A Tailored Workplace Exercise Program for Women at Risk for Neck and Upper Limb Musculoskeletal Disorders

A Randomized Controlled Trial

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Objective: The aim of this study was to evaluate a tailored physical activity protocol performed in a work environment with a group of female workers employed in manual precision tasks to reduce upper limb pain. **Methods:** Sixty female subjects were randomly assigned to an intervention group or a control group. The IG was administered of a 6-month, twice-a-week, tailored exercise program, whereas the CG received no intervention. **Results:** The IG showed a reduction on shoulder pain accompanied by increases on the range of motion measures. In addition, reductions in upper limb pain and neck disability were detected with concomitant increases in grip strength. **Conclusions:** This study indicated positive effects of a tailored workplace exercise protocol in female workers exposed to moderate risk for work-related musculoskeletal disorders, showing clinically meaningful reductions of pain symptoms and disability on upper limb and neck regions.

Work-related musculoskeletal disorders (WRMDs) are common among employees in a variety of manufacturing and occupational settings. The disorders could be the result of the culmination of repetitive use injuries or specific acute events that increase indirect costs through reduced productivity, increased disability, and insurance costs, as well as directly affecting the employee's health-related quality of life by reducing their ability to perform activities of daily living.[1]

Assessing which WRMD is responsible for this large increase has been difficult because of the lack of standardized measures. There is a directed effort to better categorize specific conditions to identify upper limb and neck symptoms and risk factors that may contribute, though it is evident that both are primary contributors to the overall problem.[2]

Working while the neck and/or body is angled forward from the waist such as during precision tasks can expose workers to musculoskeletal stressors and subsequential reported symptoms.[3] Proper workplace ergonomics notwithstanding, the existence of sex differences is apparent with physical exposure and psychosocial work environment during repetitive movements.[4] Sex anthropometric features, such differences in strength, fatigue, and muscle fiber characteristics, may be responsible for the higher prevalence WRMDs on the neck and the upper arm in a properly designed work setting.[5]

Literature on workplace physical activity programs provided a mixed but positive impact on health-related outcomes.[6–8] Physical activity is suggested to prevent musculoskeletal disorders,[9] and for work-related low back pain, physical activity seems to unequivocally lead to benefits.[10] Nevertheless, in upper limb and neck WRMDs, studies have showed contrasting results,[11] and more evidence is needed to clearly understand the contribution of physical activity on the reduction of upper body symptomology,[12] especially for workers with higher risk, such as women.[4,13]

How similar strength programs would translate to other work environments using precision tasks is unknown, especially for women. To the best of our knowledge, this is the first investigation focused on a tailored intervention in a group of women involved in precision-specific tasks that include repetitive movements. Therefore, the aim of this study was to evaluate a tailored physical activity protocol performed in a work environment on a group of female workers who perform manual precision tasks. We hypothesize that the personalized physical activity intervention may entail benefits on neck and upper limb pain function and related symptoms in a manufacturing assembly environment compared with a control group.

MATERIALS AND METHODS

Study Setting

The setting for the study was a manufacturing environment specializing in eyewear in the Veneto region, Italy. The facility is structured around several shared product lines in which the principal work tasks are the movement, assembly, finishing, and packaging of glasses. Typical work hours are 8 hours per day, 5 days per week with a routine 1-hour mid-shift break. Participants were recruited at the last stage of the assembly product workflow, where subjects manually refinish the frame, and perform fine-tuning and adjustment of each product, using small hand tools (eg, pliers). Job tasks require close visual inspection after adjustments and predominantly use pinch and power grips during tool usage. In prior workplace health reviews, the employees who work at the final stage have higher prevalence of WRMDs than other positions at the facility. Risk calculation was previously determined by an occupation physician at the facility using the Occupational Repetitive Action index,[14] as suggested in ISO 11228-3 and in EN 1005-5. The most important risk factors considered by this assessment are frequency of high action, excessive use of force according to the Borg CR-10 scale, awkward and/or stereotyped upper limb movements and postures, lack of appropriate recovery periods, net duration of the repetitive task, and additional risk factors. The risk assessment tool was used to classify the 13 workstations into six exposure levels: high, medium, light, very low, acceptable, and optimal.[14] The risk classification level, highlighted by the upper limb biomechanical overload assessment, was medium

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in 46.2% of the analyzed workstations, light in 7.7%, acceptable in 23.1%, very low in 15.4%, and optimal in 7.6%. Workers routinely shifted in these assembly line workstations.

