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Original Article

Effect of an ergonomic intervention involving workstation adjustments on musculoskeletal pain in office workers —a randomized controlled clinical trial

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Abstract: Office workers remain in a awkward position for long periods, which can lead to musculoskeletal symptoms. Ergonomic guidelines are recommended to avoid such problems. Evidence of the long-term effectiveness of ergonomic interventions is scarce. The aim of this randomised controlled trial was to compare pain intensity among office workers who received an ergonomic intervention and a control group before as well as 12, 24, and 36 wk after the intervention. Workers were randomly allocated to a control group (CG) and experimental group (EG). The EG received an ergonomic workstation intervention. Furniture measurements were related to individual anthropometric measurements to identify mismatches. The outcome was pain intensity, which was determined using a numerical pain scale and the Nordic Musculoskeletal Questionnaire. A linear mixed model was created with pain intensity as the dependent variable. Group and time were the independent variables. No significant interactions were found between group and time. Significant differences between groups were found for the pain intensity in the neck, shoulder, upper back, and wrist/hand ($p<0.05$), with lower intensity in the EG. The intervention reduced pain intensity in the neck, shoulder, upper back, and wrist/hand. However, no reduction in pain intensity was found for the lower back or elbow.

Key words: Ergonomics, Chronic pain, Worker's health, Musculoskeletal disorders, Randomized controlled trial

Introduction

Computer usage has led to a progressive increase in both work and leisure time. Office workers spend long periods with static neck postures and exercising repetitive hand/wrist movements, often with awkward back postures[1, 2]. These factors increase the chance of developing musculoskeletal pain, which can result in a reduced work performance, the need for sick leave, and even early retirement[2].

Ergonomics can assist in preventing musculoskeletal pain[1]. Studies have demonstrated the importance of ergonomic interventions, resulting in reductions in the frequency of musculoskeletal pain, discomfort, and absenteeism[3]. Moreover, there is evidence that ergonomic office interventions are effective at reducing costs associated

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with musculoskeletal disorders and can increase worker productivity[4].

Ergonomic office interventions may involve rest breaks and physical exercise during work[4, 5]. Another option is to adjust the workstation based on the anthropometrics of each worker with the aim of improving body posture and comfort as well as preventing musculoskeletal pain. Such interventions may also include an educational component to make employees aware of the risks and preventive measures[4].

Regarding furniture adjustments, a systematic review on the effectiveness of chair adjustments found reductions in the severity, intensity, and frequency of musculoskeletal pain[6]. All five studies that comprised the review described a reduction in self-reported musculoskeletal pain immediately after the intervention. Another study demonstrated that such adjustments reduce the effects of musculoskeletal disorders on the upper limbs and minimise the worker's exposure to risk factors by improving posture[7]. However, another systematic review found moderate evidence of a lack of benefit from isolated ergonomic interventions in terms of reducing pain[8].

Musculoskeletal pain varies over time and there is little evidence on the pain trajectory[2], which underscores the need for long-term pain assessment and monitoring. Therefore, the aim of the present study was to determine and compare pain intensity in the neck, shoulder, elbow, wrist/hand, and back (upper and lower) in a group of office workers submitted to an ergonomic intervention and a control group before as well as 12, 24, and 36 wk after an ergonomic intervention. Our hypothesis is that pain intensity will decrease in all body regions in the group receiving the intervention.

Subjects and Methods

Study design

A randomised controlled trial was conducted at the Distance Education Sector of a university with ninety-five employees. The sector is divided into administration, human resources, finance, institutional relations, teaching coordination, professional development, and technological innovations in education. This trial was registered with the Brazilian Registry of Clinical Trials (ReBEC: RBR-55KVHV).

Participants

We evaluated workers between 18 and 60 yr of age who worked at least 20 h per week in the office and who agreed to participate in the study by signing a statement of informed consent. The exclusion criteria were BMI higher than 30 kg/m^2, not having a fixed workstation, sharing a workstation with a co-worker, using a laptop computer, using two monitors, and having undergone surgery in the previous six months. The criterion for discontinuity in the study was having not completed the evaluations.

This study received approval from the local institutional review board (CAAE: 31938414.2.0000.5504).

Ethics statement

Informed consent was obtained from each subject. This study was approved by the local Ethics Committee.

