

A Tailored Learning Program for Prevention of Musculoskeletal Disorders

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Abstract

Background: Due to the complexity of musculoskeletal disorders (MSD), comprehensive approaches targeting both the employee and the working environment are considered to be the most promising interventions for the prevention and reduction of MSD. Such comprehensive interventions are rarely scientifically investigated and evaluated.

Aim: In this paper we evaluate a tailored ergonomic learning program for the development of low strain working techniques in respect to reducing the level of MSD among the employees at an industrial work place.

Method: In one department (n=56) all employees were participating in either intensive or team based courses, depending on the degree of severity in MSD. In another department (n=51), only employees with a high degree of MSD were participating in a course. In addition, employees in 12 support departments (n=148) were used as a reference group. The physical work environment was adjusted according to the new working techniques.

Results: There was a 33% reduction in the average number of pain regions ($p=0.0389$) among the employees in the department where all employees were participating in a course

Keywords: Participatory ergonomics; Working techniques; Musculoskeletal disorders; Number of pain regions; Rehabilitation; Prevention of sickness absence

Introduction

Employees with high physical work demands such as standing up for a long time, doing work which is highly repetitive, lifting heavy loads, working with their hands above their shoulders or working with the back twisted or bent forward, have an increased risk for musculoskeletal disorders (MSD) [1,2], long term sickness absence [3,4] and early retirement from the labor market [5]. MSD is the most common occupational disease within the EU accounting for 38% of recognized occupational diseases [6] and the economic cost of neck and upper limbs disorders is estimated to amount to 0.5-2% of GNP in the Nordic countries [7].

It is generally accepted that MSD is multifactorial, as both environmental and individual factors influence the risk of MSD [8]. Employees with low muscular strength are considered to have less tolerance to heavy physical work [9-11], and many studies have pointed out the importance of including physical exercise in workplace initiatives in order to reduce MSD [12,13]. Another and newer initiative at the individual level is cognitive-behavioral training (CBTr) [14-16]. It has been applied on patients with chronic pain, but the effects of CBTr as a primary prevention of MSD among employees with high physical work demands remain to be shown. Several reviews of ergonomic interventions have stressed that projects using participatory ergonomics which actively involve the worker are most successful regarding the reduction of MSD [13,17]. Participatory ergonomics have been shown to be effective in reducing sickness absence in work places and improving the psycho-social working conditions [18,19]. However, there are many possible degrees of employee involvement in projects using participatory ergonomics. It ranges from fully involving the employees in the decisions about how their physical work environment is designed to giving the responsibility to a third party which only represents the employees.

Due to the variety in methods and the complexity of musculoskeletal disorders (MSD), comprehensive approaches targeting both the employee and the working environment are considered to be the most promising interventions for the prevention and reduction of MSD [20,21].

The paper presented here evaluates the effectiveness of a tailored ergonomic learning program which focuses on the development of working techniques, with the purpose to reduce MSD among industrial workers.

The working techniques are designed to strain the body less, and thus the work does not cause musculoskeletal pain or wear the body down unnecessarily. Complex motion patterns are divided into simple single movements. These are trained so that the task is carried out as efficiently, safely and as easily as possible.

Apart from the low strain working techniques, the learning program consists of task-specific physical training and participatory ergonomics. The participatory ergonomic principles are applied as the employees adjust their physical working station and surroundings according to the new and healthier working techniques developed during the project. In regard to the degree of participation, the project fully involves the employees in the decisions about how their physical working environment is designed. The project also ensures that the

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employees are given both the authority and the knowledge to work according to bio-mechanic principles.

The project was developed by an experienced physiotherapist, using methods from the field of Spine Theory [22] as well as motor learning and rehabilitation [23,24]. The evaluation of the project was performed by researchers, using evidence based questionnaires.

Methods

Study population

The target industry was a large production workplace, manufacturing components for the energy sector. The work tasks involved a high degree of repetitive work with the application of moderate to high force. This poses a high risk in regard to workers developing musculoskeletal disorders. The job exposures are presented in the lower part of Table 1. Here the study population is stratified on the two production departments and a reference group, which was constituted of the 12 smaller support departments not participating in the project.

