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Physiological differences and rating of perceived exertion (RPE) in professional, amateur and young cyclists

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Background. **The aim of this study is to measure and compare the physiological characteristics and the rating of perceived exertion (RPE) in 72 high level road cyclists of 3 different categories.**
Methods. **These cyclists were divided in 3 groups according to their age (24 professionals, mean age 26 years, 22 amateurs, 22 years and 26 juniors, 18 years). Measures: they carried out a progressive test to exhaustion in a specific cycloergometer, starting with a power output of 100 watts and increasing 50 watts each 4 min. $\dot{V}O_2$ was measured continuously. At the end of each one of the 4 min steps the subject was asked about his RPE using the 6-20 Borg's scale.**
Results. **Professional cyclists showed a $\dot{V}O_{2max}$, $\dot{V}O_2 \cdot kg^{-1}$ and a maximum power output significant higher than other groups, while there were no significant differences between amateurs and juniors. $\dot{V}O_2$ and RPE were significantly different, in all the categories, during high work loads. No significant differences were found between RPE and %$\dot{V}O_{2max}$. RPE and heart rate (HR) were significantly different between professionals and juniors. RPE and %HR max were significantly different with low loads, but no with high loads. In the same way, RPE/w and RPE/($w \cdot kg^{-1}$) were significantly different in all categories.**
Conclusions. **We conclude that professional road cyclists reached a $\dot{V}O_{2max}$, $\dot{V}O_{2max} \cdot kg^{-1}$ and a maximum power higher than the other categories; so, therefore, these parameters are good as performance indicators, and RPE is of practical value to prescribe exercise training intensities in each category.**

KEY WORDS: Exercise - Oxygen consumption - Heart rate - Bicycling.

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Road cycling has been classified as a physiologically demanding endurance sport, mainly because of the exercise time which is required in some of the stages.[1] The maximal oxygen uptake ($\dot{V}O_{2max}$) is usually related to sports performance in endurance exercises.

Thus, cyclists reach values which range between 65 and 80 $ml \cdot kg^{-1} \cdot min^{-1}$.[1-5]

In the 1960's Borg suggested that the RPE could be employed as a measure of the intensity of physical activity,[6] due to the fact that this represents the integration of several factors, both central (cardiopulmonary system, oxygen uptake) and local (muscular pain, lactate concentration).

Although many studies have attempted to identify the physiological and psychological mechanisms that influence the RPE, these currently remain unclear from all points of view.[7] However, a good correlation exists between the RPE and different physiological variables, such as the percentage of $\dot{V}O_{2max}$, blood lactate, anaerobic threshold and heart rate (HR),[8-11] in trained and untrained subjects.[12] For this reason the subjective perception of exertion has been used as the scale, which evaluates the intensity of dynamic exercise in treadmill,[13-15] rowing,[16] swimming [11] and cycling.[17] Similarly, the various studies which relate blood lactate and the subjective perception of exertion [12, 18, 19] demonstrate that the RPE is a valid parameter for the prescription of exercise intensity, and is as such useful for the indication of physical exercise in different population groups,[17-20] and, an element which permits the evaluation of the development of training.[12]

Very little data exists on the physiological parameters of elite cyclists and the RPE has not been evaluated in this group of athletes; moreover no studies exist related to these parameters in different levels of training. For this reason, we attempt here to know if the are any differences in the parameters usually measured in an exertion test in cyclists of different ages and competition levels, and whether differences exist in the perception of exertion on the bicycle ergometer between professional, amateur and young cyclists. The aim of this study is therefore: 1) to describe and compare the physiological parameters in 3 groups of elite cyclists of different ages; 2) to examine the relationship between the RPE and the physiological parameters normally registered during exertion in order to prescribe the exercise intensity: oxygen uptake ($\dot{V}O_2$), absolute power (w), the power in relation to body weight ($w \cdot kg^{-1}$), heart rate (HR) and % of HRmax.