Equipment and instruments

An online questionnaire was used to characterise the participants. The questionnaire addressed personal data, dominant side, educational level, occupational history, pain or physical discomfort, leisure time physical activity, and living habits.

The effects of the intervention were assessed using a numerical pain rating scale ranging from 0 (absence of pain) to 10 (worst possible pain). The scale was administered together with the Nordic Musculoskeletal Questionnaire[9], which addresses pain in the neck, shoulders, upper back, elbows, lower back, and wrist/hand in the previous seven days. Then, the Nordic Musculoskeletal Questionnaire was used to specify the different parts of the body, and for each body part a numerical pain rating scale was used.

Assessment protocol

The participants were randomly allocated to the control and experimental groups. The grouping unit was the room in which the subject worked, such that all workers in the same room were allocated to the same group. The aim of this procedure was to minimise the effect of contamination between groups, preventing a worker from observing changes in the workplace of a colleague and adapting his/her own workstation accordingly. There were five clusters in each group and the number of workers in each cluster varied from four to 10 workers. There were no changes in the clusters throughout the 36 wk. The intra cluster correlation was calculated and varied from 0.01 to 0.36 in the control group and 0.01 to 0.27 in the experimental group, indicating low correlation.

A link containing the questionnaire was sent by email. After completing the questionnaire, the workstation intervention began in the experimental group. The questionnaire was sent every 12 wk to both groups (Fig. 1).

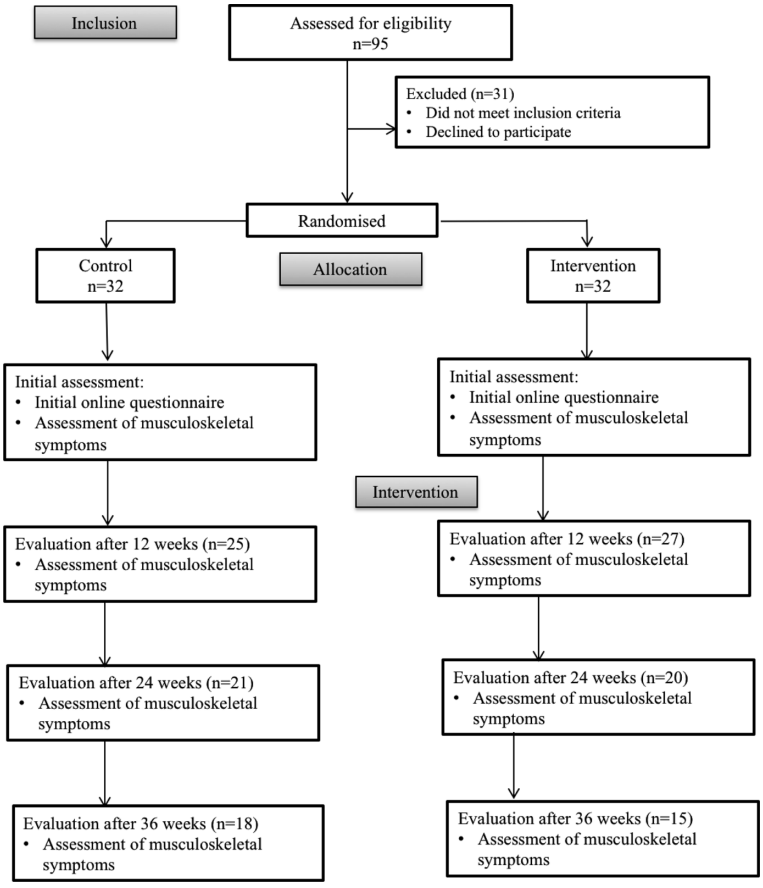

Fig. 1. Flowchart of data collection process.

Ergonomic workstation intervention

The workstations were adjusted based on ergonomic recommendations[10]. Furniture measurements were related to individual anthropometric measurements to identify mismatches.

Table height was adjusted based on elbow and shoulder height. The minimum table height was equal to the elbow height in relation to the floor and maximum table height was obtained by applying the following formula: 0.8517 hE + 0.1483 hS, in which hE is elbow height and hS is shoulder height in relation to the floor in the seated position. This equation was proposed by Parcells *et al*[11]. As the table height was not adjustable, this adjustment was performed by adjusting chair height.