As can be seen from the table, for a majority of the workers in production department 1, the work involved a high degree of repetitive movements and working with their hands lifted above their shoulders. In the other production department, the work involved twisting, bending back and stooping without the support of hands or arms. The company initiated the study in order to reduce the prevalence of musculoskeletal symptoms and sickness absence among the employees in the production departments.

At baseline, 14.1% of the responders were females and 85.9% males. The average age was 43.7 years. The age and gender distribution

is similar among the departments. For more demographic details, see (Table 1).

The company had 538 employees at the start of the study in August 2006, counting both administrative workers and workers in the production line. Extensive questionnaires were given to all workers at baseline, a year after intensive courses were completed in October-November 2007 and again for a second and final follow up 6 months after the participating work teams had completed the team courses in May-April 2009. Moreover, participants at the intensive courses were interviewed immediately after the courses were finished.

In the baseline measurement, 448 subjects returned the questionnaire (80%). 35 employees (7.8%) were working in the administrative unit and were therefore excluded from further analyses. At the 1st follow up in October-November 2007, 478 subjects returned the questionnaire (75%). At the 2nd follow up, in May-April 2009, 438 subjects returned the questionnaire (71%). From baseline to 2nd follow up (2½ years) it was possible to match 255 employees. These 255 employees worked in either one of the two departments participating in the learning programme or the departments used as reference group. Of the 31 participants in the intensive courses, 29 were interviewed and 20 were further evaluated using a matched case-control design and questionnaire data. The intensive courses took place in the period between the baseline survey and the 1st follow up. The team courses were conducted between the 1st follow up and the 2nd follow up. See Table 2 for a summary of the characteristics of the participants.

In the department which was considered to have the most strenuous physical working conditions (Dep. 1), all participated in a course. This was either intensive or team based. In the other department (Dep. 2), only intensive courses involving the employees with a high degree of

	All (n=255)	Department 1 (n=56)	Department 2 (n=51)	Reference group (n=148)
Age (Mean, SD)	43.7 (9.2)	44.1 (9.5)	42.1 (10.1)	44.1 (8.8)
Male (%)	85.9	82.1	88.2	86.5
Female (%)	14.1	17.9	11.8	13.5
Work Place seniority (years, mean, SD)	4.3 (2.2)	4.8 (1.8)	3.7 (2.4)	4.3 (2.3)
Education (vocational, or other type of education with duration 1 year +, %)*	73.2	72.2	75.5	72.8
Physical activity in leisure in %				
Very high	1.2	1.8	3.9	0.7
High	20.6	8.9	23.5	14.6
Moderate	63.0	76.8	60.8	77.8
Low	15.2	12.5	11.8	6.9
Job exposure**(Mean, SD)				
a. Working with the neck bent backwards or stooping	2.5 (1.0)	2.6 (1.0)	2.5 (0.9)	2.4 (1.1)
b. Working with hands lifted to shoulder height or higher	2.8 (1.2)	3.5 (1.0)	2.7 (0.9)	2.7 (1.2)
c. Working twisting or with the back bended	3.0 (1.1)	3.1 (1.1)	3.6 (0.8)	2.8 (1.1)
d. Working with the back strongly stooped without support of hands/arms	2.5 (1.1)	2.6 (1.0)	3.3 (1.0)	2.3 (1.1)
e. Working in squatting or kneeling position	2.3 (1.1)	2.5 (1.0)	3.0 (0.9)	2.1 (1.1)
f. Doing the same movements with the hands or fingers many times	3.8 (1.1)	4.2 (0.9)	3.7 (1.1)	3.7 (1.1)
g. Often or always/almost always pulling more than 20 kg.	21.2 %	7.4 %	50.0 %	17.0 %

*Education is categorised as either no further education or education of more than 1 year in addition to their secondary school education.

** The scale for the measurement of job exposure was a 5-points ordinal, verbally labeled scale. It ranges from: 1) Never/almost never, 2) Seldom, 3) Sometimes, 4) Often, 5) Always /almost always.

Table 1: Demographic characteristics and job exposure for the Study Population at Baseline.