Study Population

Inclusion criteria included female sex, aged 30 to 60 years, had a compatible personal schedule to take part in the program, and agreed freely to participate in the exercise protocol. Although a baseline pain threshold was not defined as an inclusion criterion, all recruited subjects reported a minimum score of 3 cm at least in one of the bodily regions evaluated (neck, shoulders, elbows, and wrists) through the Visual Analogue Scale (VAS). None of the subjects was having acute pain or pain-related impairments limiting her participation to the protocol nor was presenting disability (see Disability of the Arm, Shoulder and Hand [DASH] and Neck Pain and Disability Scale [NPDS] scores). Workers were also required to be full-time employees with job functions specific to the last stages of the assembly product workflow in the past 3 years. Exclusion criteria included participation in a structured physical activity or exercise program in the prior 6 months. Participants were also excluded if they had been diagnosed with a history of central nervous dysfunction such as hemiparesis, myelopathies, cerebral ataxia, significant musculoskeletal deformities (ie, amputation, dysmetria, or scoliosis), or any abnormalities or severe arthritis that limited movements. Family and personal history physical examination and other clinical measures were collected by an occupational physician, whereas physical efficiency was measured by a PhD student, and the outcome assessors were blinded from subjects' allocation. The study complied with the current laws of Italy for research on human participants and was approved by the local University review board.

Ninety-six female workers operating in the department were contacted by a formal letter in which the investigation was briefly introduced and were asked to respond to study staff if interested to set up an appointment for an evaluation. Eligibility was compared against the recruitment criteria during the physician evaluation. Information about study purpose and procedure was given to each participant during the evaluation. If accepted, written informed consents were obtained before participation in the study protocols.

Randomization, Allocation Concealment, and Blinding

Subjects were randomly allocated to either an intervention group (IG) or a control group (CG) using 10 blocks of six subjects each, to assign all eligible participants in one of the two arms. Neither the staff responsible for recruitment nor the outcome assessors and the exercise specialist were involved in the allocation procedure (randomization procedure concealed). Outcome assessors were also blinded from subjects' allocation; however, this investigation, for its nature, cannot be considered a double-blind investigation because subjects who were enrolled to the IG consciously participated to the exercise protocol.

Intervention

The intervention consisted of a 6-month, twice-a-week, tailored exercise program from November 2012 to June 2013. The exercise program was led by an exercise specialist, and performed in a dedicated room at the workplace. The first month of activity was used to build familiarization with the exercise program, whereas sessions in subsequent months focused on training progression. Each session was structured into three parts and lasted approximately 30 minutes overall.

The first part (~8 minutes) included warm-up exercises at very low intensities; in addition, mobilization exercises of shoulder and upper limbs were performed. The primary content of the exercise class was composed of three sets of five exercises. Time between sets was kept to 30 seconds, with a minute or so between exercises. The program was tailored to each of the subjects, in which exercises and loading were personalized basing on her pain or limits revealed during the initial assessment at T0 (eg, exercise difficulty selection, modifying the range of motion, and intensities used).[15] Specifically, in the presence of pain, active mobilization of the upper arms (eg, no weight) was preferred, whereas, in the absence of pain, strength exercise (eg, bands and weights) was administered. These exercises constituted the main part of each session (about 15 minutes) and intensity was targeted between 5 to 7 on a perceived exertion scale of 0 to 10.[16] To maintain this intensity, the weight of dumbbells and grip width/elastic resistance of the elastic bands were modified accordingly. Finally, at the end of each training session, approximately 8 minutes were dedicated to the cool down, using six additional stretching positions maintained from 60 to 90 seconds. Stretching intensity was maintained at moderate intensity (5 to 6 on a scale of 0 to 10) as recommended by American College of Sports Medicine guidelines.[17] The CG received no intervention.