For the adjustment of chair height, the ratio between the popliteal fossa and seat height was between 0.88 to 0.95[10]. In some situations, the chair might be raised to adjust elbow height to table height, requiring a footrest.

After adjusting the height of the chair and footrest, the height of the monitor was adjusted so that the worker's vision was level with the upper third of the screen. The ratio between monitor height and vision height was close to one[10]. Monitor height was adjusted by using supports of different heights to meet the needs of each worker. The monitor was positioned directly in front of the worker[12].

The recommended distance from the monitor to the eyes was between 40 and 75 cm[12]. The keyboard and the mouse were positioned at a distance that enabled the forearm to rest on the table. The mouse was aligned with the shoulder and positioned close to the keyboard[12].

Data analysis

The dependent variable was pain intensity in different body regions. The independent variables were the comparison groups (GE vs. CG) and time (pre-intervention vs. 12 wk vs. 24 wk vs. 36 wk post-intervention). Descriptive statistics were performed, with measures of central tendency, variability, and confidence intervals. Statistical analysis was performed using a mixed linear model to compare groups and times as well as the interaction between group and time. The data were analysed using the SPSS program (version 22.0), with the level of significance set at 5%.

Missing data was treated according to the procedures suggested by Jakobsen *et al*[13]. Sensitivity analysis was applied considering different scenarios: complete case analysis, best-worst and worst-best case.

Results

The personal and demographic data of the two groups are displayed in Table 1. Average age, weight, height, BMI, and daily working hours were similar between groups. The groups differed slightly in terms of working time. Both groups had a higher proportion of women. Heterogeneity was found among workers in both groups regarding education. Average education was high, as about 26% of the population in both groups had completed post-graduate studies. The groups had similar proportions of symptomatic individuals and the EG had a slightly higher proportion of physically active workers. Daily consumption of alcohol and cigarettes was low in both groups.

Table 1. Personal and demographic data of control group (CG) and experimental group (EG)

Characteristics	CG (n=32)	EG (n=32)
Age (yr) [mean (SD)]	29.1 (7.9)	28.8 (4.3)
Weight (kg) [mean (SD)]	68.5 (13.7)	68.2 (9.0)
Height (cm) [mean (SD)]	167.2 (9.9)	169.4 (10.1)
BMI (kg /cm²) [mean (SD)]	24.1 (3.3)	23.7 (1.5)
Daily working hours [mean (SD)]	7.2 (1.3)	7.1 (1.5)
Job seniority (months) [mean (SD)]	28.4 (23.6)	32.1 (18.4)
Women [n (%)]	22 (68.7)	19 (59.4)
Educational level [n (%)]		
undergraduate	7 (21.9)	9 (28.1)
graduated	25 (78.1)	23 (71.9)
Pain symptoms [n (%)]	15 (46.9)	15 (46.9)
Leisure time physical activity [n (%)]	14 (43.7)	17 (53.1)
Smoking [n (%)]	4 (12.5)	5 (15.6)
Alcohol [n (%)]	0 (0.0)	1 (3.1)

Data expressed as mean and standard deviation (SD), absolute number, and percentage (%).

Symptoms of the neck, shoulder, elbow, upper back, lower back, and wrist/hand at 0, 12, 24 and 36 wk are shown in Fig. 2 and Table 2. No significant interaction between group and time was found for any body region ($p>0.05$). Likewise, no significant differences were found between times in any region ($p>0.05$). Significant differences between groups were found for the neck, shoulder, upper back, and wrist/hand ($p<0.05$), with greater pain intensity in these regions in the CG compared to the EG.

The loss of follow up was high: 19% after 12 wk, 36% after 24 wk and 48% after 36 wk. However, there were no differences between groups for the missing values (CG: 22% vs. EG: 16%; $p=0.52$ after 12 wk; CG: 34% vs. EG: 38%; $p=0.79$ after 24 wk; CG: 44% vs. EG: 53%; $p=0.31$ after 36 wk). The sensitivity analysis showed that the original results were similar to complete case analysis. The best-worst case analysis showed an overestimation of the intervention benefits for the elbow, lower back, hip/thigh, knee and foot/ankle. The worst-best case analysis showed a sub estimation of the intervention benefits for the shoulder, upper back and hand/wrists. For the neck pain the results were the same for all tested scenarios (Table 3).

