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Original Article

COMPARISON OF TESTS TO EVALUATE THE VERTICAL REBOUND JUMP IN BASKETBALL PLAYERS

COMPARAÇÃO DE TESTES PARA AVALIAÇÃO DO RESSALTO VERTICAL EM JOGADORES DE BASQUETEBOL

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RESUMO
O objetivo do presente estudo foi comparar o desempenho do ressalto vertical de jogadores de basquetebol por meio dos testes Hurdle Jump e Drop Jump a partir de diferentes parâmetros de desempenho e verificar se a altura dos obstáculos utilizados (barreira e caixote) se equivalem quando forem determinadas a altura ótima e a máxima para os testes mencionados. Participaram do estudo 13 jogadores de uma equipe de basquetebol masculina (idade 18,77 ±1,78 anos, estatura 182 ±7,97 centímetros, massa corporal 76,4 ±9,55 quilogramas, tempo de prática 6,0 ±1,8 anos). A normalidade e a homogeneidade dos dados foram testadas por meio dos testes Shapiro-Wilk e Levene, respectivamente. O Test T pareado foi utilizado na comparação das médias dos resultados obtidos nos testes e o nível de significância foi p≤0,05. Os resultados das comparações das médias dos parâmetros de desempenho: ressalto vertical máximo e índice de força reativa, não apresentaram diferenças significativas (p=0,256 e p=0,243, respectivamente), em contrapartida, foram identificadas diferenças nas alturas dos obstáculos correspondentes. Essas diferenças podem ser atribuídas às características da individualidade de cada sujeito e às especificidades dos testes.
Palavras-chave: Força muscular. Exercício pliométrico. Esportes.

ABSTRACT
This study aimed to compare the vertical rebound jump performance of basketball players by using Hurdle Jump and Drop Jump tests based on different performance parameters, in addition to investigating whether the height of the hurdles used (barrier and box) are equivalent when the optimal and maximum heights for the tests mentioned are determined. Thirteen players of a male basketball team were included in this study (age 18.77 ±1.78 years old, height 182 ±7.97 m, body mass 76.4 ±9.55 kg, practice time 6.0 ±1.8 years). Data normality and homogeneity were tested by applying Shapiro-Wilk and Levene tests, respectively. The paired t-test was used to compare the means of the results obtained in the tests; the significance level was p ≤ 0.05. The results regarding the comparison of the performance parameters means were the following: the maximum vertical rebound jump and reactive strength index did not show significant differences (p = 0.256 and p = 0.243, respectively); on the other hand, differences were seen for the corresponding obstacle heights. These differences can be attributed to both, individual characteristics of each subject and the specificities of the tests.
Keywords: Muscle Strength. Plyometric Exercise. Sports.

Introduction

Plyometric training (PT) is one of the most often used methods in sports, since it is an effective procedure for the development of physical capabilities, such as explosive strength and acceleration[1-3]. The mechanisms that explain PT effectiveness are closely associated with an efficient use of the Stretch-Shortening Cycle (SSC), which reflects a fast transition between eccentric-concentric muscle actions, capable of reducing the chances of dissipating the stored potential elastic energy and producing a greater magnitude of muscle strength[4-6].

In addition to the need of a fast transition between the eccentric-concentric phases, pre-activation also seems to directly affect the SSC action, which manifests itself as an initial phase to generate muscle tension with the purpose of preparing the skeletal muscle for a later vigorous muscular action, such as the moment before the feet contact the ground after a jump or the instant before a rebound jump (RJ). At the moment of the eccentric muscular action, the stimulus to the stretch reflex also occurs, which will be associated with the stored elastic energy, generating a more powerful concentric contraction. Therefore, three conditions are fundamental for an effective SSC action: a) a well-programmed pre-activation phase preceding the eccentric action; b) a short and fast eccentric action; c) an immediate transition between the eccentric-concentric actions.[7]

Literature shows the plyometric exercises that use RJ as the more often applied ones, such as: Drop Jump[8,9] and Hurdle Jump[10,11]. Drop Jump refers to the execution of a vertical rebound Jump (VRJ) immediately after the feet contact the ground, after a leap at a predetermined box height[12]. The Hurdle Jump, on the other hand, refers to performing a RJ after jumping over a barrier at a predetermined height[13].