Measures

Prior randomization, all participants underwent functional evaluation at T0, one month before the beginning of the physical activity program and at a follow-up time during the last 2 weeks of the protocol (T6). Height, weight, and calculated body mass index (kg/m^2) were performed. The primary outcome was the reduction of pain we measured it through the VAS, and self-reported questionnaires. For this purpose, an horizontal 100-mm VAS,[17] was used to evaluate pain in the neck (VAS_{neck}), shoulder ($VAS_{shoulder}$), elbow (VAS_{elbow}), and in wrist (VAS_{wrist}). Participants were asked to complete the Italian versions of the DASH questionnaire (DASH)[18] and the NPDS-I.[19] These questionnaires have been validated and widely used to assess functional limitations and pain.[18,19] Secondary outcomes included improvements in physical function. Handgrip strength was measured by a handgrip dynamometer with each hand alternately tested three times (EN-120247, Baseline, Elmsford, NY). Back scratch was performed to evaluate upper body flexibility.[19] The range of motion during shoulder elevation (SH_{el}) and abduction (SH_{ab}) was measured throughout using a digital goniometer with the subject lying in the supine position with knees flexed. Finally, head flexion (FL_{head}), extension (EX_{head}), lateral inclination (LI_{head}), and rotation (RO_{head}) were measured with the digital goniometer applied to a helmet (GPS 400, Chinesport Medical Equipment, Udine, IT).

Statistical Analyses

Statistical analysis was carried out using SPSS (version 18.0 for Windows, SPSS Inc, Chicago, IL). Results were expressed as means ± standard deviation or percentage. The intention-to-treat analysis was applied to all the endpoints (ie, T6), and missing values were replaced analytically with baseline measures carried forward. The Kolmogorov-Smirnov test (K-S) was used to test data for normality. In addition, Levene's test was performed to test the homogeneity of variance. Baseline demographics were analyzed using *t* tests for continuous and chi-square tests for categorical values. Because of sample size and data distribution, Wilcoxon signed rank test was used to detect statistical differences postintervention in addition to subsequent permutation tests on any significant findings to compare the efficacy of the intervention between the two groups. Wilcoxon signed rank tests were used to test for statistically significant differences between pre- (T0) and postmeasurements (T6) to test within treatment-group effects. Significance limits were set at an α level of $P = 0.05$.

RESULTS

Sixty-seven subjects positively replied and accepted the mailed invitation to be evaluated. Of these, three were excluded due to not meeting inclusion criteria, and 4 excluded themselves due to lack of interest. Therefore, 60 participants were recruited (mean

age = 39.11 [standard deviation = 6.32] years; body mass index = 23.16 [standard deviation = 4.88] kg/m^2); 30 participants were assigned to either the IG or the CG. No significant differences at baseline (T0) were detected between the IG and the CG (Table 1). During the 6-month protocol, a total of 12 participants dropped out of the study and did not perform the evaluation at T6. Of these seven subjects were from the CG (23.3% attrition) and five participants were from the IG (16.7% attrition) because of lack of interest (n = 2) or change of job (n = 3). No adverse events or safety concerns were found during the course of the study; average adherence resulted in the IG cohort completing 81.5% of all sessions (25 subjects). Figure 1 shows a diagram of the recruitment process.

Primary and Secondary Outcomes

Figure 2 illustrates the results from T0 to T6 using Wilcoxon tests. We found a between-group exercise effect on DASH (P = 0.006) and NPDS-I (P = 0.007) questionnaire scores. There were also differences found for handgrip strength (P = 0.013) and back scratch (P = 0.014) scores. Other differences between groups include shoulder flexibility (P = 0.008), shoulder elevation (P = 0.035), shoulder abduction (P = 0.003), lateral inclination (P < 0.001), rotation of the head (P = 0.002), and $VAS_{shoulder}$ (P = 0.039) favoring the IG (Table 2).

DISCUSSION

This study showed the effectiveness of a tailored physical activity program, for female employees in an assembly work environment to reduce WRMD-related pain symptomology in the upper extremities and the neck region by increasing strength and flexibility in the arms, shoulders, hands, and neck. The personalized approach used in the physical activity program seemed to induce a distinct reduction of pain, especially for the shoulders and wrists though no improvements were found in other sites (ie, elbow and neck). In addition, a reduction in upper limb disability was shown with increases in grip strength and shoulder flexibility. Generally, when a strength protocol has been included in workplace exercise interventions, benefits are found for pain symptoms with the upper body,[20] neck, and shoulder.[21] Although pain and disability symptoms were

TABLE 1. Baseline Characteristics*

	All	Intervention Group	Control Group
Age, yrs mean (SD)	39.21 (6.18)	38.05 (6.07)	40.32 (6.32)
Weight, kg, mean (SD)	62.02 (13.68)	57.87 (12.73)	56.57 (13.51)
Height, cm, mean (SD)	160.15 (13.46)	162.22 (8.42)	165.00 (6.15)
Body mass index, kg/m^2, mean (SD)	23.19 (5.33)	22.59 (3.78)	24.03 (4.32)
Smoking status, %	41.67	36.67	46.67
History characterized by repetitive movements, %	19.16	18.33	20.00
Vibrations, %	3.34	5.00	1.67
Length of service, mos, mean (SD)	172.78 (68.75)	173.78 (71.61)	170.95 (65.53)

*All comparisons between IG and CG were $P > 0.05$.
SD, standard deviation.