Discussion

In the present study, significant differences between groups were found for the neck, shoulder, upper back, and wrist/hand, with greater pain intensity in the CG compared to the EG. These results were expected, as evidence demonstrates that workstation adjustments can prevent the occurrence of musculoskeletal pain[14].

The neck region is the most affected by pain among office workers[15], as found in the participants of the present study. Shariat *et al.*[16] evaluated pain intensity after an ergonomic intervention and also found a reduction in neck pain in the experimental group as well as the persistence of pain intensity in the control group. On the other hand, Côté *et al.*[17] found improvements in neck symptoms, but workstation adjustments were not sufficient for this purpose and the inclusion of additional treatments was necessary, such as improvements in physical fitness. Thus, it is possible that better results would be achieved if the ergonomic intervention is complemented with an improvement in the workers' physical capacity.

The present findings revealed a reduction in the intensity of shoulder symptoms, which is in agreement with data reported by Shariat *et al.*[16], who also demonstrated a reduction in pain intensity after an ergonomic intervention involving furniture adjustments. One factor that may explain this reduction in pain in the experimental group is the support of the arm on the table, which was strongly emphasised in the workplace adjustments in the present study. This support diminishes activity in the upper trapezius and deltoid muscles and reduces shoulder torque due to the lower biomechanical load when using the computer mouse[18, 19]. Depreli and Angin[20] state that ergonomic risk factors can significantly affect the positioning of the scapula at rest; scapular protrusion results reductions in