Although Drop Jump[4-6] and Hurdle Jump[13,14] are commonly used as tests and as a type of training[15], the comparison of these exercises based on some biomechanical parameters is needed for better understanding and correctly using them in plyometric training programs. Assessing the VRJ, which is part of the two aforementioned test situations, is fundamental so that the development of explosive strength regarding the athletes' lower extremities is monitored by coaches[16].

Drop Jump is extensively used to evaluate the VRJ performance in athletes; the maximum flight height of the VRJ is more commonly investigated[12,17-19]. The reactive strength index (RSI), which is determined by the ratio of the maximum flight height at the VRJ by the contact time, has been pointed out as another significant parameter to evaluate performance[20,21]. The Hurdle Jump can also be used to assess the VRJ, however, little research has been found that further uses it as a test. It is worth mentioning that the performance in Drop Jump might not be the most suitable one to prescribe and monitor training on barriers, thus, investigating the Hurdle Jump specificity for this training situation is fundamental.

Despite the significance of the aforementioned tests and the use of both also as a type of training, investigations comparing Drop Jump and Hurdle Jump with regard to some performance parameters have not been found so far, that is, maximum VRJ (maximum flight height at VRJ) and a higher RSI (optimal flight height at VRJ).

The abilities of jumping and RJ are widely used in basketball games so that decisive fundamentals are performed, such as jump shot and rebound[22,23]. Due to these characteristics, using tests that evaluate jump performance[24] and RJ in basketball players[25] is extremely important. Thus, the detailing of issues related to these tests can assist in the process of assessing this sport athletic conditioning.

Therefore, the present study aimed at: 1) comparing the performance of the VRJ of basketball players by using Hurdle Jump and Drop Jump tests based on different performance parameters and; 2) investigating whether the height of the hurdles used (barrier and box) are equivalent when the optimum and maximum height for the aforementioned tests are determined.

Methods

Subjects

A male basketball team was selected, 13 athletes (age 18.77 ± 1.78 years old; height 182 ± 7.97 m; body mass 76.4 ± 9.55 kg; practice time 6.0 ± 1.8 years). All the subjects had experience in regional and national competitions. The inclusion criteria adopted so that the subjects could participate in the study were the following: have been practicing basketball for at least four years; have been training no less than four times a week, and not reporting musculoskeletal injuries in the lower extremities in the past six months. The study was approved by the Ethics Committee of the Medical Sciences Center of the Brazilian University referred to as *Universidade Federal da Paraíba* (UFPB), according to Resolution 466/2012, of the National Health Council, under opinion number 2.188.167.

Instruments

Considering data collection, the following instruments were used: CESCORF® anthropometer (vertical stadiometer) with an accuracy of 0.05 cm to measure the height of the subjects; BIOLAND® digital scale with an accuracy of 0.02 kg to quantify the body mass; multisprint contact mat (100 x 66 cm) manufactured by Hidrofit® (Belo Horizonte, MG), connected to the Software Jump Test PRO 2.10 to obtain the VRJ height values and the contact time. The following hurdles were used: 10 wooden boxes with a height of 10 cm and a width of 70 cm, which together totaled a height of 100, and 9 PVC barriers with heights varying between 20 and 100 cm, besides adjustable widths that were intended to make them more stable.

Experimental design

Collections were performed in four sessions, in non-consecutive days, with an interval of 48 hours between the first and second days, 96 hours between the second and third days and 48 hours between the third and fourth days. Familiarization with the jumping techniques used in the tests was carried out in the first two sessions. The tests to obtain data were performed in sessions 3 and 4. The VRJ performance (flight height), the hurdles height and the contact time were controlled during the tests; the latter was one of the criteria used either for the no validation attempt or elimination in the tests. RSI was calculated according to the ratio of the maximum flight height by the contact time.

In the first session, after voluntarily accepting to participate in the research, the subjects answered the PAR-Q questionnaire, which must be applied before the beginning of physical activity programs as a way to identify inadequacies with regard to the practitioners' health and their need for medical follow-up. Thus, including it for greater safety in data collection was significant. Still in the first session, after the signature of the necessary terms, anthropometric characteristics (body mass and height) were collected. Soon afterwards, a preparatory activity that met the specificity of the tests was carried out. The order according to which the tests were performed was randomly defined. In the second session, familiarization was performed once more. In sessions 3 and 4 the Hurdle Jump and Drop Jump tests were applied, that is, a type of test for each day, with the order also randomized. Each session was preceded by a preparatory activity specific to the test performed.

