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Effects of preference-based workplace active breaks on physical function, muscular strength, and pain

Iñigo Perez-Garcia

inigo.perezg@ehu.eus

University of the Basque Country (UPV/EHU)

Natalia Burgos Alonso

University of the Basque Country (UPV/EHU)

Ana Belén Fraile-Bermúdez

University of the Basque Country (UPV/EHU)

Idoia Zarrazquin-Arizaga

University of the Basque Country (UPV/EHU)

Amaya Irazusta

University of the Basque Country (UPV/EHU)

Lars Louis Andersen

National Research Centre for the Working Environment (NFA)

Jon Torres-Unda

University of the Basque Country (UPV/EHU)

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Abstract

Purpose: To evaluate, in a pragmatic preference-based workplace setting, the comparative effects of an 8-week high-intensity strength active-break program versus a standard stretching program on physical function and pain among workers in the Basque Country (Spain).

Methods: This non-randomized pre-post study included 207 volunteer workers from 13 companies who selected their preferred intervention: stretching (n = 77) or strength training (n = 130). The strength program comprised brief 4-minute breaks with four progressive resistance exercises at a perceived exertion of 6–8/10. The stretching group followed a 5-minute mobility program. Outcomes assessed before and after included the 30-second sit-to-stand test, handgrip strength, shoulder abduction strength, and questionnaire-based pain and work ability. Within-group changes used paired tests, and between-group differences used ANCOVA controlling for confounders.

Results: Both groups significantly improved physical performance, with greater gains in the strength group. Sit-to-stand performance increased 26.2% (stretching) versus 44.0% (strength) ($p < 0.001$). Handgrip strength improved 3.2% versus 10.9% ($p < 0.001$), and shoulder abduction strength 4.3% versus 14.2% ($p < 0.001$). Both groups showed within-group reductions in total pain, pain frequency, and pain-related work limitation, but no significant between-group differences. Work ability tended to improve more with strength training ($p < 0.10$).

Conclusion: In a real-life setting where workers chose their preferred program, a brief high-intensity strength intervention produced superior improvements in functional capacity and muscular strength compared with stretching. Both approaches improved pain-related outcomes, supporting the feasibility and health benefits of preference-based active breaks in occupational settings.

Trial registration: ClinicalTrials.gov identifier: NCT07417527 (Registered February 11, 2026).

INTRODUCTION

Musculoskeletal disorders (MSDs) remain one of the most persistent challenges in occupational health. Globally, musculoskeletal conditions affect approximately 1.71 billion people and are the leading contributor to disability, with low back pain alone ranking as the leading cause of disability in many countries [1]. In working populations, MSDs are not only a source of pain, but also a determinant of productivity loss, sickness absence, reduced work ability, and premature exit from the labor market [2]. This burden is driven by multiple interacting factors. Repetitive movements, forceful exertions, awkward or sustained postures, manual handling, and sedentary work can all increase exposure to musculoskeletal strain and sickness absence, particularly when the physical demands of the job exceed the worker's functional capacity [3–5].

Preserving muscular strength and physical function is therefore a central goal of occupational musculoskeletal prevention. When strength and functional capacity decline because of aging, inactivity, pain, or insufficient muscular conditioning, ordinary work tasks require a higher relative effort. This can increase perceived exertion, reduce recovery capacity, and weaken the balance between individual resources and work demands. Conversely, workplace exercise that improves strength can make demanding tasks feel lighter and help maintain work ability [6, 7].

The workplace is a practical setting for this kind of prevention because adults spend a substantial portion of waking hours at work, and interventions can be delivered where occupational strain accumulates [8]. However, feasibility is decisive. Interventions that require travel, changing clothes, long sessions, equipment-heavy

supervision, or substantial disruption to production are difficult to sustain. Active breaks, i.e. short, structured bouts of movement inserted into the workday, address this problem by making exercise brief, visible, and easy to integrate into existing routines. In many workplaces, active breaks are based on mobility and stretching because these activities are simple, low-cost, and usually well tolerated. Stretching may reduce discomfort in some workers, but because it is not designed to provide progressive overload, it may have limited ability to improve muscular strength or objective physical function [2, 9]. On the other hand, a recent review suggests that stretching may influence pain-related outcomes through neurological, neurovascular, and psychological pathways, including relaxation and autonomic modulation [10].