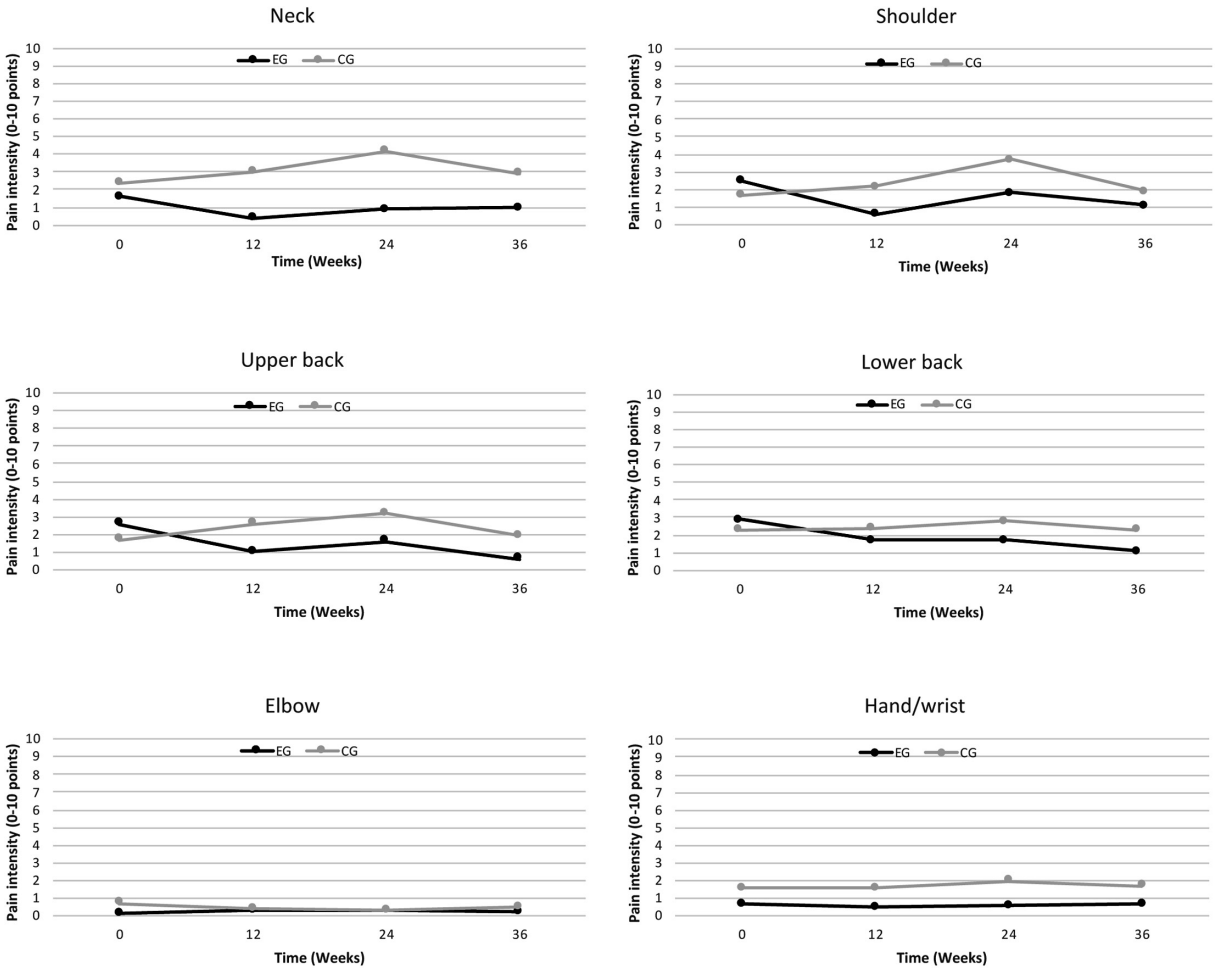

Fig. 2. Pain intensity in neck, shoulder, upper back, elbow, lower back, and wrist/hand at four evaluation times: pre-intervention (0), after 12, 24, and 36 weeks in control group (CG) and experimental group (EG). Data expressed as means.

Table 2. Pain intensity in neck, shoulders, upper back, elbows, lower back, wrist/hand, hip/thigh, knee, and ankle/foot at four evaluation moments: pre-intervention (0), after 12, 24, and 36 wk in control group (CG) and experimental group (EG)

Region	0		12		24		36		*p*		
	CG (n=32)	EG (n=32)	CG (n=25)	EG (n=27)	CG (n=21)	EG (n=20)	CG (n=18)	EG (n=15)	Group *Time	Time	Group
Neck	2.4 (3.0)	1.6 (2.5)	3.0 (3.1)	0.4 (1.4)	4.2 (2.9)	0.9 (2.9)	2.9 (3.1)	1.0 (2.7)	0.05	0.28	**<0.01**
Shoulder	1.7 (3.0)	2.5 (3.3)	2.2 (3.2)	0.6 (1.4)	3.7 (2.8)	1.8 (2.5)	1.9 (2.7)	1.1 (2.4)	0.06	0.09	**0.02**
Upper back	1.7 (3.1)	2.6 (3.3)	2.6 (2.9)	1.0 (2.1)	3.2 (3.1)	1.6 (2.4)	1.9 (2.9)	0.6 (1.1)	0.05	0.37	**0.03**
Elbow	0.7 (2.0)	0.1 (0.4)	0.4 (1.4)	0.3 (0.9)	0.3 (1.3)	0.3 (0.7)	0.5 (1.7)	0.2 (0.6)	0.56	0.98	0.15
Lower back	2.3 (3.3)	2.9 (3.3)	2.4 (2.9)	1.7 (2.6)	2.8 (3.1)	1.7 (2.3)	2.3 (2.9)	1.1 (1.9)	0.36	0.51	0.19
Hand/wrist	1.6 (2.6)	0.7 (1.9)	1.6 (3.0)	0.5 (1.4)	2.0 (3.1)	0.6 (1.3)	1.7 (2.9)	0.7 (1.4)	0.94	0.96	**<0.01**
Hip/thigh	0.4 (1.7)	0.8 (2.0)	0.6 (1.7)	0.4 (1.4)	0.6 (1.6)	0.2 (0.8)	1.2 (2.1)	0.1 (0.5)	0.21	0.87	0.19
Knee	0.3 (1.1)	0.7 (1.9)	0.9 (2.1)	0.8 (1.7)	0.9 (1.9)	1.0 (1.5)	1.4 (2.5)	0.8 (1.9)	0.34	0.5	0.64
Foot/ankle	0.4 (1.8)	0.3 (1.1)	0.0 (0.0)	0.0 (0.2)	0.0 (0.0)	0.1 (0.7)	0.6 (1.6)	0.0 (0.0)	0.49	0.32	0.43

Data expressed as mean standard deviation (SD).