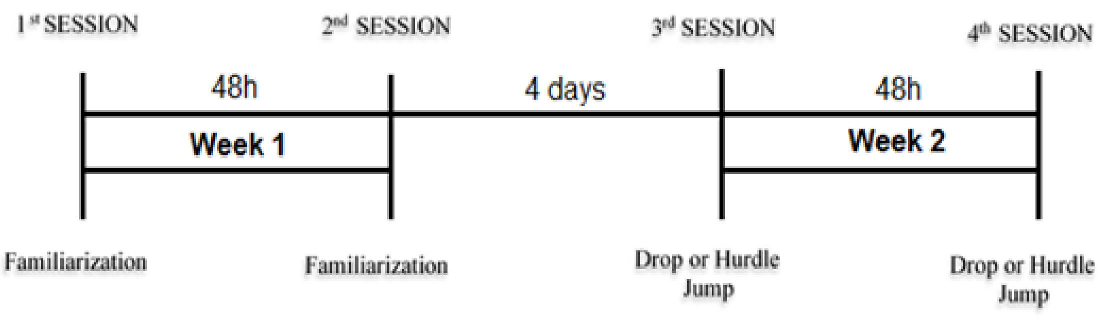

Figure 1. Schematic representation of the experimental design
Source: the authors

Details of the Preparatory Activity carried out in the four sessions

The subjects performed a general preparatory activity in sessions 1 and 2 consisting of three minutes of running, at an average speed of 7 km/h on a flat surface, followed by a specific preparatory activity determined by drawing lots (Drop Jump or Hurdle Jump). This preparatory activity consisted of three sets of three VRJ at a height of 20, 30 and 40 cm for boxes or barriers, with an interval of 10 seconds between the jump sets. In sessions 3 and 4, the preparatory activity was used according to the test performed in that session.

Details of the Familiarization with the tests (session 1 and session 2)

After the specific preparatory activity, the subjects performed at least twelve RJ with a 30-second rest interval between attempts, at a fixed jump height of 40 cm (in the case of Drop Jump)[26] and a height for jumping over a barrier fixed at 40 cm (in the case of the Hurdle Jump); the order of these RJ were compatible with the drawing carried out initially. Soon after the subjects rested for 5 minutes and, then, they went on to the specific preparatory activity (with specific test hurdles). After the specific preparatory activity, familiarization was carried out under the same conditions, however with the test opposite to that performed at the first moment.

Vertical Rebound Performance Tests

Drop Jump

The boxes used in the test varied between 20 and 100 cm. The box heights were progressively increased every 10cm[5]. The subjects performed the Drop Jump with three attempts for each box height. The highest values of both VRJ and reactive force index (RSI) were recorded for each box height; the maximum value of 200 milliseconds contact time was seen in each attempt[19,27]. Regarding each execution, the subjects were instructed to do the following: start the jump by taking a step forward with the dominant foot, letting the body drop; using the forefoot when landing, avoiding the use of heels during the first contact with the ground; jumping vertically as high and fast as possible; in addition to keeping their hands on the hips (on the supra-iliac region) throughout the test, and knees extended during the RVJ flight phase. In case the subject was able to maintain the contact time equal to or less than 200 milliseconds, the box height would be increased, with an interval of 30 seconds between attempts. If in none of the three attempts the contact time was equal to or less than 200 milliseconds or the subject performed the test incorrectly (removing hands from the hips, not extending the knees on the VRJ, dropping off the contact mat), the test would be interrupted and the height of the previous box would be considered the maximum height.

Hurdle Jump

The same requirements demanded for the Drop Jump protocol concerning hand placement were adopted. Since the VRJ was evaluated, the contact time was determined from the contact of the feet onto the ground (landing after jumping over the barrier) to the loss of contact between the feet and ground (takeoff). Furthermore, the subjects were instructed to jump at the moment of leaping the barrier. The distance between the feet and the top of the barrier, at flight time, should not be exceeded in order to create a pattern among the subjects with regard to the transposition of barriers.

