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# Effects of Resistance Training Intensity, Volume, and Session Format on the Postexercise Hypotensive Response

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**Abstract.** Simão, R., S.J. Fleck, M. Polito, W. Monteiro, and P. Farinatti. Effects of resistance training intensity, volume, and session format on the postexercise hypotensive response. *J. Strength Cond. Res. 19(4):853–858. 2005.*—The effect of resistance exercise (RE) on the postexercise systolic and diastolic blood pressure (SBP and DBP) response in young men was investigated. Group 1 (G1) and group 2 (G2) performed three 6 repetition maximum (6RM) sets in a set repetition format for 5 and 6 exercises, respectively. G1 and G2 also performed a circuit and set repetition format session, respectively, using 50% of the 6RM for 3 sets of 12 repetitions (12-repetition protocol). SBP and DBP were determined before and up to 60 minutes postexercise. G1's postexercise SBP demonstrated a significant decrease from its preexercise SBP, lasting 50 minutes after both RE sessions. G2's postexercise SBP demonstrated a significant difference from its preexercise SBP after the 6RM and 12-repetition protocol, lasting 60 and 40 minutes, respectively. The only significant difference in the DBP from rest was at 10 minutes postexercise for G2 after the 12-repetition-per-set protocol. In summary, results indicate that RE intensity affects the duration, but not the magnitude, of the postexercise hypotensive response.

Key Words. blood pressure, hypotension, weight training

## Introduction

Worldwide, blood pressure (BP) disorders constitute a major public health problem. One of 4 Americans is hypertensive. This condition is associated with the development of coronary artery disease, acute myocardial infarction, kidney insufficiency, and other pathologic conditions (4, 16). According to the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (2), treatment of all classifications of hypertension should include lifestyle modifications.

Physical exercise is a relevant nonpharmacologic option for the prevention and treatment of BP disorders. There is evidence that aerobic exercise is effective in reducing BP at rest and can be considered a relevant nonpharmacologic intervention (21). Moderate BP decreases have been reported after 1 aerobic training session (18). The effects of this decrease have been shown to last from 1 to 12 hours following exercise (10). The magnitude of the postexercise hypotensive response might be associated with whether or not an individual is hypertensive or normotensive. Decreased BP response after an aerobic training session has been observed in both populations (20). Some studies have reported the postexercise hypotensive response to be more evident in hypertensive than in normotensive individuals (7), while others have shown no significant difference in the postexercise response between hypertensive and normotensive subjects (3, 5).

Vasodilating responses responsible for the postexercise hypotensive response after aerobic exercises have not been entirely explained. The BP decrease is probably caused by complex interactions involving the sympathetic nervous system, baroreceptors, and nitric oxide liberation, as well as other presently unknown mechanisms (19, 21). Generally, whatever the mechanism, an aerobic exercise bout is followed by a hypotensive response.

However, whether or not resistance exercise (RE) results in a postexercise hypotensive response is relatively unknown. Only a few studies have investigated the postexercise hypotensive response following RE, and these have shown conflicting results. The studies that have investigated the BP response post of a RE protocol have generally shown some postexercise hypotensive response. Significant decreases in both systolic BP (SBP) and diastolic BP (DPB) were shown 1 minute post of a RE session consisting of 3 sets of 4 exercises performed using 70% of 1 repetition maximum (1RM) to failure (9). However, no hypotensive response was shown from 15 to 60 minutes postexercise. The average SBP and DBP both demonstrated a postexercise hypotensive response during the first hour after a RE session consisting of 7 exercises performed for 3 sets of 8–12 repetitions using an 8–12RM resistance (8). However, no hypotensive response was shown in the average 1-hour SBP or DBP from 2 to 24 hours postexercise in this study. The average SBP, but not the DBP, after a RE session that consisted of 5 exercises performed for 3 circuits of 15 repetitions using 50% of the 1RM during 60 minutes postexercise demonstrated a significant hypotensive response (4). SBP, but not DBP, also showed a significant hypotensive response from 10 to 60 minutes after a RE session consisting of a unilateral leg press exercise for 15 minutes at 65% of 1RM (14). These studies showed a short-lived but significant postexercise hypotensive response using set repetition (performing all sets of 1 exercise before performing the next exercise) and circuit-training formats, and a hypotensive response was shown when sets were and were not performed to failure. The possible short duration of the postexercise hypotensive response following RE was demonstrated by a study showing no significant change