Active breaks with strength training provides a potent stimulus, which can also be achieved within minutes. Randomized trials in workers with neck/shoulder pain show that targeted strength training can reduce pain and disability more effectively than advice, general fitness, or stretching-only approaches [11, 12]. Importantly for implementation, the minimal effective duration is brief. A randomized trial among office workers found that as little as 2 minutes of progressive resistance training per workday over 10 weeks produced clinically relevant reductions in neck/shoulder pain and tenderness, while also increasing muscle strength [12]. Systematic reviews further support strength training as one of the most consistent workplace exercise strategies for reducing MSDs, including among workers with physically demanding jobs[2, 13] .

Yet evidence from randomized trial alone does not resolve the main implementation challenge about what happens when an active-break program is introduced under normal workplace conditions. Randomized trials are essential for internal validity, but forced allocation can conflict with how workplace programs are actually adopted. Participation in worksite health promotion depends on worker characteristics, program characteristics, accessibility, and organizational context [14]. In addition, trial-methodology literature recognizes that strong participant preferences can influence recruitment, adherence, and outcomes, thereby affecting generalizability [15]. Pragmatic and preference-based designs can therefore complement randomized efficacy trials by estimating comparative effects in conditions closer to real-world occupational health practice [16].

Despite the growing support for workplace strength training, a specific applied gap remains. Few studies have compared a very brief high-intensity strength active break with a conventional stretching active break when workers are allowed to choose the program they prefer and when outcomes include objective measures of functional capacity, pain, and work ability. This gap is important for occupational health teams and employers because the program most likely to be implemented at scale is not necessarily the program with the strongest physiological rationale, but the one that is both acceptable to workers and effective within the time limits of the workday.

The aim of this study was to evaluate, in a pragmatic preference-based workplace setting, the comparative effects of an 8-week high-intensity strength active-break program and a standard stretching active-break program on physical function, muscular strength, pain-related outcomes, and work ability among workers in the Basque Country (Spain).

MATERIALS AND METHODS

Context and Collaborative Framework

The study was conducted in real-world workplace settings at 13 companies in the Basque Country, within the framework of an occupational musculoskeletal disorder (MSD) prevention program. This initiative was carried out

in direct collaboration with a non-profit statutory occupational health and workers' compensation insurer, which served as the supervising and facilitating body for recruitment of the worksites. The interventions were specifically designed to be integrated into working hours while respecting the operational pace and usual dynamics of each production line or administrative center.

Study Design

A preference-based (nonrandomized) pre-post design was used to compare the effectiveness of two brief active-break modalities. Assignment to intervention groups was by convenience and according to the voluntary preference expressed by the employees at each company.

The intervention lasted 8 weeks. Standardized quantitative and qualitative assessments were performed immediately before the start of the program (baseline) and at the end of week 8 (postintervention), combining objective physical functional tests with validated perceived-health questionnaires.

The decision to use a preference-based design rather than a randomized controlled trial (RCT) was driven by strict ethical and operational requirements of the real-world industrial setting, as agreed with the insurance and the management teams of the participating companies. Imposing individual random assignment in these high-demand workplace ecosystems often severely compromises adherence and creates operational friction among workers within the same section. Allowing free choice maximized acceptability and ensured an ecologically valid setting for assessing the real-world feasibility of large-scale implementation of the program in the Basque Country (Spain).

The study protocol was formally approved by the Ethics Committee for Research involving Human Beings of the University of the Basque Country (UPV/EHU) (Official Reference No.: M10/2025/322). The investigation was conducted in strict accordance with the principles of the Declaration of Helsinki. All participants received detailed verbal and written information regarding the study's objectives, procedures, risks, and benefits before providing their written informed consent prior to enrollment. Participation was entirely voluntary, and data confidentiality was strictly maintained throughout the study. "The study protocol was registered at ClinicalTrials.gov (identifier: NCT07417527) on February 11, 2026.

Participants

Recruitment was conducted in collaboration with the compensation insurance by contacting companies in the Basque Country (Spain) interested in implementing active breaks as a preventive measure against musculoskeletal disorders. Participation was voluntary and was managed during working hours after provision of study information and signing of informed consent. To ensure operational feasibility and data-recording quality, participation was limited to a maximum of 30 workers per worksite. Before the start of the interventions, an in-person introductory session lasting approximately 1 hour was held at each company. During this session, the study objectives, protocol structure, and exercise procedures were explained in detail.