Figure 2. Schematic representation of the Hurdle Jump
Source: Authors

The Hurdle Jump was started with a barrier height of 20 cm. If the subject was able to maintain the contact time equal to or less than 200 milliseconds the barrier height would be increased every 10 centimeters, adopting an interval of 30 seconds between the attempts. If after three attempts the contact time was over 200 milliseconds, the test would be interrupted and the height of the previous barrier would be considered the maximum height. The protocol created by Soares[28] was used to determine the maximum barrier height (the highest value of the VRJ) and the optimal barrier height (considered the one in which the subject reached the highest RSI value).

Statistical Analysis

In order to describe the results found, measures of central tendency and variability (mean and standard deviation) were used. Data normality and homogeneity were verified by applying Shapiro Wilk and Levene tests, respectively. For inferential statistics, the paired t-test was used to compare the means of the results obtained, that is, the highest value of the VRJ, the highest value of the reactive strength index in the two tests used, in addition to comparing the hurdles height. Regarding data analysis, SPSS software version 22.0 was used, and the significance level of $p \leq 0.05$ was adopted for all the cases.

Results

Figure 3 shows the comparison between the means obtained based on the performance parameter known as 'maximum vertical rebound jump' (MVR) in both tests - Drop Jump and Hurdle Jump. The values used to estimate the average refer to the highest flight height achieved during the MRV. No significant differences were found ($p = 0.256$) between the highest VRJ value achieved in Hurdle Jump compared to the highest VRJ value obtained in Drop Jump.

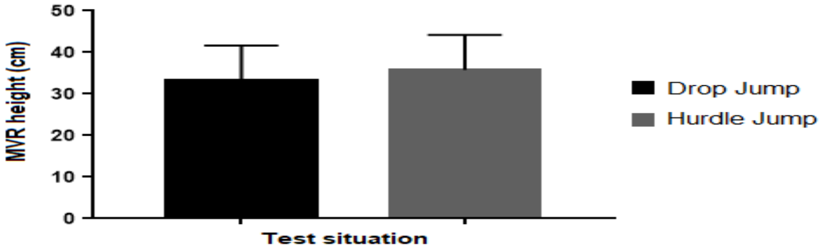

Figure 3. Performance according to the maximum vertical rebound jump in the tests assessed
Note: The values are expressed as means
Source: the authors

Figure 4 shows the comparison between the means obtained by applying the performance parameter known as 'reactive strength index' in the two tests. The values used to estimate the average refer to the ratio of the highest VRJ (flight height) by the corresponding contact time. Although the mean of the reactive strength index in Hurdle Jump was slightly higher than in Drop Jump, no significant differences were found (p = 0.243).

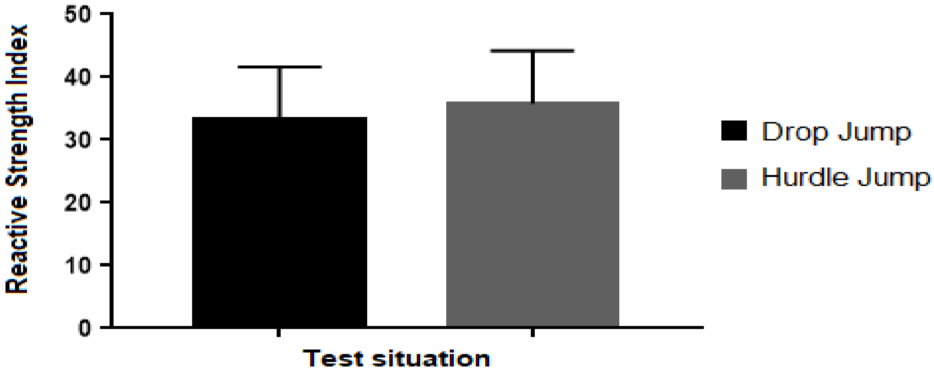

Figure 4. Performance by using the reactive strength index in the tests assessed
Note: The values are shown as means
Source: Authors

When comparing the height means of the box (40.76 ± 17.05 cm) and barriers (54.61 ± 24.36 cm), which resulted from the Maximum Vertical Rebounds, a significant difference was found (p = 0.04). When comparing the height means of the box (41.53 ± 16.75) and barriers (60 ± 21.98), which resulted in the highest Reactive Strength Indices, the difference was also significant (p = 0.01).