**Table 1.** Procedures performed by the 2 groups on the 3 testing days.*

| Day | Group 1 | Group 2 |
|---|---|---|
| 1 | 6RM determination of 5 exercises | 6RM determination of 6 exercises |
| 2 | 3 sets of 6RM of 5 exercises in set repetition format. | 3 sets of 6RM of 6 exercises in set repetition format. |
| | BP determined preexercise and up to 60 min postexercise | BP determined preexercise and up to 60 min postexercise |
| 3 | 3 sets of 12 repetitions at 50% of 6RM in a circuit format. | 3 sets of 12 repetitions at 50% of 6RM in a set repetition format. |
| | BP determined preexercise and up to 60 min postexercise | BP determined preexercise and up to 60 min postexercise |

* 6RM = 6 repetition maximum; BP = blood pressure.

in ambulatory BP from rest during a postexercise period lasting from 30 minutes to 24 hours after a RE session (17).

Contradictory to studies examining the hypotensive response post of a RE protocol, studies comparing 2 different RE intensities show no postexercise hypotensive response. In a comparison of 50% (12–20 repetitions per set) and 80% (4–8 repetitions per set) of 1RM training intensities, no significant postexercise hypotensive response was shown immediately post to 180 minutes after the RE sessions, and no significant difference in the BP response was shown between intensities (6). Similarly, a comparison of the intensities of 40, 60, and 80% of 1RM performed for 3 sets of 10 repetitions showed no significant hypotensive response for any of the intensities for a time period of 120 minutes postexercise, and no difference was shown between intensities (15). In fact, a significant increase in SBP was shown at 1 minute postexercise for the intensities of 60 and 80% of 1RM and at 15 minutes for the 80% of 1RM. A comparison of 40% (20–25 repetitions) and 70% (8–10 repetitions) of 1RM for 3 sets showed no significant difference in the postexercise BP response for a period of 60 minutes postexercise (1). However, this study showed a significant hypotensive response for both intensities for DBP at 2, 5, and 10 minutes postexercise and for SBP at 2 minutes postexercise. All of these studies showed no significant difference between training intensities and used a set repetition–training format as opposed to a circuit-training format.

Because of the relatively small amount of information available and the contradictory nature of data on the existence of a postexercise hypotensive response following RE, this study was undertaken. The purpose of this study was to compare the postexercise hypotensive response following different training intensities (6 RM and 12 repetitions using 50% of 6RM), volumes (6 and 12 repetitions), and methodologies (set repetition format and circuit training).

## Methods

### Experimental Approach to the Problem

To investigate the effect of RE of varying intensity and varying volume and different training methodologies on the postexercise hypotension response, subjects performed 4 different RE sessions. The experimental procedures were performed on 3 nonconsecutive days with 48 hours separating the days on which experimental procedures were performed. The timeline of the project is depicted in Table 1. On the first day, the 6RM for each exercise comprising the RE sessions of each group was determined for both groups. Group 1 (G1) and group 2 (G2) performed exercise sequences consisting of 5 and 6 exercises, respectively. The RE sessions of G1 were composed of the bench press, leg press, lat pull-down, standing shoulder press, and biceps curl, with the exercises being performed in the order listed. The RE sessions of G2 were composed of the bench press, leg press, lat pull-down, knee curl, shoulder press, and biceps curl with the exercises being performed in the order listed.

For the 6RM tests, each subject performed a total of no more than 5 attempts on each exercise with an interval of 2–5 minutes between attempts. After the 6RM load in a specific exercise was determined, an interval not shorter than 10 minutes was allowed before the 6RM determination of the next exercise. Standard exercise techniques were followed for each exercise. No pause was allowed between the eccentric and concentric phases of a repetition or between repetitions. For a repetition to be successful, a complete range of motion as is normally defined for the exercise had to be completed. Using this protocol on a subset of the study's subjects, excellent day-to-day 6RM reliability for each exercise was shown. The subset of subjects performed 6RM testing on 2 occasions separated by 24 hours. The data were analyzed by Pearson product moment correlations (G1: bench press, $r = 0.96$; leg press, $r = 0.94$; lat pull-down, $r = 0.98$; shoulder press, $r = 0.92$; biceps curl, $r = 0.97$; and G2: bench press, $r = 0.98$; leg press, $r = 0.96$; lat pull-down, $r = 0.98$; knee curl, $r = 0.93$; shoulder press, $r = 0.95$; biceps curl, $r = 0.99$).