Inclusion and Exclusion Criteria

To participate in the study, workers had to meet a set of predefined criteria intended to ensure intervention safety and sample relevance. The following table summarizes the inclusion and exclusion criteria applied during the selection process (Table 1).

Interventions

Prior to the intervention, a physical therapist and an occupational health technician conducted on-site workspace evaluations at all 13 companies to customize the exercises based on specific biomechanical demands and workers' baseline musculoskeletal complaints.

The operational phase of the program began with the aforementioned introductory session, which also served as the time point for baseline assessment of participants. To streamline this process and ensure standardized data recording, the sessions included the presence and technical support of the insurance professional responsible for entering functional data into a centralized database.

Both groups performed active breaks during the workday, with in-person supervision by a specialized physical therapist once per week. Visual guides were provided for the autonomous sessions performed during the remaining four workdays of each week.

At the explicit request of the insurance and the factory management teams, to ensure the program's feasibility, both protocols had to comply with a strict time limit of no more than 5 minutes per session.

The active break for the stretching group consisted of approximately 5-minute sessions performed at light intensity. The protocol included segment-specific joint mobility (1 set of 10 repetitions) and passive-active stretching (3 sets of 5 to 7 second holds) targeting muscles exposed to occupational static load. They were selected directly from the insurance database of corporate preventive programs.

The strength group performed 4-minute sessions consisting of a circuit of four exercises (2 upper-limb and 2 lower-limb, 1 minute per exercise) based on Dr. Lars Andersen's brief-exercise protocol. The execution format was structured using fixed time blocks: each exercise began with an auditory cue and ended early as soon as the participant reached the target intensity (6–8/10 on the perceived exertion scale). Once this intensity was reached, the participant rested until the next auditory cue (at the end of the minute), at which point the next exercise began. The circuit ended after completion of all four exercises. While exercise selection varied across companies for ergonomic personalization, all routines shared an identical nature of neuromuscular overload via resistance bands or body weight.

Variables

Variables were grouped into two domains: physical function and subjective perception of health and work-related well-being. Pre- and postintervention measurements were performed in spaces provided by the companies, ensuring suitable conditions and maintaining confidentiality.

Physical function was assessed using three tests: the 30-second sit-to-stand test (30s Sit-to-Stand) for lower-extremity strength; bilateral handgrip dynamometry using a GripX® electronic dynamometer (EH101, China); and 90° shoulder abduction isometric strength, recorded using the Tindeq Progressor® (Tindeq AS, Norway).

The subjective perception of health and work-related well-being was assessed using the Senior Working Life Questionnaire, developed by Dr. Lars Andersen's research group. To optimize completion and minimize transcription errors, this instrument was administered digitally. Participants accessed the interactive questionnaire online by scanning a QR code provided during the introductory session. This instrument collects information on

perceived health status, musculoskeletal pain, the functional impact of pain, workplace characteristics, health-related behaviors, and psychosocial perceptions of work.

Statistical Analysis

Statistical analyses were performed using SPSS software (IBM Corp., Armonk, NY, USA). Baseline sample characteristics were compared using Pearson's chi-square test for categorical variables and the Mann-Whitney U test (or Student's t test, according to normality criteria) for continuous variables. Data normality was assessed using the Kolmogorov-Smirnov test. Within-group changes (pre- vs. postintervention) were analyzed using the paired-samples Student's t test. For between-group comparisons of postintervention changes, analysis of covariance (ANCOVA) was performed to control for group variability and isolate the net effect of the interventions. Age, sex, occupational category, physical activity at work, physical activity at leisure time and smoking status were entered as covariates. Statistical significance was set at $p < 0.05$.

RESULTS

A total of 207 workers from 13 companies participated in the study. In accordance with the preference-based design, participants selected their preferred active-break modality. A total of 77 workers chose the stretching program, whereas 130 workers chose the strength training program (Fig. 1). Baseline characteristics of the total sample and of participants according to their chosen intervention are presented in Table 2. The sample was predominantly male, with men representing 74.9% of participants. Most workers were employed in jobs involving handling, production, or transportation of objects (68.6%), and approximately three-quarters reported physically active work, either involving standing or walking with frequent lifting or carrying (50.5%) or heavy or fast-paced physical exertion (25.3%).