	Intensive courses (IG, n = 20)	Matched control group (CG, n = 34)	P-value difference between IG and CG
Men (%)	60	79	0.207 ^b
Age (mean, SD)	43.5 (9.4)	44.1 (7.6)	0.907 ^a
Physical exertion (scale 6 – 20) (mean, SD)	14.9 (1.6)	15.1 (1.4)	0.560 ^a
Influence at work (mean, SD) ^c	2.8 (0.8)	2.75 (1.2)	0.607 ^a
Pain in neck/shoulder, %, ^d	75.0	67.6	0.755 ^b
Pain in low back, %, ^d	80.0	73.5	0.746 ^b

^a measured with Mann-Whitney U tests.

^b measured with Chi-Square tests.

^c 1 = always; 2 = often; 3 = sometimes; 4 = rarely; 5 = (almost) never

^d percentage of participants with pain the past 12 months

Table 2: Characteristics of the participants in intensive courses (IG) and the matched control group (CG) at baseline.

musculoskeletal pain were conducted. In 12 other smaller departments, no changes were initiated on individual level. These departments were used together as a reference group (Ref. group).

Project description

The work place was economically responsible for the project. A physiotherapist led and designed the project and conducted the courses. The design of the project was complex, as employees were participating in differentiated courses depending on the severity of the MSD they experienced and their proneness to sickness leave. There were organizational constraints to the selection of workers for the intensive courses due to the management's wish that an equal number of workers from the two major production units should attend the intensive courses. Thus employees were enrolled into the intensive courses either by direct request from a team leader or due to their high degree of MSD. If there were not enough participants at a course, employees with a particular interest in becoming trainers were offered to enroll in the intensive courses as well. This was the case for 3 - 4 out of the 31 participants. Along the project, the physical work environment was surveyed and continuously adjusted by employees according to participatory principles. New helping tools were acquired when needed in the implementation of the new working routines. Often this involved equipment now being fitted to the items handled, such as tables and stands.

The project consisted of 5 concepts:

Concept 1: For employees with intensive muscle pain and proneness to sickness leave. It is an intensive, 6 day course (30 hours), mostly in groups of 8 participants, involving: 1) individual clinical examinations, 2) analysis of work functions and work related body movements in the actual work situation by recording work method, fittings, equipment and body movements on diary films, 3) learning the self-treatment of muscle pain, 4) theory about body constitution and functioning, 5) theory about physical laws and rules affecting how work related movements strain the body, 6) cognitive therapy, 7) coding healthy movements into the body, 8) physical training of balance, strength and coordination, 9) development of new and healthy working techniques, 10) examining the work place interior and work tools. Every session was evaluated and the participants were given the opportunity to come up with new ideas.

The developed techniques are transferred to the actual work situations and further discussed with co-participants at the course for development of "best practices" for the most risky work tasks. A risky work task could involve repetitive movements performed on stiff, taut legs, standing at great distance from the work object or having work tools placed at a great distance from the body with arms raised high

over the head. The underlying assumption is that older employees and employees with pain can provide valuable knowledge on both pain provoking working methods and efficient ways of doing the job.

Concept 2: A film about the Best Practices was developed in cooperation with the participants of the intensive courses. The film shows the employees how they can avoid risk factors at work, and presents basic rules for healthy working techniques and methods when doing strenuous physical work. Moreover, working techniques and methods for the most risky work tasks at the work place are presented as Best Practices. The film is used for both existing and new employees to present the results of the training and education on the intensive courses in an easily accessible way. The physiotherapist who led the project was also responsible for the production of the film.

Concept 3: Team courses lasting from 6 to 9 hours for the workers not participating in the intensive, longer lasting courses. Participants with similar work routines and areas were assigned to the same course teams.

Concept 4: Educating selected participants at the intensive courses so that they become internal trainers and resource persons. This will ensure that the new working methods are maintained.

Concept 5: Individual treatment and instruction for pain cases.

A reactive approach of participatory ergonomics was used with the employees being involved in identifying existing risks and opportunities for improvements based on their own experiences and competences gained through the project. CBT_r was an integrated part of the project both at team level and at individual level. It implied that employees with a high degree of muscle pain should learn to treat their pain themselves and to be responsible in regard to own musculoskeletal health. CBT_r in work teams consisted of group discussions on how to take care of the body during work and how to better cooperate within the team for solving the work tasks in a healthy way. The effect of CBT was qualitatively evaluated by the interviews focusing on the employees becoming aware of the relation between working methods/movements and pain.