On the second testing day, subjects performed three 6RM sets of each exercise in a set repetition format with 2-minute recovery intervals between sets and exercises. G1 and G2 performed the 5 and 6 exercises comprising their RE sessions, respectively. This allowed comparisons of 2 different training volumes (5 vs. 6 exercises of 3 sets each) performed at a relatively high intensity (6RM). On the third testing day, both groups performed the 12-repetition protocol. However, G1 performed exercises in a circuit format, repeating the circuit 3 times, whereas G2 performed exercises in a set repetition format as it had on the previous testing day. This allowed a comparison of 2 sessions of equal intensity, slightly different volumes, and different session formats (circuit vs. set repetition). Two minutes of rest were allowed between sets and exercises for both G1 and G2 during the RE sessions on the third day of testing. During all RE sessions, subjects were asked not to perform a Valsalva maneuver. RE sessions of individual subjects were performed at approximately the same time of day.

Although both groups performed a different number of repetitions at a different intensity on testing day 2 (6 repetitions per set using 6RM) compared to day 3 (12-repetition protocol), the total training volume (repetitions × resistance) was the same within each group on the 2 days. However, because G2 performed 1 more exercise per RE session, the total volume was always higher for G2 than for G1. Additionally, G1 and G2 performed their RE sessions using the same training methodology (set repetition format) on test day 2. On test day 3, G1 performed its RE session using a circuit format, while G2 again used a set repetition format. Thus, comparisons between and within the 2 groups on the 2 testing days allowed comparisons of the effect of training intensity, training volume, and training methodology on the postexercise hypotension response.

### Subjects

Fourteen male university students ranging in age from 18 to 30 years with at least 1 year of RE experience participated in the present study. Subjects were randomly divided into 2 groups (G1: age, 22 ± 4 years; height, 178.5 ± 7 cm; weight, 76 ± 8 kg; and G2: age, 24 ± 4 years; height, 171 ± 8 cm; weight, 65 ± 13 kg) of 7 subjects each. Exclusion criteria with regard to participating in the study included the following: (a) the use of ergogenic aids, (b) the presence of muscle and osteoarticular injuries that would totally or partially impair exercise performance, and (c) the use of medications that would affect BP. Subjects did not ingest caffeine or alcohol during the 24-hour period prior to any of the testing protocols and did not perform any rigorous physical activity during the 48 hours prior to any of the testing protocols. All subjects volunteered to take part in this study and signed an informed consent form approved by a human subject's research committee in accordance with the Helsinki Resolution prior to participation in the study.

### BP Determination

Before beginning each RE session, the same experienced evaluator assessed via auscultation the SBP (first Korotkoff sound) and the DBP (fifth Korotkoff sound) at rest after the subject had been seated and calm for 10 minutes. Resting BP was determined 2 times separated by 2 minutes. The 2 resting values of both the SBP and DBP were significantly correlated ($r = 0.95$) and were not significantly different from each other (dependent Student's $t$-tests, $p \leq 0.05$). The means of the 2 resting SBP and DBP were used as the baseline BP for each session for statistical analysis. After each RE session, BP was measured at 10-minute intervals for 60 minutes, resulting in a total of 6 readings post each RE session. After each RE session, subjects were fitted with ambulatory BP monitoring (ABPM) equipment (Spacelabs Medical, Redmond, WA), and this equipment was used for all post-RE session BP determinations. The ABPM equipment was autocalibrated before each use. During BP post-RE session monitoring, subjects remained in a seated position in a controlled quite room (23° C). Previous research from our laboratory showed no significant differences between the resting SBP or DBP determined by an experienced evaluator regardless of whether it was assessed by auscultation or ABPM (16).