Table 3. Sensitivity analysis for pain intensity in neck, shoulders, upper back, elbows, lower back, wrist/hand, hip/thigh, knee, and ankle/foot considering complete, best-worst and worst-best case analysis

Region	Complete case			Best-worst case			Worst-best case		
	Group*Time	Time	Group	Group*Time	Time	Group	Group*Time	Time	Group
Neck	0.4	0.74	**<0.01**	**<0.01**	0.28	**<0.01**	**<0.01**	**0.04**	**0.04**
Shoulder	0.33	0.21	**<0.01**	**<0.01**	0.02	**<0.01**	0.07	**<0.01**	0.21
Upper back	0.81	0.54	**<0.01**	**<0.01**	0.29	**<0.01**	0.37	**0.01**	0.39
Elbow	0.5	0.9	0.06	0.22	0.81	**<0.01**	**<0.01**	0.67	0.05
Lower back	0.97	0.98	0.05	**<0.01**	0.43	**<0.01**	0.89	0.18	**0.03**
Hand/wrist	0.94	0.91	**0.02**	**0.01**	0.67	**<0.01**	0.12	0.86	0.89
Hip/thigh	0.22	0.75	0.29	**<0.01**	0.29	**<0.01**	0.89	0.61	0.08
Knee	0.43	0.62	0.28	**<0.01**	0.21	**<0.01**	0.46	0.31	**<0.01**
Foot/ankle	0.25	0.48	0.13	**<0.01**	**<0.01**	**<0.01**	0.47	0.07	0.33

p-values are shown in the table.

the subacromial space and rotator cuff strength as well as increased tension of the anterior glenohumeral ligaments and scapular stabilising muscles. Such conditions affect functioning and can generate pain in the upper limbs[20, 21].

The findings were positive for the upper back region, which may be attributed to the better positioning of the thoracic spine and greater support on the chair back after the intervention. Improvements were also found for the wrist/hand. Monotonous office work can affect the wrist/hand[22] due to repetitive movements involving ulnar deviation[23]. Lintula *et al.*[24] found that supporting the arm reduces the extension of the wrist, which may explain the positive results for this region.

No significant reduction in pain intensity was found in the lower back. This result was not expected, as the intervention emphasised the use of lumbar support and seat adjustments. Indeed, previous studies have found a reduction in pain in this region after ergonomic adjustments, which enable the adoption of more neutral positions[6, 16, 25]. Studies suggest that typical office users rarely use the lumbar support, and do not know how to use the seat adjustments[26]. The lack of positive results for this region may be explained by the low pain intensity and small sample size. Moreover, low back pain is recognised for its multifactor origin[27]. Thus, adjustments of the workplace alone may not be sufficient to control low back pain. The lack of positive results for the elbow region may be explained by the low pain intensity in this region in both groups and the fact that the ergonomic intervention did not focus on specific measures for elbow symptoms.

Despite the reductions in pain in the experimental group, a small increase in pain intensity occurred in the neck, shoulder, upper back, and wrist/hand after 24 wk. This may have occurred due to the lack of control in the workplace. As there was no monitoring of the workstation over time, we do not know whether the adjustments were maintained. Therefore, it is important to consider periodic supervision to ensure the continuity of the intervention.

Study limitations

The present study had limitations that should be considered. As there was no continual monitoring, it is possible that some workers made changes to their workstations. The duration of sitting as well as frequency of transitions from sit-to-stand were not measured. Also, intermittent bouts of physical activity across the workday were not monitored or measured. Moreover, the Nordic Questionnaire does not enable identifying the source of the pain, which may be muscle-related or joint-related and some workers may report pain due to an unrelated event, such as a sport injury. Finally, the relatively small sample size and missing data may have affected the results.

Suggestions for practice and future studies

Based on the findings of the present study, we recommend that ergonomic interventions be performed for office workers in addition to physical exercises to improve physical capacity as effective measures for reducing pain. Further studies should be carried out with similar methods but with a larger sample size, continual monitoring of the workstations to ensure the continuity of the ergonomic adjustments, and the inclusion of physical exercises to optimise the results.

Conclusion

The proposed ergonomic workstation intervention seems to be effective at reducing pain intensity in the neck,

shoulder, upper back, and wrist/hand.

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