Several baseline differences were observed between those who chose stretching and those who chose strength training. Participants who chose stretching were older, had higher body weight and body mass index than those who chose strength training, whereas height differed only slightly between groups. Occupational category and physical activity at work also differed significantly according to intervention choice. A greater proportion of those who chose strength training performed office-based work, whereas a greater proportion of those who chose stretching performed heavy or fast-paced physically demanding work. Smoking status also differed between groups. Leisure-time physical activity did not differ significantly between those who chose stretching and those who chose strength training.

Regarding intervention compliance, participants completed an overall mean of 15.46 ± 11.23 sessions out of the 40 planned sessions, representing an average completion rate of 38.65% ± 28.09%. No statistically significant differences in adherence were observed between the intervention groups ($p = 0.850$). Specifically, the mean number of completed sessions was 15.66 ± 11.88 (completion rate: 39.15% ± 29.71%) for the first intervention group and 15.89 ± 10.86 (completion rate: 39.73% ± 27.15%) for the second group.

Pre- to postintervention changes in work ability, pain-related outcomes, and physical function are shown in Table 3. Work ability did not change significantly among those who chose stretching, decreasing slightly from 7.54 to 7.38 points (-2.12%; $p = 0.370$). In contrast, those who chose strength training showed a small increase from 7.71 to 7.97 points (3.37%), although this change did not reach conventional statistical significance ($p = 0.065$). The between-group comparison suggested a tendency toward a greater improvement in work ability among those who chose strength training, but this difference was not statistically significant after adjustment ($p = 0.098$).

Pain-related outcomes generally improved in both preference-selected intervention groups. Among those who chose stretching, neck and shoulder pain decreased significantly from 5.02 to 4.25 points (-15.34%; p = 0.020), while the sum of pain across the three body regions decreased from 14.27 to 12.80 points (-10.30%; p = 0.044). Pain frequency also decreased significantly from 3.55 to 3.22 points (-9.30%; p = 0.008), and pain-related work limitation decreased from 2.17 to 1.91 points (-11.98%; p = 0.018). Back pain and arm pain did not change significantly in this group.

Among those who chose strength training, significant improvements were observed for arm pain, the sum of pain across the three body regions, pain frequency, and pain-related work limitation. Arm pain decreased from 4.25 to 3.56 points (-16.24%; p = 0.017), while the sum of pain decreased from 13.20 to 11.77 points (-10.83%; p = 0.027). Pain frequency decreased from 3.10 to 2.87 points (-7.42%; p = 0.018), and pain-related work limitation decreased from 2.11 to 1.78 points (-15.64%; p = 0.001). Back pain and neck and shoulder pain decreased numerically but did not reach statistical significance. Adjusted between-group comparisons showed no statistically significant differences between the two chosen intervention modalities for any pain-related outcome.

Both preference-selected interventions produced significant improvements in objective physical function, but the magnitude of improvement was consistently greater among those who chose strength training. Among those who chose stretching, 30-second sit-to-stand performance increased from 19.48 to 24.59 repetitions (26.23%; p < 0.001). Mean handgrip strength increased from 44.85 to 46.29 kg (3.21%; p = 0.012), and mean shoulder abduction strength increased from 11.46 to 11.95 kg (4.27%; p = 0.020). Among those who chose strength training, 30-second sit-to-stand performance increased from 19.49 to 28.06 repetitions (43.97%; p < 0.001), mean handgrip strength increased from 39.88 to 44.22 kg (10.88%; p < 0.001), and mean shoulder abduction strength increased from 10.65 to 12.16 kg (14.17%; p < 0.001).

Adjusted between-group analyses confirmed significantly greater improvements among those who chose strength training for all objective physical function outcomes. Compared with those who chose stretching, those who chose strength training showed larger gains in 30-second sit-to-stand performance, handgrip strength, and shoulder abduction strength, with all between-group ANCOVA p values < 0.001. These findings indicate that although both preferred active-break modalities improved physical performance, the high-intensity strength active-break program was associated with superior gains in functional capacity and muscular strength.