The employees in the department with the most physically strenuous work functions (Dep. 1) were participating in concept 1, 3, 4 and 5. In the other production department (Dep. 2), only employees with the highest degree of muscle pain were offered the intensive courses (concept 1, 4 and 5).

Questionnaire

Muscle pain was measured as level of pain intensity on a 0-10 points scale. The question was only answered if the respondent had experienced pain within the last 7 days. The following body regions

were included: Neck, shoulders, elbows, hands, back, lower back, hips, knees and feet. The number of pain regions with pain intensity above 4 on the 10 point scale was calculated as well as maximum pain intensity in any of the mentioned body regions.

Job exposure was based on questions regarding work postures and pushing, pulling or lifting. The following exposures were included in the analyses: Working with the neck bent backwards or stooping, working with hands lifted to shoulder height or higher, working with twisted or bended back, working with the back strongly stooped without support of hands or arms, working squatting or kneeling, doing the same movements with the hands or fingers many times an hour, often or always/almost always pushing or pulling more than 20 kg, often or always/almost always lifting or carrying more than 20 kg. The scale for the measurement of job exposure was a 5-points ordinal, verbally labeled scale. It ranges from: 1) Never/almost never, 2) Seldom, 3) Sometimes, 4) Often, 5) Always /almost always. Finally, the employees were asked how physically demanding they find their job in general on a 6 to 20 points scale [25].

Interviews

The intensive courses were followed by interviews covering the individual gains and experiences from the course. 29 out of the 31 participants were interviewed. The interviews were conducted just after completion of the courses. The interviews were performed by the physiotherapist who lead the project and performed the courses. Questions were semi-structured. In regard to pain the following questions were posed: How did you feel before the course? How did you feel after the course? What did the course mean to you? The interviews were filmed and the analysis was performed by the author LS through qualitative narrative themes based analysis [26].

Statistical analyses for evaluation of the intensive courses

The intensive courses were evaluated by identifying employees not assigned to the intensive courses who matched the participants on the intensive courses in regard to age, gender, physical exertion, pain in neck/shoulder, pain in the lower back and influence at work. A comparison was made between this group of employees and the participants of the intensive courses, in order to analyse significant within group and between group changes in pain intensity between baseline and 1st follow up. The matching employees were identified for comparison to the participants at the intensive courses by performing a "nearest neighbour matching" and calculating propensity scores. This matching procedure provided a selection of individuals that were comparable to the employees participating in the intensive course, in regard to the selected observed covariates [27,28].

Selecting the one or two nearest neighbours in propensity scores per participant at the intensive courses yielded a sample of $n = 34$ matching employees. 20 participants of the intensive courses responded to the questionnaire survey at 1st follow up. In order to check the quality of the propensity score matching, Chi Square Tests for covariates with ≤ 3 answering categories and Mann-Whitney U Tests for covariates with >3 answering categories were conducted.

In Table 2, the values for age group, gender, physical exertion in the job, pain in neck/shoulder, pain in the low back and influence at work for participants at the intensive courses versus the matched comparison group can be seen. Of the 4 outcome measures, pain intensity in the neck and shoulder, and the lower back, were tested with Wilcoxon Signed-Rank tests for within group differences from baseline to the 1st follow up. For physical exertion and influence at work Chi-Square Tests

are used. For this test, the values of physical exertion and influence at work were grouped in three categories. In category 1, subjects have increasing values from baseline to post-test. In category 2, subjects have similar values at baseline and 1st follow up. In category 3, subjects have decreasing values from baseline to post-test. Between group differences were tested using the Mann-Whitney U Test.

Evaluation of the project as a whole

In order to evaluate the whole project, a reference group was formed, consisting of the workers in the departments not participating in the learning programme. Including a reference group could enable us to discover if changes at the company level over the 2.5 years' time span have an impact on the results of the project. For evaluation of the whole project, we then compare the two departments which have participated in the project with each other as well as the reference group. The populations in these comparison groups are similar in regard to age, gender, seniority and education (Table 1). When comparing between the two production departments and the reference group, a paired t-test is used if the differences between the paired observations are normally distributed. Where the differences between the paired observations are not normally distributed, the Wilcoxon Signed-Rank test is applied.