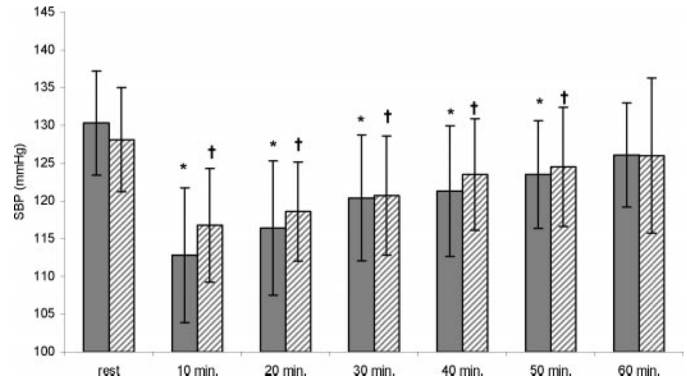


**FIGURE 1.** Group 1 systolic blood pressure response to the 2 resistance exercise sessions (mean ± *SD*). Dark gray bars = 6 repetition maximum (6RM) session; light gray bars = circuit-training session. * = significant difference from rest in the 6RM session at that time point. † = significant difference from rest in the 12-repetition-per-set circuit-training session at that time point.

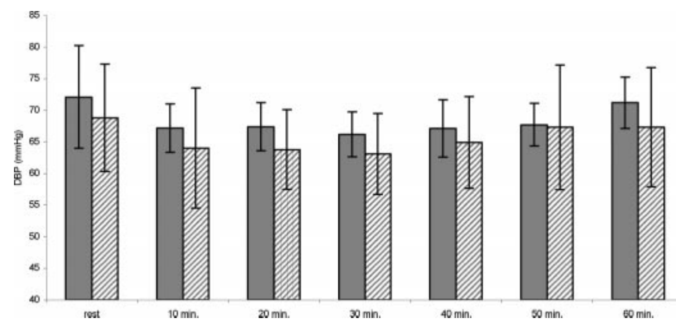


**FIGURE 2.** Group 1 diastolic blood pressure response to the 2 resistance exercise session (mean ± *SD*). Dark gray bars = 6 repetition maximum (6RM); light gray bars = circuit-training session.

### Statistical Analyses

A 2-way repeated-measures analysis of variance and then a Tukey post hoc test, where indicated, were used to analyze SBP and DBP. The level of significance was set at $p \leq 0.05$ for all statistical procedures. Version 5.5 of Statsoft Statistica for Windows (Tulsa, OK) was used for all data analyses.

## RESULTS

All subjects performed 6 repetitions per set of all exercises during the 6RM RE sessions, and 12 repetitions per set in the 12 repetition per set at 50% of 6RM protocol. In G1, when SBP values were compared to values at rest, postexercise SBP values showed a significant decrease that lasted up to 50 minutes following circuit-training and 6RM protocols (Figure 1), whereas postexercise DBP presented no change with either RE session when compared to the resting value (Figure 2).

In G2, the 6RM RE protocol resulted in a significant SBP decrease at all time points compared to the resting value, while the 12-repetition-per-set protocol resulted in a SBP decrease up to 40 minutes after the RE session (Figure 3). As for DBP, no change was observed following the 6RM RE session, but for the 12-repetition-per-set ses-

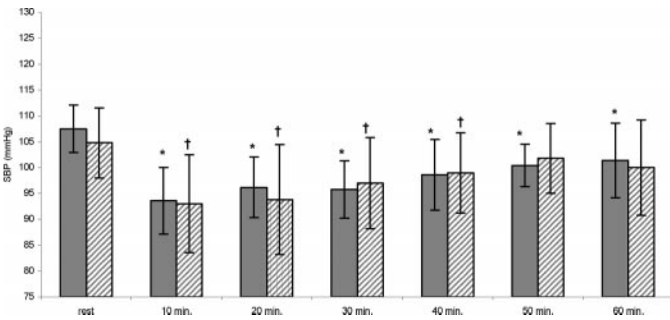


**FIGURE 3.** Group 2 systolic blood pressure response to the 2 resistance exercise sessions (mean ± *SD*). Dark gray bars = 6 repetition maximum (6RM) session; light gray bars = 12-repetition session. * = significant difference from rest in the 6RM session at that time point. † = significant difference from rest in the 12-repetition-per-set training session at that time point.