Materials and methods

Subjects

A group of 72 cyclists with 3 different levels of training and different ages were included in this study. All were elite cyclists: 26 junior cyclists, 22 under 23-elite category of the U.C.I. (former "amateur" category) and 24 professionals. The study protocol, previously evaluated by the Ethics Committee of University of Oviedo (Spain) was signed by all participants. Anthropometric characteristics of those taking part are shown in Table I. Among the professional cyclists were those belonging to the "First Team of the World" in the classification of the Union of International Cyclists, the first and second classified individually by this organisation. The pool also contained overall 1 to 3 weeks event winners and winners of stages of the Tour de France, Giro d'Italia and Vuelta a España. All subjects were in good health, as determined by normal physical examination, which included an ECG and blood analysis.

All subjects were familiarised with the protocol of the study prior to participation and the Borg Scale [2-4, 8, 9, 17, 18, 20-27] was explained.[6]

Experimental design

The cyclists underwent a warm-up period on the bicycle ergometer (Orion, Toulose, France) lasting 10-15 min at 85-105 rpm and at a heart rate of 120-140 beats/min. The subjects were able to see their HR on a monitor and could control the intensity of the exertion in accordance with this. After a 5-10 min rest, the test was begun at 85-105 rpm, (the pedalling cadence normally used by cyclists during training and/or competitions), which corresponds to the maximum pedalling cadence for the maximum power produced in relation to the time of exercise,[22, 26] with the maximum metabolic efficiency,[28] and which for Hull *et al.*,[25] is that which minimises in greater measure the muscular stress. Each cyclist was using his own pedalling cadence.

The progressive test was begun at a power of 100 w with a 50 w increase every 4 min until exhaustion, or even until the subject was unable to maintain the load for 15 sec at 70 rev/min. The rate of perceived exertion (RPE), the HR and the power were determined in the last 15 sec of each stage. The subjects were verbally encouraged during the last stage until reaching exhaustion. The uptake of oxygen was determined continuously during exercise by employing a breath-to-breath metabolimetre Vmax 29 (Sensor-Medics, Yorba Linda, CA). The gas analysers and the volume flow-meter were calibrated according to the manufacturer's instructions, prior to each of the tests.

The subjects completed between 6 and 9 stages until reaching maximum exertion. This was assured following the criterion of gas interchange $R>1.15$ or a "plateau" in the $\dot{V}O_2$ (the $\dot{V}O_2$ did not increase when the power of the bicycle ergometer was increased).[24] The HR was continuously monitored by telemetry using "Sport-tester PE 4.000 (Polar, Kempele, Finland) pulsemeters". A copy of Borg's 15-point scale remained on view throughout the test.

Statistical analysis

The results are expressed as the mean±SD. The maximum data reached by the 3 groups under study were compared by means of a 1 factor analysis of variance (ANOVA) and the *posthoc* test of Scheffe, for multiple comparisons. The differences among

TABLE I.—*Mean±standard deviation of the anthropometric characteristics of the study participants.*

Parameters	Participants		
	Professionals (n=24)	Amateurs (n=22)	Young cyclists (n=26)
Age (years)	26.4±4.5	21.8±3.6	18.3±0.9
Height (cm)	176.7±4.3	174.6±7.1	176.5±6.4
Weight (kg)	67.0±4.3	68.3±8.3	66.4±6.4
Total 6 skinfolds (mm)*	37.0±5.5	46.1±13.3	42.0±14.0

* Total±SD of abdominal, supra-iliac, triceps, subscapular, thigh and medial calf skinfolds.

the different RPEs for each of the levels of intensity were analysed using the statistical package SPSS-4.0. Lineal regression analysis was made between the RPE and the different data analysed. The difference for $p<0.05$ was considered as statistically significant.

Results

Characteristics of subjects

The physical and physiological and training characteristics of the cyclists are in Tables I and II.

Maximal testing data

The maximum values of $\dot{V}O_2$, $\dot{V}O_2 \cdot kg^{-1}$, maximum power (w), the power in relation to body weight ($w \cdot kg^{-1}$) and kilometers covered in 1 year are shown in Table II. Significant differences exist for the $\dot{V}O_{2max}$ between professionals (5053±445 $ml \cdot min^{-1}$) and amateurs (4584±458 $ml \cdot min^{-1}$) for a $p<0.05$, this representing a 9.28% greater maximum consumption of oxygen for professionals in comparison to amateurs. The differences between professionals and young cyclists (4368±445 $ml \cdot min^{-1}$) were also significant for a $p<0.05$.