DISCUSSION

Principal findings

In this pragmatic, preference-based study conducted across 13 Basque workplaces, two brief active-break modalities delivered within a ≤ 5-minute slot both improved objective physical function and pain-related outcomes over 8 weeks, but differed in effectiveness. The high-intensity strength program produced substantially larger gains in functional capacity than stretching. Sit-to-stand performance increased by 44.0% versus 26.2%, handgrip strength by 10.9% versus 3.2%, and shoulder abduction strength by 14.2% versus 4.3%. All between-group comparisons, controlled for various confounders, favored strength training over stretching at p < 0.001. Pain-related outcomes, by contrast, improved comparably in both groups, with no statistically significant between-group differences for any pain variable. Work ability showed a non-significant trend favoring strength (p = 0.098). The central message is therefore twofold. When workers were free to choose, a 4-minute resistance circuit was

markedly superior for building strength and function, yet both modalities relieved pain to a similar degree. Both groups are

Strength gains and the dose-efficiency rationale

The superiority of the strength protocol for objective function is the expected consequence of progressive overload, which stretching does not provide [2, 11]. Our findings extend a well-established line of evidence showing that even very small doses of workplace resistance training can yield meaningful strength and symptom benefits. In a randomized trial among office workers, as little as 2 minutes of progressive resistance exercise per workday over 10 weeks produced clinically relevant reductions in neck/shoulder pain and increases in muscle strength [12], and targeted strength training has repeatedly outperformed general fitness or advice-only approaches for musculoskeletal complaints [17]. Systematic reviews likewise identify strength training as the most consistent workplace strategy for reducing musculoskeletal disorders, including in physically demanding jobs [2, 13]. Our study shows that these benefits are obtainable from an even more time-constrained 4-minute format, supervised in person only once weekly and otherwise performed autonomously, i.e. a structure compatible with the operational constraints of real production lines.

Crucially, these substantial benefits were achieved despite an overall adherence rate of approximately 40%, with participants completing a mean of only 16 out of 40 planned sessions. This low compliance reflects the real-world operational challenges of industrial environments. However, the fact that significant functional gains and pain reduction were still captured underscores the clinical relevance of a minimum effective dose. It demonstrates that even partial compliance to twice-weekly brief active breaks is sufficient to trigger highly beneficial adaptations, making this format exceptionally viable for high-demand workplaces.

The sectoral adaptation of exercises across the 13 worksites aligns with evidence showing that varying resistance vectors can induce regional hypertrophy or distinct muscle activation patterns [18]. However, regarding occupational pain relief and general strength, evidence demonstrates that the specific exercise choice is secondary to targeting the affected anatomical region [19], provided that high effort intensity and consistent adherence are maintained [20].

The pain paradox and the role of preference

A central and instructive finding is that pain improved in both groups without a significant between-group difference, even though only previous randomized trial have shown the strongest evidence for an effect of strength training. Several explanations are plausible and not mutually exclusive. First, pain is multifactorial and responsive to non-specific elements common to both arms such as regular movement, interruption of sustained sedentary postures, increased bodily attention, and the supportive context of a supervised workplace program. Stretching can relieve discomfort even without conferring strength [9]. A recent review of the stretching literature broadens this interpretation by emphasizing that stretching may influence neurological, neurovascular, and psychological outcomes, not only flexibility [10]. Their review summarizes studies indicating that acute and chronic stretching can be associated with post-stretch reductions in heart rate, blood pressure, cortisol, perceived stress/anxiety, and pain-related outcomes, although the evidence remains heterogeneous and not consistently superior to active comparators. This supports the possibility that the stretching arm in the present study improved pain through relaxation, autonomic modulation, and other non-specific exercise-related mechanisms rather than through increases in muscular capacity.

A second explanation follows directly from the design and deserves emphasis. Because participants chose their preferred intervention, the act of choosing may itself have shaped subjective outcomes such as pain. Receiving a preferred treatment is associated with greater expectation of benefit, stronger motivation and adherence, and higher satisfaction, i.e. factors that disproportionately influence self-reported and expectation-sensitive endpoints like pain, while leaving objectively measured performance comparatively unaffected. This “preference effect” is precisely what randomized allocation is designed to neutralize, and it is well documented that patients receiving their preferred arm tend to report better subjective outcomes than those randomized to the same treatment [15, 21]. In our study, every participant received a preferred program, so this mechanism would be expected to act in both groups and could plausibly explain why pain improved similarly despite divergent physiological stimuli. In other words, the same design choice that maximizes ecological validity and adherence also limits the inferences we can draw about the specific analgesic efficacy of either modality. This interpretation should be read as a candidate explanation rather than a demonstrated one, but it reframes the null between-group pain result as expected rather than anomalous.