Results

Results from interviews

22 out of 29 reported markedly less pain. 15 out of 29 after the course felt a connection between pain and the way they used to perform the work tasks. 9 out of 29 reported that they experienced a relationship between exercises and a reduction in pain.

Results from case-control study at the 1st follow up

Table 3 provides the within and between group differences between the participants enrolled at the intensive courses (IG), and the matched control group (CG). The differences are calculated for pain intensity in neck/shoulder and low back, and influence at work. Moreover, the results of four binary logistic regressions are presented, indicating whether there are differential changes for the IG versus the CG on each of the four outcome variables.

The analysis of within-group differences showed that both the IG ($p < 0.001$) and the CG ($p < 0.02$) reported significantly decreased physical exertion from baseline to follow-up. However, the between group statistical analyses showed no significant differences between the groups on physical exertion at baseline and follow-up. There were not any significant within group or between group differences from baseline to follow-up, in terms of pain intensity in the neck/shoulder and lower back regions, and influence at work.

Results from comparisons at department level

The results from the evaluation on department level in regard to musculoskeletal pain are shown in Table 4. At baseline, the employees in Dep. 1 reported the highest degree of musculoskeletal pain compared to both Dep. 2 and the reference group. This is valid for the average maximal pain intensity, average number of pain regions and pain in all individual muscle groups, except for neck pain where employees in the reference group report higher pain intensity.

Pain in all muscle groups decreased from baseline to 2nd follow up among the employees in Dep. 1. However, only the reduction in the average number of pain regions with high intensity pain was significant

	Baseline (t ₁) values			Follow-up (t ₂) values			Within group difference		Between group difference		Binary logistic regression/ improvement or worsening		
	IG (n=20) CG (n=34)	M	SD	IG	M	SD	IG	P	t ₁	p ^c	β	SE B	OR(CI95)
Pain intensity neck/ shoulder	IG	2.50	2.91	IG	2.10	2.73	IG	0.551 ^a	t ₁	0.42	0.03	0.84	1.0 (0.2-5.3)
	CG	1.82	2.46	CG	2.03	2.42	CG	0.533 ^a	t ₂	0.91			
Pain intensity low back	IG	3.35	3.12	IG	3.10	3.04	IG	0.918 ^a	t ₁	0.30	0.32	0.77	1.3 (0.3-6.2)
	CG	2.56	2.89	CG	2.38	2.46	CG	0.768 ^a	t ₂	0.45			
Physical exertion^e	IG	14.85	1.60	IG	13.35	2.13	IG	0.001 ^{b*}	t ₁	0.60	0.26	0.80	1.3(0.3-6.1)
	CG	15.06	1.41	CG	13.65	2.47	CG	0.016 ^{b*}	t ₂	0.88			
Influence at work^f	IG	2.80	0.77	IG	2.75	0.79	IG	0.477 ^b	t ₁	0.61	0.51	0.89	1.6(0.3-9.4)
	CG	2.71	1.20	CG	2.59	1.21	CG	1.0 ^b	t ₂	0.41			

^a P-value calculated with Wilcoxon Signed-Rank tests *: p < 0.05

^b P-value calculated with Chi-Square tests *: p < 0.05

^c P-value calculated with Mann-Whitney U tests *: p < 0.05

^d Scale 0-10

^e Scale 6-20

^f 1 = always; 2 = often; 3 = sometimes; 4 = rarely; 5 = (almost) never

Table 3: Within and between group differences and binary logistic regression of the group participating in intensive courses (IG) and matched control (CG) groups.