The differences in the consumption of oxygen in relation to weight ($\dot{V}O_{2max} \cdot kg^{-1}$) were also statistically significant between professionals (75.3±4 $ml \cdot kg^{-1} \cdot min^{-1}$) and amateurs (67.5±7.5 $ml \cdot kg^{-1} \cdot min^{-1}$), which in percentages represented a $\dot{V}O_{2max} \cdot kg^{-1}$ (of 10.3%) less for amateurs. Differences between professionals and young cyclists (65.6±3.9 $ml \cdot kg^{-1} \cdot min^{-1}$) were also statistically significant. No significant differences were found between amateurs and young cyclists.

Statistically significant differences were also found for the maximum power developed (W) for professionals (424±32 W) and amateurs (371±42 W) for a $p<0.05$. This difference represents 12.4% more in professionals. The differences were also significant between professionals and young cyclists (350±50 W) for a $p<0.05$. The difference between amateurs and young cyclists was not significantly different.

TABLE II.—*Mean±SD of the physiological characteristics and kilometers covered in 1 year according to sports category.*

Parameters	Participants (n=72)		
	Professionals (n=24)	Amateurs (n=22)	Young cyclists (n=26)
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	5053±445	4584±458*	4368±445^
$VO_{2}max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	75.3±4.0	67.5±7.5*	65.5±3.9^
Power max (W)	424±32	371±42*	350±50^
Power max ($w \cdot kg^{-1}$)	6.4±0.4	5.5±0.6	5.2±0.6^
Km covered/year	30.000-35.000	15.000-18.000	11.000-13.000

*Statistically significant difference between amateurs and professionals, $p<0.05$; ^significant difference between young cyclists and professionals, $p<0.05$.

Statistically significant differences were found for the maximum power produced in relation to kg of body weight ($w \cdot kg^{-1}$) between professionals (6.4±0.4 $w \cdot kg^{-1}$) and amateurs (5.5±0.6 $w \cdot kg^{-1}$) for a $p<0.05$, which represents a difference of 14%. The differences between professionals and young cyclists (5.23±0.56 $w \cdot kg^{-1}$) were also significant for a $p<0.05$, which in terms of percentages, is 18.2% greater in professionals. The difference between amateurs and young cyclists was not significantly different.

Comparison of the physiological parameters and the RPE

The relationship between RPE and oxygen consumption ($\dot{V}O_2$) is shown in Tables III and IV. No significant differences exist among the 3 groups of cyclist at low intensities (up to 12-15 RPE), the differences begin from 16 RPE between professionals and young cyclists and between professionals and amateurs for a $p<0.05$. No differences were found between young cyclists and amateurs.

The relationship between RPE and percentage of $\dot{V}O_{2max}$ (Table III, Figure 1): no significant differences exist among the 3 groups between RPE and % $\dot{V}O_{2max}$.

TABLE III.—*Mean±SD of the data for %$\dot{V}O_{2max}$ in the 3 groups of cyclists studied in relation to their RPE during exercise.*

RPE	% $\dot{V}O_{2max}$ (mean±SD)		
	Amateurs (n=22)	Young cyclists (n=26)	Professionals (n=24)
6	35.0±1.5	34.9±2.8	34.5±2.1
7	37.5±5.8	37.0±7.1	36.7±8.0
8	41.6±8.7	42.5±7.9	34.7±2.9
9	48.7±9.4	42.5±10.5	39.4±7.1
10	45.9±10.9	48.3±11.5	46.8±8.4
11	52.6±10.9	48.9±10.2	47.8±6.9
12	59.5±8.0	54.9±12.0	59.2±7.6
13	64.8±12.0	66.9±11.9	66.3±8.7
14	67.2±10.6	67.5±12.0	74.8±9.8
15	80.1±10.9	82.4±10.4	82.1±6.7
16	81.0±7.7	82.9±10.8	88.9±4.6
17	89.4±9.6	90.0±19.0	95.6±5.9
18	95.2±5.3	94.9±4.1	95.9±2.8
19	97.9±4.8	98.8±2.4	99.3±1.8
20	100	100	100

TABLE IV.—*Significant differences among HR, %HR $\dot{V}O_2$ submaximum, $\dot{V}O_2$ relative to weight, %$\dot{V}O_{2max}$, mean power (watt), watt·kg^{-1} and RPE among the different groups studied.*

