is difficult for coaches to understand if an increase in aerobic capacity is due to physiological responses and/or technical improvements. In fact, the same test used to assess critical velocity could be used to determine critical stroke rate. The coach just needs to count the number of stroke cycles of each swimmer during the tests to discover his critical stroke rate.

Swimmers not only increased their critical velocity (p=0.01) but also decreased their critical stroke rate (p=0.02). One can speculate that their technical ability was improved during the 12 weeks of training. In fact, the swimmers can perform at the same physiological intensity at higher velocities and with lower stroke rate. This interesting result could help swimming coaches to monitor training without expensive instruments. Wakayoshi et al. (1993b) reported a similar tendency after six months of aerobic swim training. Although there was no significant increase in stroke rate, six of seven subjects increased their maximal aerobic velocity due to increases in stroke length. Further, mean stroke length after the training protocol was significantly higher.

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Moreover, it was interesting to note that this tendency was not the same in both groups. Within the swimmers having higher values of critical velocity (group 1) both critical velocity and critical stroke rate increased between the first and second trial. Although critical velocity increased, critical stroke rate did not improve between trials for group 2. Group 1 improved their performance associated with a significant improvement in technical ability, whereas group 2 improved their performance without significant improvements in technical ability. The authors did not find differences in critical stroke rate between the two groups in both evaluations; however, the changes in this parameter seemed to be an important component to performance improvement. The findings of the present study can be useful in designing effective training programs based on intermittent exercises (Renoux, 2001). Coaches could use critical velocity combined with the analysis of the stroke rate parameters. This would allow them to set not only the aerobic training load but also to control stroke technique during swimming training (Clipet et al., 2003). According to Marinho et al. (2006), swimmers may swim an aerobic training set using a specific and controlled individual stroke rate to cover each length.

In summary, we can state that after 12 weeks of training, critical velocity of a group of young swimmers increased and critical stroke rate decreased. It seems that technical ability was improved during the 12 weeks of training. The swimmers were able to perform at the same physiological intensity at higher velocities and with lower stroke rate. This information could help swimming coaches monitoring training without expensive instruments.

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