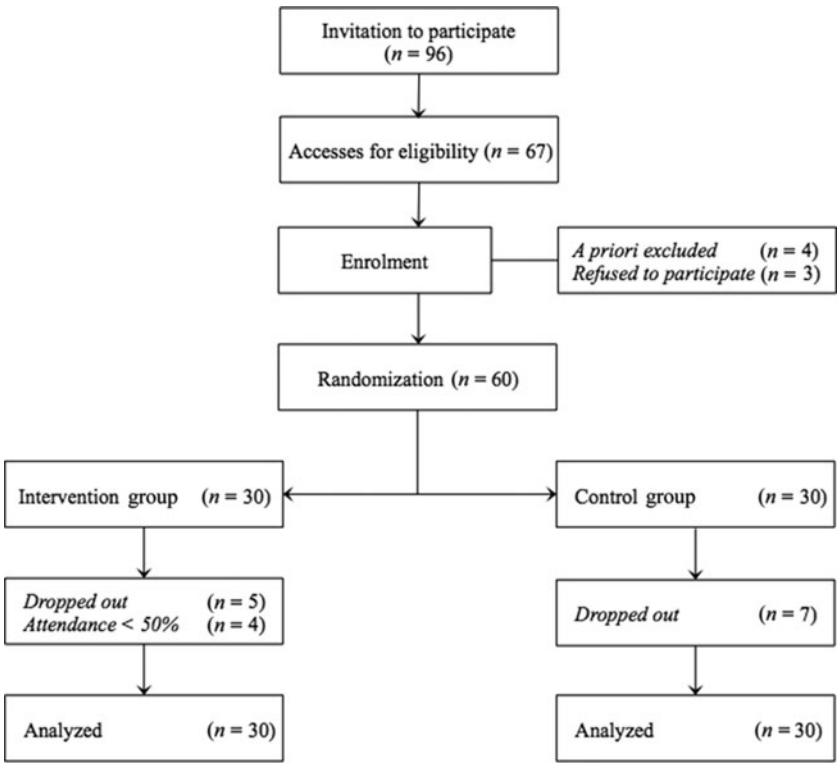

FIGURE 1. The flow diagram of the recruitment process.