RPE	HR (l·min^{-1})	% HR	$\dot{V}O_2$ (ml)	$\dot{V}O_2$ (ml·kg^{-1})	%$\dot{V}O_2$ max	Mean Power (W)	Power/kg (W·kg$_{-1}$)
6							
7	°	°	°			°^	°^
8	°*	°*					
9	°	°					°
10	°	°^					
11	°*	°*				°	°^
12	°		°	°		°	°
13	°^	°				°	°*
14				°*		°*	°*
15	°^	°^				°	°
16			°*	°*		°*	°*
17	°		°*	°*		°*	°*
18			°*	°*		°*	°
19	°		°*	°^*		°^*	°^*
20			°*	°*		°*	°*

° Significant differences between young cyclists and professionals, $p<0.05$; ^ significant differences between young cyclists and amateurs, $p<0.05$; * significant differences between amateurs and professionals, $p<0.05$.

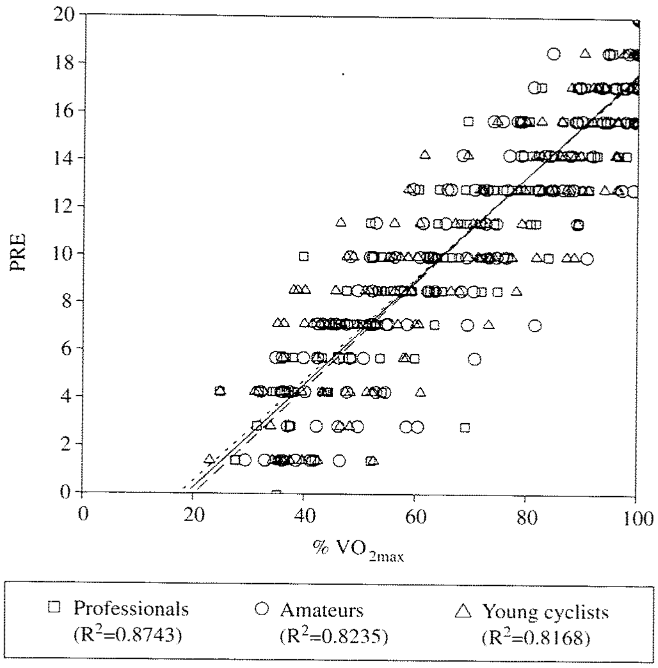

Fig. 1.—Correlation of rate of perceived exertion (RPE) and percentage of oxygen uptake (%$\dot{V}O_{2max}$).

The relationship between RPE and $\dot{V}O_2$·kg^{-1} (Tables III and IV: no significant differences exist among the 3 groups of cyclists at low intensities (up to 11-13 RPE), the differences being from RPE 14, between professionals and young cyclists and between professionals and amateurs, for a $p<0.05$. No differences were found between young cyclists and amateurs.

The relationship between RPE and HR (Tables III and IV: statistically significant differences exist in young cyclists with respect to professionals for a $p<0.05$; no differences were found, however, between professionals and amateurs, or between young cyclists and amateurs.

The relationship between RPE and % max HR (Tables III and IV, Figure 2): statistically significant differences exist ($p<0.05$) in young cyclists with respect to professionals for values of RPE up to 15. No differences exist in % max HR in respect to the RPE from a value of 15 on the Borg scale (the value of 15 of the 3 groups, corresponds to 85% of the max HR). No differences were found between professionals and amateurs, or between the latter and young cyclists.

The relationship between RPE/watt and RPE/(watt·kg^{-1}): (Tables III and IV, Figure 3): significantly statistical differences were found with respect to the RPE between professionals and young cyclists, and also between professionals and amateurs, but not between amateurs and young cyclists.