Table 1 shows the individual results found with regard to the hurdles height for Drop Jump and Hurdle Jump, considering the two parameters under analysis.

Table 1. Data related to the maximum flight height (the highest VRJ), in addition to the highest RSI value and the corresponding hurdles height

	Drop Jump				**Hardle Jump**			
	MVR (cm)		**RSI (m/s)**		**MVR (cm)**		**RSI (m/s)**	
Subjects	RH	CBH	RSI Value	CBH	RH (cm)	CBRH	RSI Value	CBRH
1	41,7	50	2,35	50	39,6	50	2,32	50
2	47,0	30	2,64	30	43,1	100**	2,25	100**
3	38,3	30	1,99	40*	37,2	30	2,13	40*
4	44,6	40	2,26	40	47,0	60**	2,47	60**
5	26,9	50	1,51	50	35,8	30**	2,06	30**
6	25,9	50	1,34	50	26,3	60**	1,49	60**
7	41,2	30	2,35	30	34,7	20**	1,73	40* **
8	26,4	20	1,52	20	29,7	40**	1,63	40**
9	30,4	80	1,65	80	51,8	90**	2,92	90**
10	27,5	40	1,55	40	36,1	70**	1,84	90* **
11	34,0	60	1,78	60	32,6	70**	1,75	70**
12	21,7	30	1,13	30	20,7	60**	1,20	60**
13	27,7	20	1,66	20	29,7	30**	1,94	50* **

Note: MVR: Maximum Vertical Rebound Jump; RSI: Reactive Strength Index; RVH: Rebound Vertical Height; CBH: Corresponding Box Height; CBRH: Corresponding Barrier Height. *Intratest different hurdles height. ** Intertest different hurdles height
Source: Authors

Drop Jump test showed the height of the obstacles with equal values for most subjects, except for subject 3 (MVR = 30cm, RSI = 40cm). On the other hand, comparison between MVR and RSI parameters for Hurdle Jump showed the height of the obstacles with equal values for most subjects, except for subjects3 (MVR = 30, RSI = 40), 7 (MVR = 20, RSI = 40), 10 (MVR = 70, RSI = 90) and 13 (MVR = 20, RSI = 50), all with a higher RSI value.

The intertest comparisons showed that the hurdles height with regard to the performance based on the maximum VRJ were different for most subjects, except for subjects 1 (50 cm) and 3 (30 cm). The same was seen for performance comparisons by using the RSI, so that only subjects 1 (50 cm) and 3 (40 cm) had equal hurdles height for Drop Jump and Hurdle Jump.

Discussion

The present study aimed at comparing the VRJ performance of basketball players by using the Hurdle Jump and Drop Jump tests based on different performance parameters, that is, MVR and RSI. The authors had the perspective of contributing to minimize the possible misunderstandings related to the estimation of the load components regarding the Plyometric Training (PT) assessment.

In addition to defining the load components by considering any systematic training that aims to achieve an efficient adaptation, respecting individual differences is important, so that the training load is related to the neuromuscular capacity of each subject. In the specific case of PT, it is often possible to identify that the training sessions of athletes are based on fixed box heights (in the case of Drop Jump) and, in fact, the interventions that used this type of training proved to be efficient in increasing capacities related to explosive strength[29,30]. However, other studies[20,21] pointed out that the individualized jump height brings effective results and reduces the chances of interfering in the principle of biological individuality. If in Drop Jump and Hurdle Jump the heights of drop and barrier are too low, a reduction in the adaptation chances shall occur. Conversely, if these heights are too high, the subject may not be able to effectively control the rapid transition between the eccentric-concentric phases[20,21].

Under this perspective, the present study used two parameters to determine the individual maximum height (the highest VRJ value) and optimal height (the highest RSI value) with regard to drops and barrier transposition. Such parameters are mainly characterized by the possibility of adjustments depending on the needs of the subject and the purposes prescribed by the coach, given that it is not interesting to constantly train at the maximum hurdle height[28]. Following this premise, the results found in the present study showed the significance of individualizing the hurdles height for each type of test and each parameter investigated, since the subjects had their best performance at different hurdles heights, both inter and intra tests (Table 1). However, the performance means for the maximum VRJ and reactive strength index (Figures 3 and 4) did not show significant differences ($p = 0.256$ and $p = 0.243$, respectively).