	All (n=255)	Dep. 1 (n=56)	Dep. 2 (n=51)	Ref. group (n=148)
Average maximal pain intensity 0-10 points: Mean(SD)	Baseline	3.3 (2.8)	3.8 (2.7)	2.9 (2.8)*
	2nd follow up	3.6 (2.9)	3.1 (2.7)	3.9 (3.1)*
Sum of pain regions above 3 points: Mean (SD)	Baseline	1.2 (1.7)	1.5 (2.0)*	1.1 (1.5)
	2nd follow up	1.3 (1.8)	1.0 (1.7)*	1.5 (2.0)
Neck pain within last 7 days (points): Mean (SD)	Baseline	1.2 (2.0)	1.1 (1.9)	0.9 (1.7)
	2nd follow up	1.1 (2.0)	1.0 (1.9)	1.0 (2.0)
Shoulder pain within last 7 days (points): Mean (SD)	Baseline	1.2 (2.2)	1.6 (2.4)	1.1 (2.2)
	2nd follow up	1.2 (2.1)	1.3 (2.4)	1.4 (2.2)
Low back pain within last 7 days (points): Mean (SD)	Baseline	1.8 (2.5)	1.9 (2.5)	1.8 (2.5)
	2nd follow up	1.9 (2.6)	1.5 (2.3)	2.1 (2.7)
Upper back pain within last 7 days (points): Mean (SD)	Baseline	0.7 (1.8)	0.9 (2.2)	0.5 (1.6)
	2nd follow up	0.6 (1.7)	0.5 (1.4)	0.7 (1.9)
Knee pain within last 7 days (points): Mean (SD)	Baseline	1.1 (2.1)	1.5 (2.5)	1.1 (2.1)
	2nd follow up	1.3 (2.4)	0.8 (1.8)	1.5 (2.4)
How physically demanding do you normally find your job? 6-20 points: Mean (SD)	Baseline	12.8 (3.1)	13.3 (2.6)	14.5 (2.0)
	2nd follow up	12.3 (3.4)	13.0 (2.8)	13.4 (3.7)

* Significant difference between baseline and 2nd follow up, significance level: P < 0.05.

Table 4. Results: Musculoskeletal pain and perceived exertion at the job at baseline and 2nd follow up.

(33%, p=0.04). At the 2nd follow up, employees in Dep. 1 reported less pain than employees in Dep. 2 in regard to average maximal pain intensity, average number of pain regions and pain in all individual muscle groups. When compared to the employees in the reference group, employees in Dep. 1 also report less pain in regard to maximal pain intensity, average number of pain regions and all individual muscle groups, except for shoulder pain.

In Dep. 2, the average of maximum pain experienced increased by 34.5% (p=0.02). The perceived exertion in the job showed a non-significant decrease by 6.9 % (p=0.194). In the reference group there were no significant changes.

Discussion

In the study presented in this paper, employees are given the tools to design their own healthy work methods. When interviewing the participants in the intensive courses, we came to the conclusion that the goal of increasing the awareness of work postures and movements that provoke pain was achieved. The project involves a high degree of both participation and empowerment.

The management made the project possible by financing it, allowing

new working techniques to be developed away from the production process and carrying out the necessary adjustments in the physical working environment. The adjustments turned out to be both simple and economically feasible. Since the courses had to be coordinated with the production, the time span was longer than in most studies (2½ years). This increased the size of turnover and the number of people dropping out of the project.

The results from the matched case-control analyses of employees participating in the intensive courses showed a success in the reduction of physical exertion. However, there were no statistically significant differences between any of the other effect variables. As the employees during the intensive courses continued working in their usual teams, and as some were educated as trainers, they were likely to have taught employees from the other work groups the new working techniques. This could explain the lack of differences between cases and controls.

The project applied different measures depending on the degree of musculoskeletal disorders. Employees with a high degree of MSD were given rehabilitating treatment and educated to prevent future MSD. A recent review shows that the longer the sickness absence, the smaller the benefits of the efforts taken to return to work [29]. This

suggests that early preventive measures are important. This particular study feature could also be applied as a long term strategy for keeping employees in the job.

In the department where all employees were participating in the learning program, the average number of pain regions decreased significantly. Recent studies have indicated that a high number of pain regions are an independent risk factor for reduced work ability [30]. A high number of pain regions also have a negative impact on health in general [31] and increase the risk for long term sickness absence [32].

In the department where only employees with the highest degree of musculoskeletal pain were participating in courses, the average of maximum pain experienced increased significantly while the perceived exertion in the job showed a non significant decrease. An explanation for this could be the acquisition of new helping equipment when transferring heavy items from the support departments. The reason for the increase in MSD among these employees is unknown. It may have been provoked by changes in the psycho-social work environment, such as increased time pressure. Unfortunately, the questionnaire did not evaluate the characteristics of the psycho-social work factors at the 2nd follow up.

Conclusion

The study showed that it is feasible to implement low strain working techniques at an industrial workplace. A tailored learning program according to individual needs and involving all employees in a department resulted in a reduction of the average number of pain sites.

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