Discussion

The physical and physiological and training characteristics of the cyclists in our study are in accor-

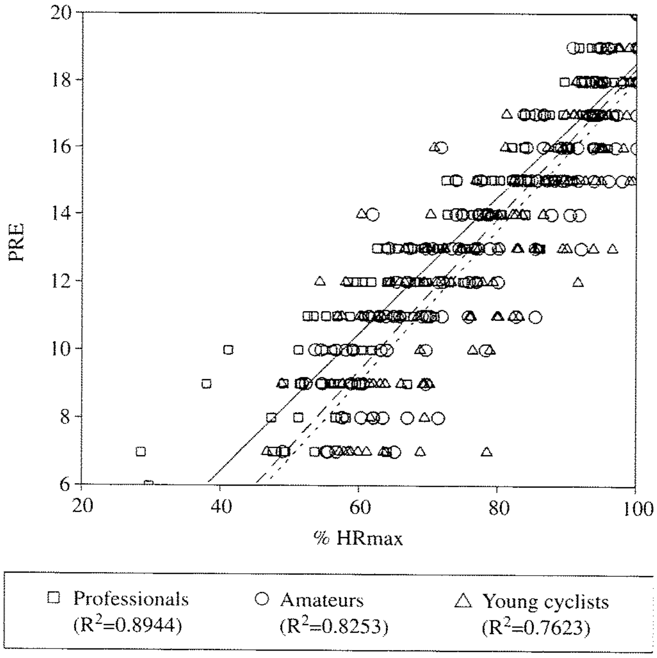

Fig. 2.—Correlation of rate of perceived exertion (RPE) and percentage of heart rate maximum (%HR).

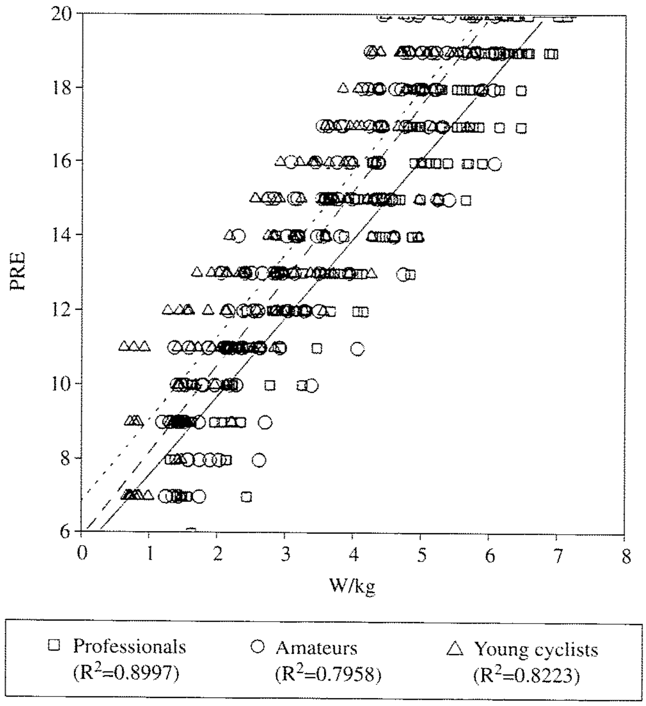

Fig. 3.—Correlation of rate of perceived exertion (RPE) and power in relation to weight (watt·kg-1).

dance with the published data of Spanish cyclists in similar categories.[29, 30]

The uptake of oxygen of professional cyclists is significantly higher than that of amateurs and young cyclists. These results are in agreement with the classical data in which the higher consumption of oxygen is related to greater performance.[5] These results have been questioned, in a certain way, by some authors[4, 30] as they did not find differences in $\dot{V}O_{2max}$ between professionals and amateurs, and they explain the greater performance of professional cyclists as being due to parameters such as the lactate threshold, the strength applied in each pedal cycle or the percentage of type I muscular fibres. This discrepancy could be due to the type of protocol used by Lucia *et al.*[30] (short protocol on a ramp, with a duration of 1 min and an increase of 25 watts, with a rather low, 70-80, fixed cadence), because changes (*i.e.* reducing from 100 to 75 rpm) in the cadence of a cyclist could influence his performance, or due to the similar level of the cyclists studied by Coyle *et al.*[4] Among the group of cyclists in our study are those occupying the first places of the classification of the UCI and winners of the most important tours or stages of such, and the classic ones, and they were pedalling at similar cadences (85-105) during the tests as during their training and competitions.[3] Similarly, Tanaka *et al.*[31] found differences between elite cyclists and amateurs ($\dot{V}O_{2max}$ 4.98±0.14 and 4.72±10.15 l·min-1, respectively). The mean value of $\dot{V}O_{2max}$·kg-1 of weight for the 3 groups in our investigation is indicative of a high level of training in the cyclists studied. It is important to emphasize the values of the professional cyclists studied (75.3±4 ml·kg-1·min-1, with a range between 80.7 and 73.4 ml·kg-1·min-1). These results are situated in the upper range of the data obtained by other authors who studied cyclists (between 65 and 80 ml·kg-1·min-1).[2, 4, 5, 30]