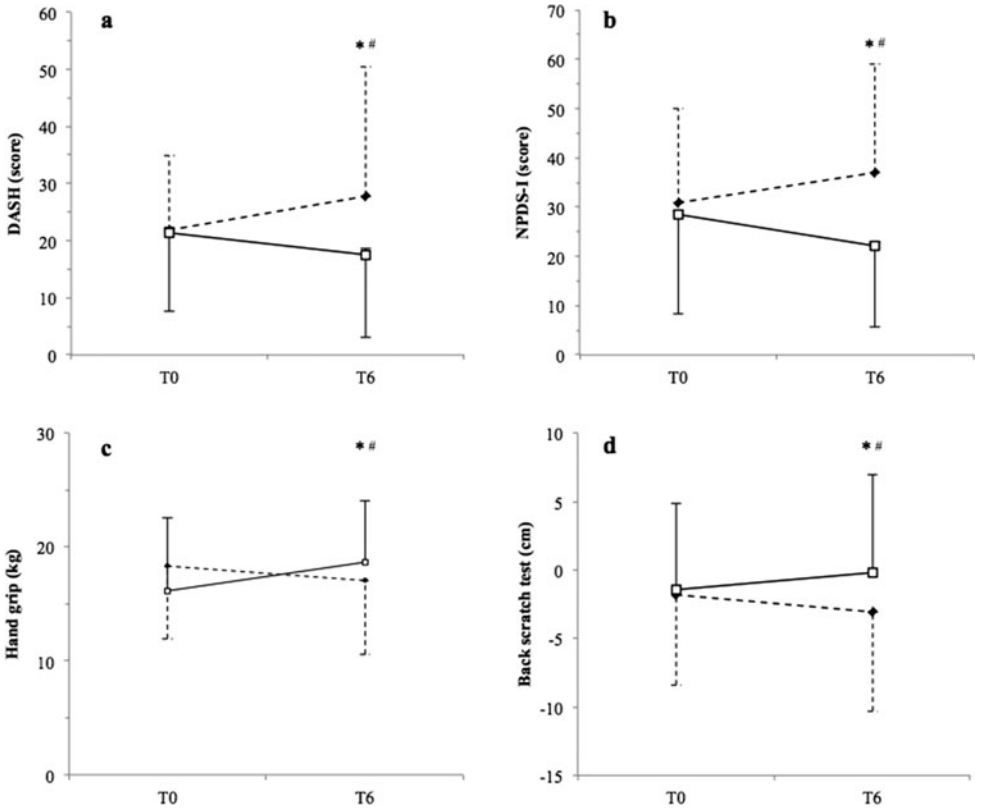

FIGURE 2. The scores of DASH (a) and NPDS-I (b) questionnaires, handgrip strength (c), and back scratch test (d). Measures were collected at baseline (T0) and after 6 months (T6). *A statistical significant difference in the within-group comparison. #A statistical significant difference in the between-group comparison.

TABLE 2.

	Intervention Group ($n = 30$) Mean (SD)		Control Group ($n = 30$) Mean (SD)	
	T0,	T6	T0	T6
VAS_{neck}, cm	4.09 (2.88)	3.73 (2.65)	4.81 (2.79)	4.38 (3.00)
$VAS_{shoulder}$, cm	2.39 (2.58)	1.79 (2.15)*	2.03 (2.20)	2.85 (2.41)
VAS_{elbow}, cm	1.07 (1.93)	0.65 (1.19)	0.86 (1.51)	0.51 (1.01)
VAS_{wrist}, cm	3.25 (2.51)	1.70 (1.85)	4.36 (2.94)	3.50 (2.55)
SH_{el}, °	164.91 (7.25)	170.12 (7.67)*	167.60 (11.48)	167.05 (16.48)
SH_{ab}, °	162.99 (13.42)	170.05 (10.12)*	161.46 (16.83)	160.20 (26.15)
FL_{head}, °	44.75 (10.11)	45.38 (7.48)	42.40 (12.50)	42.59 (8.67)
EX_{head}, °	54.73 (11.66)	56.03 (11.99)	51.56 (11.41)	48.68 (7.46)
LI_{head}, °	35.80 (3.86)	39.56 (3.66)*	36.48 (5.05)	37.87 (5.55)
RO_{head}, °	69.93 (11.48)	74.02 (7.62) *	73.82 (8.39)	67.60 (12.34)

*A statistically significant change postintervention between the two groups ($P < 0.05$).

Handgrip was measured three times in each hand alternately; the results reported are derived from the average between the mean measures (three attempts) of the right and left hands.

Higher scores indicate better performance (SH_{el}, SH_{ab}, FL_{head}, EX_{head}, LI_{head}, and RO_{head}). Lower scores indicate better outcome (VAS_{neck}, $VAS_{shoulder}$, VAS_{elbow}, and VAS_{wrist}).

EX_{head}, extension of the head; FL_{head}, flexion of the head; LI_{head}, lateral inclination of the head; RO_{head}, rotation of the head; SD, standard deviation; SH_{ab}, shoulder abduction; SH_{el}, shoulder elevation; VAS_{elbow}, Visual Analogue Scale (elbows); VAS_{neck}, Visual Analogue Scale (neck); $VAS_{shoulder}$, Visual Analogue Scale (shoulders); VAS_{wrist}, Visual Analogue Scale (wrists).

not clinically relevant in this study sample, our results confirmed that a personalized physical activity intervention approach was beneficial in women. In fact, the majority of the work-related tasks entailed hand movements such as pinching materials with concomitant twisting and/or bending the wrists and moving the neck into positions to inspect detailed work. In a similar fashion, Rasotto et al[22] showed comparable results. After their 9-month tailored exercise intervention, the recruited workers showed a remarkable decrease on pain symptoms for neck, shoulders, elbows, and on wrists. Our results are also in agreement in part with those by Heinrich et al,[23] which compared two workplace exercise protocols with and without a cognitive behavioral component. Their findings supported initial improvement with symptoms; however, at the 12-month follow-up, they did not find any benefits on pain severity and functional status. In another study reviewing musculoskeletal outcomes, Brewer et al[24] recommended that a program length be in excess of 4 months to allow the conditioning effects to persist. This implies a well-known fact that the benefit of the exercise programs lasts only as long as the continual participation in the exercise protocols, thus needing upper management buy-in to devote the resources necessary to continue these programs.