When comparing the two performance parameters, exclusively for Drop Jump, it was found that the vast majority obtained the maximum and optimal heights with the same hurdle heights; only subject 3 showed a difference for the box height (MVR = 30,RSI = 40), which was higher for the reactive strength index (Table 1). This finding differs from those found in the study by Byrne et al.[20] according to which 19 out of the 22 subjects had different hurdle heights for the Drop Jump, considering RSI and MVR parameters. However, in such an investigation, no comparisons were performed for the Hurdle Jump. The present study, when assessing the Hurdle Jump, showed that subjects 3, 7, 10 and 13 obtained different barrier heights with regard to the comparison between MVR and RSI parameters (it was higher for the latter). No studies were found that had carried out such a comparison by using the Hurdle

Jump test. In view of these results, further studies are needed to explain the highest box and barrier heights for the RSI found in the present study.

Comparison between Drop Jump and Hurdle Jumps concerning the MVR performance parameter showed that only two subjects (1 and 3) had equal box and barrier heights. The same was seen for the RSI performance parameter. This result highlights the need for individualization concerning the hurdles height, so as to meet the specific training purposes, especially when working with different tests, considering that 11 out of the 13 subjects who participated in the research showed different box and barrier heights for the two parameters assessed.

It is also relevant to establish the heights of both, drop and barrier transposition, which should be performed by using specific jumping techniques for each test. In a previous study, carried out by Cappa and Behm[13], whose purpose was to compare the leaps over bilateral and unilateral barriers with the countermovement jump (CMJ), the maximum height reached in the latter was used to determine the initial barrier height. The hurdle height was changed from 100, 120, 140 to 160% of the CMJ for the bilateral jumps; and 70, 80 and 90% of the CMJ for unilateral the jumps. However, the present study performed the Drop Jump test to establish the maximum box height with regard to MVR and RSI performance parameters, in addition to the Hurdle Jump test to determine the maximum barrier height for the same performance parameters, with specific jump techniques for each test. This fact points to the significance of respecting specificity and individuality principles when individualizing the height of barriers and boxes, which was considered in the present study. This investigation found that, when the heights of the boxes and barriers that resulted in the highest values of VRJ and RSI were compared, statistical significant differences were seen in the two comparisons, with higher values for the barrier, a fact that corroborates the specificity significance of the tests, which have their own performance characteristics. It can be speculated that different actions can cause different levels of muscle activation and pre-activation, which could influence performance. However, a more accurate analysis under a biomechanical point of view shall bring relevant information, which was not the purpose of this study, nor was specific equipment used for such analysis.

Specifically in relation to basketball and considering Drop and Hurdle Jumps, studies have ascertained the result of applying training programs by emphasizing the use of Drop Jump as a test[31,32], and as a type of training[32-33]. However, in such studies, no protocol was applied to individually establish the heights applied in training. These fixed heights have also been used to evaluate training[32]. No instigations were found that applied the Hurdle jump as a test in basketball players. When the Hurdle Jump was used for basketball players as a training exercise, there was no mention of the barrier height[34].

Conclusions

The present study showed no significant differences between Drop Jump and Hurdle Jump regarding the means of the performance parameters according to the MRV and reactive strength index achieved by the basketball athletes herein investigated. However, the hurdles heights corresponding to the highest RSI values and MRV for each test were different. Therefore, these findings show that in order to increase the benefits from Drop Jump and Hurdle Jump, it is recommended to apply individualization based on the values of the MRV and reactive strength index for each test, in order to contribute to the adaptations with the training load provided. It was found that the height of the hurdles used (barrier and box) were not equivalent when the optimal (the highest RSI value) and maximum heights (the highest VRJ value) were determined.

The focus of the present study was on the specificity of the tests and performance individualization. However, when thinking about the results generalization, specifically regarding basketball training as a collective modality, and in face of some difficulty to individualize the training hurdles, the subjects with approximate height values for barriers or boxes (taking into account the MVR or RSI parameters) should be included, with the purpose of making the training more profitable. In addition, it is worth emphasizing the need for further studies that compare the tests used in the present research, since there is lack of scientific information regarding the comparisons shown herein.

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