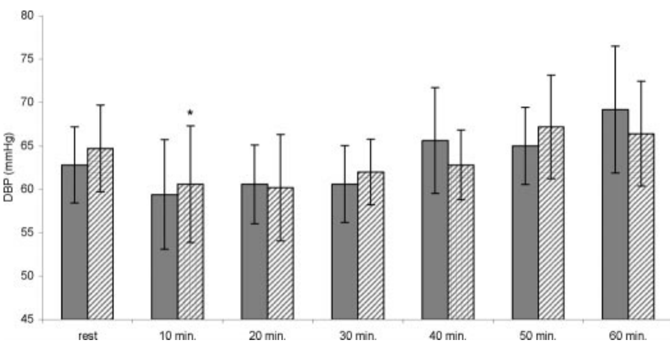


**FIGURE 4.** Group 2 diastolic blood pressure response to the 2 resistance exercise sessions (mean ± *SD*). Dark gray bars = 6 repetition maximum (6RM) session; light gray bars = 12-repetition session. * = significant difference from rest in the 12-repetition-per-set training session at that time point.

sion, there was a significant decrease 10 minutes post of the RE session (Figure 4).

Comparisons of the G1 and G2 postexercise response showed no significant difference between SBP and DBP at any time point between any of the RE sessions. However, the SBP decrease following the 6RM RE session lasted slightly longer in G2 than in G1 (60 vs. 50 minutes).

## DISCUSSION

The major finding of the present study is that the postexercise hypotensive response duration is related to RE intensity under certain conditions. This conclusion is supported by the longer duration of the SBP hypotensive response in G2 (6 exercises per session) after the 6RM RE sessions compared to the 12-repetition protocol that was performed in a set repetition format. By contrast, G1 (5 exercises per session) showed no significant difference between the set repetition format (6RM) and the circuit format (12-repetition protocol). Although the duration of the SBP hypotensive response may be related to RE intensity, the magnitude of the response appears not to be related to either exercise intensity or volume, as no significant difference in SBP was noted between RE sessions in either group or between groups. Intensity may be a determinant of the hypotensive response duration, but training volume may also affect its duration at higher intensities. This is indicated by the longer-duration (60 vs. 50 minutes) hypotensive SBP response in G2, which performed 6 exercises, compared to G1, which performed 5 exercises in the 6RM RE session. The effect on DBP post RE appears to be minimal, as only 1 time point after all 4 RE sessions (G2 at 10 minutes after the 12-repetition protocol) showed a significant DBP hypotensive response. Training methodology (set repetition or circuit format) does not appear to influence the magnitude of the post-RE session hypotensive response, as no significant difference at any time point was shown between the 3 set repetition formats and the circuit format.

The possible effect of training intensity on the duration of the SBP postexercise hypotensive response is a new finding. Previous studies that have compared different RE training intensities have shown no significant difference between the magnitude or the duration of the postexercise hypotensive response when present at intensities ranging from 40 to 80% of 1RM (1, 6, 15). The possible reason for this contradiction with previous studies is unclear, but it may be related to whether or not sets were performed using true (to failure) RM resistances. In the present study, the 6RM sessions used true RM resistances, while the 12-repetition sessions used 50% of the 6RM resistances rather than a true 12RM resistance. In previous studies that have compared intensity, it was at times unclear whether or not sets were performed to failure, but it appears that sets were not performed using true RM resistances. For example, comparisons of intensity have been made between sets at 50% of 1RM for 8–12 repetitions per set and 80% of 1RM for 4–8 repetitions per set (6); at intensities of 40, 60, and 80% of 1RM performed for 3 sets of 10 repetitions (15); and at 40% of 1RM for 20–25 repetitions per set and 70% of 1RM for 8–10 repetitions per set (1). A variety of exercises were performed in these previous studies, and it is unlikely that all or possibly any sets of some exercises were performed to failure. However, the effect, if any, of carrying sets to failure is unclear, as one study reports a significant average 1-hour SBP and DBP postexercise hypotensive response when training sessions used 8–12RM resistances for 3 sets of 7 exercises (8), whereas another study reports a significant hypotensive SBP and DBP response at 1 minute postexercise and no difference in SBP and DBP from rest at 15–60 minutes postexercise when sets were carried to failure using 70% of 1RM (9). The effect, if any, of performing exercises with true RM resistances on the postexercise hypotensive response warrants further investigation.