A greater heterogeneity between studies exists in the definition of clinically meaningful changes in pain.[25] To describe the meaning of our measures, we combined the pain scales with the functional evaluations others have used (Table 2).[26] Our tailored approach to exercise showed a small reduction in shoulder pain and a consistent and significant increase in shoulder elevation and abduction, together with a reduction in NPDS-I and DASH scores. For the wrist outcomes, the VAS score decreased more than 1 point, which surpasses a clinically relevant threshold.[27]

From a clinical perspective, the ability to use the upper extremities depends not only on strength but also shoulder flexibility.[28] Flexibility was found to be affected in workers with lower musculoskeletal fitness compared with healthy workers.[29] In our IG, we found improvements in the grip strength and upper limb mobility, measured through the back scratch test that agree with the results from Hagberg and colleagues.[30] It is likely that our positive effects were not only due to the mobility exercises, largely performed in the initial part of the intervention, but also due to the sustained administration of flexibility exercises at the end of each session. In addition to flexibility, the IG showed an increase in the range of motion for the shoulder. Although the range of motion, in some cases, has been considered a clinical determinant of injury, it has often not been an indicator to quantify limited function or with functional disability.[31] Indeed, Hudak et al[32] supported the idea that an increase in the range of motion should not be interchangeable with an increase in symptomatology or susceptibility of injury. The range of motion is a measure not broadly adopted in WRMD studies, but it is comparable with physiological reference norms. The maintaining of a normal range of motion, and not only in the shoulder joint, preserves the elasticity and contractibility of the muscles concurring during movement in the joints.[33] In addition, an increase in the range of motion has been suggested to lead to an angiogenesis stimulation or an optimization in the local oxygen uptake and rapid byproduct removal and in all, the range of motion is considered an important parameter of physical function.[26] Focusing on the neck region, we observed an increase in rotation and flexion of the head without a reduction on VAS scoring. Although a higher mobility in the neck region has been found to be a protective factor for neck pain,[34] Palmer and Smedley[35] underlined a weak association between the level of pain with the range of motion in the cervical spine.

This tailored exercise program also showed potential to increase upper limb strength. Handgrip strength is commonly recognized as a good predictor of general disability and limitation in activities of daily living in men and women. Recent studies accurately examined the upper limb strength loss as a parameter indicating the onset of upper limb musculoskeletal disorders. Alperovitch-Najenson et al[36] suggested hand dynamometer testing as a useful diagnostic tool to determine the loss of handgrip strength, which may indicate the development of musculoskeletal disorders of the upper extremities. In contrast, according to the results of Faber et al,[37] low muscle strength should not be considered as a predictor for musculoskeletal disorders and long-term sickness absence in the general working population.

Study Limitations

There are several limitations that should be considered when interpreting this study. The type of work dealt with precision tasks and the results may not translate to other assembly tasks or work conditions. Because the study was made only of female subjects, the results may not be generalizable to men or to women outside the sample's age range.

The adherence to the intervention is a key factor for the success of any exercise protocol, but several features of the psychosocial domain should also be considered when implementing exercise at the workplace.[38] Even though overall mean adherence was high, several members did not reach 70% (four people had approximately 45% adherence) of the exercise sessions. Aims may be needed to incentivize exercise programs in the workplace to maintain adherence to protocols. The lack of more positive findings may be due to sample size, together with a low-moderate level of pain at baseline. Although we applied an intention-to-treat analysis to all endpoints, a larger sample size could have determined a greater impact on our results.

CONCLUSIONS

This study was designed to assess the effectiveness of a tailored physical activity program, performed in a work environment on WRMDs and on selected variables of physical function in a group of female precision task assembly workers. Participants who were enrolled in the IG reported reduced pain symptoms in the neck, shoulders, elbows, and wrists. Specifically, scores from DASH and NPDS-I questionnaires, grip strength, and shoulder mobility resulted in improved scores after the 6-month physical activity program.

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