With respect to the maximum power reached on the bicycle ergometer in progressive tests, Coyle *et al.*[4] and Lucia *et al.*[30] show differences among groups of cyclists of different levels. These mean values being between 311-346 and 428-466 W, respectively.

In our study the maximum power reached was similar to those values in studies mentioned in the bibliography: young cyclists 350±50 W, amateurs 371±42 W and professionals 424±32 W. These data of maximum power could be different, not only because of the level of the cyclists studied but also because of the different protocol used in the evaluation of the cyclists. In relation to the maximum power expressed in relation to the weight of these athletes, the results found were similar to other authors.

The perception of exertion plays an important role in the performance of cyclists.[21, 23] In our study we found high linear correlations between the RPE and HR, %HR, $\dot{V}O_2$, %$\dot{V}O_2$, power produced (for all groups), (Figures 1 and 2), and these are in accordance with Lamb and Eston,[27] even though these authors conducted studies in children.

Our data, similar to those of Robertson *et al.*,[15] indicate that the RPE is a valid method for prescribing the intensity of exercise in % of $\dot{V}O_{2max}$ but not in relation to the absolute $\dot{V}O_2$within the same level of competition, even though their study was made using treadmill and a bicycle ergometer in 8 normal subjects. Dunbar *et al.*[17] in a study on 17 males of low sports levels (42 $ml \cdot kg^{-1} \cdot min^{-1}$ of $\dot{V}O_{2max}$), re-affirm this finding at intensities between 50 and 70% of the $\dot{V}O_{2max}$, and conclude that the RPE provides a valid physiological method for the regulation of exercise intensity.

Steed *et al.*[32] using treadmill obtained an RPE of 11.8; 14.9 and 16.8 to 76.7; 87.5 and 91.7% of $\dot{V}O_{2max}$ respectively, while in our study, at the same RPE we obtained, using a bicycle ergometer, percentages of $\dot{V}O_{2max}$ of 52.6, 80.1 and 89%. These data indicate the specificity of RPE with respect to the type of exercise made. Coyle *et al.*[33] studied high level cyclists during 30 min of exercise and obtained an RPE of 13.1±0.4 to 79.4% of $\dot{V}O_{2max}$; in our study with a RPE of 13, the professional cyclists were carrying out exercise at 66% of the $\dot{V}O_{2max}$; on the other hand, cyclists of lower levels studied by the same authors, obtained an RPE of 15.2±0.3 for an exercise intensity of 79.3±0.4, while in our study an RPE of 15 was equal to 82.1±6.7% of the $\dot{V}O_{2max}$.

In the three groups the HR was similar at high exercise intensities, but not at low intensities. This is possible due to the parasympathetic stimulation of the higher level cyclists and the greater number of years in training, and this implies that the value of the RPE in prescribing exercise intensities is not physiologically valid in absolute terms for all intensity ranges.[34] However, in relative percentage terms of the maximum HR, the RPE does appear to be of value.

In high level cyclists the RPE could be a good method for evaluating the exercise intensity and can be used by athletes and their coaches as a means for calibration of training. Even if the RPE is of value in the evaluation of training, athletes of different sports level should not be mixed.

Conclusions

With the protocol employed differences exist in the maximum data reached in an endurance test among professional, amateur and young cyclists. This fact emphasises the importance of $\dot{V}O_{2max}$ as a predictive factor of performance. And there is the same relationship between RPE and %$\dot{V}O_{2max}$ whatever the difference of $\dot{V}O_{2max}$.

The RPE is a valid and practical method in the regulation of exercise intensity in high level cycling, although the different categories and age must be borne in mind, as it is not possible to compare the data of groups of high level cyclists with those which have a lower sports level.

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