The lack of an effect in the present study due to different training intensities and volumes on the magnitude of the postexercise SBP hypotensive response is supported by previous studies that have shown no significant difference between different training intensities and volumes in the postexercise BP response (1, 6, 15). However, the possible effect of training volume increasing the duration of the hypotensive response at higher intensities is a novel finding. Previous studies that have compared training intensities have had different training volumes at the different intensities because of the performance of fewer repetitions at the higher intensity (1, 6) or the same number of repetitions at higher intensities, but with a greater resistance (15). The confounding factor of whether or not sets were performed to failure in previous studies also hampers the ability to make any conclusion concerning the effect of training volume on the duration of the hypotensive response. In the present study, a comparison of 2 of the protocols allows the comparison of different volumes, but with sets performed using RM resistances. In the 6RM protocol, G1 performed 5 exercises, and G2 performed 6 exercises. Thus, G2 had a higher training volume and showed a slightly longer SBP postexercise hypertensive response (60 vs. 50 minutes).

The minimal effect (only 1 time point in the 4 exercise protocols, G2 at 10 minutes after the 12-repetition protocol) on DBP post RE is supported by previous studies that have shown no hypotensive effect on DBP (4, 14, 15, 17). However, a significant short-duration DBP hypotensive response has been shown at 1–10 minutes post RE (1, 8, 9). Generally, it appears that a post-RE DBP hypotensive response does not occur and that, when present, is of short duration.

No significant differences between the magnitude of the postexercise BP response due to the use of different training methodologies (set repetition vs. circuit format) were shown. This was true for a comparison of a circuit protocol (12-repetition protocol) to higher-intensity set repetition (6RM) protocols and a lower-intensity (12-repetition protocol) set repetition protocol. To our knowledge, this is the first study to directly compare the postexercise BP response, not just at different training intensities but also with different training methodologies. The results of the present study indicate that training methodology has no effect on the post-RE hypotensive response.

The mechanism or mechanisms responsible for the effects observed in the post-RE hypotensive response are unclear. However, the aerobic postexercise hypotensive response has been attributed to a diminished vascular resistance, although the main causes of such a diminishment remain unclear. It is not likely that postexercise hypotensive responses result either from thermoregulation or blood volume changes (11). Although some data suggest a diminished postexercise activity in sympathetic efferent nerves, evidence to the contrary has been found in humans and in mice (11).

Baroreceptors and specific hormones might be the most important factors associated with the diminished sympathetic efferent nerve activity, but further investigation is necessary. Evidence from studies on rodents suggests that central levels of serotonin influence the hypotensive response (11–13), but this has not been confirmed by studies in humans. Changes in circulating hormones seem, in part, to mediate the hypotensive response. However, some vasodilating hormones and other agents, such as adrenaline, adenosine, potassium, and atrial natriuretic peptide, have been reported to increase during the postexercise hypotensive response (11). Similarly vasoconstrictive agents, such as rennin, angiotensin II, and anti-diuretic hormone, may increase, decrease, or remain unaltered following exercise (11). Whether or not these same mechanisms are involved in the post-RE hypotensive response remains to be investigated. However, it has been shown that atrial natriuretic peptide is not correlated with the post-RE hypotensive response (14).

There is evidence that the hypotensive response lasts up to 17 hours following aerobic exercise (7). However, our data as well as previous data indicate that, after RE, the hypotensive response, when present, is less than 10 minutes long (1, 4, 9, 15) or is at most 60 minutes long (8, 14). Why the hypotensive response following RE is substantially shorter in duration compared to aerobic exercise is unclear.

## Practical Applications

In summary, the findings of the present study suggest that there is a post-RE SBP response and that the intensity of strength training influences the duration, but not the magnitude, of the postexercise hypotensive response. There is little or no DBP post-RE hypotensive response. Whether or not resistance training is performed in a set repetition or circuit format does not affect the magnitude or duration of the post-RE hypotensive response. If true resting BPs are to be obtained after a resistance training session, they should not be obtained within 1 hour of the last session. However, given that the present data show a significant systolic hypotensive response with one of the resistance session protocols at 60 minutes postexercise, the practice of not obtaining resting BP until at least several hours after the last training session seems appropriate.

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