Practical implications

The results point to a practical gap that randomized trials alone cannot resolve, i.e. what happens when an active-break program is introduced under normal workplace conditions, where uptake depends on worker characteristics, program accessibility, and organizational context [14]. Forcing individual randomization in high-demand industrial ecosystems can compromise adherence, whereas allowing choice favors acceptability. Pragmatic, preference-based designs therefore complement randomized efficacy trials by estimating comparative effects under conditions closer to routine occupational practice [16]. For occupational health teams, the program most likely to be implemented at scale is not necessarily the one with the strongest physiological rationale, but the one that is both acceptable to workers and effective within the time limits of the workday. Our data suggest that a brief high-intensity option satisfies both criteria, i.e. it was chosen by the majority of workers (130 of 207) and delivered superior functional gains without sacrificing acceptability. On the other hand, stretching remains a reasonable, well-tolerated entry point for pain relief and for workers with lower readiness for high-intensity exercise. Because preserving muscular strength and functional capacity is itself protective when job demands approach a worker's functional ceiling [7], the strength-related advantage is likely to matter most for the physically demanding roles that predominated in this sample.

Strengths and limitations

The principal strengths of this study are its high ecological validity, its use of objective functional measures alongside validated questionnaires, its multi-worksite recruitment, and a pragmatic format with direct implementation relevance. Several limitations should also be acknowledged. First, the non-randomized, preference-based design produced groups that were not exchangeable at baseline. Thus, participants who chose stretching were heavier and more often performed heavy or fast-paced manual work, whereas those who chose strength were leaner and more often office-based, and smoking status also differed. Although ANCOVA adjusted for these and other confounders (age, sex, occupational category, physical activity at work, physical activity at leisure time and smoking status), residual and unmeasured confounding cannot be excluded. Also, self-selection limits causal inference, particularly for subjective outcomes such as pain. Second, the absence of a no-intervention control means that natural history, regression to the mean, and familiarization effects cannot be fully ruled out. This is especially relevant for the sit-to-stand test, where a learning component may inflate apparent gains in both groups. Third, the 8-week horizon provides no information on durability, retention, or longer-term adherence. Finally, pain and work ability were self-reported and thus susceptible to placebo and expectation effects.

Conclusion

In a real-life occupational setting where workers chose their preferred active break, a brief high-intensity strength program produced superior improvements in functional capacity and muscular strength compared with a conventional stretching program, while both modalities improved pain-related outcomes to a similar degree. The comparable pain response may reflect shared non-specific effects of movement and, plausibly, the preference effect inherent to a design in which everyone received their chosen program. Together these findings support the feasibility and health value of preference-based active breaks in the workplace, while underscoring the need for adequately powered randomized and longer-term trials to isolate the specific contribution of each type of intervention.

Statements and Declarations

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Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Author contributions

IP and JTU conceived the study and designed the methodology. Iñigo Perez Garcia IP, Amaya Irazusta AI, and Idoia Zarrazquin-Arizaga IZA performed participant assessments and collected the data. Natalia Burgos Alonso NBA performed the statistical analyses. Iñigo Perez Garcia IP and Lars Louis Andersen LLA drafted the manuscript. Jon Torres-Unda JTU supervised the study and the overall research process. All authors critically reviewed the manuscript, approved the final version, and agreed to be accountable for all aspects of the work.

Ethics approval

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee for Research involving Human Beings of the University of the Basque Country (UPV/EHU) (Official Reference No.: M10/2025/322).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Data Availability

The datasets generated and analyzed during the current study are not publicly available due to institutional data protection policies and confidentiality agreements with the participating companies and the occupational health insurer, but are available from the corresponding author on reasonable request.

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Tables

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Age ≥ 18 years	Pregnancy
Current employment contract	Surgery within the previous month
Ability to perform light-to-moderate physical exercise	Medical contraindication to physical activity

Table 2. Baseline characteristics of the total sample and the two intervention groups. Values are presented for the total sample and separately for participants who selected the stretching or strength active-break program. Continuous variables are reported as mean (SD) or median [IQR] as appropriate, and categorical variables as n (%).

Between-group differences at baseline were analyzed using the Mann–Whitney U test or Student’s t test for continuous variables, as appropriate, and chi-square test for categorical variables

Variable	Total Sample (N = 207)	Stretching Group (n = 77)	Strength Group (n = 130)	p value
Age, mean (SD)	44 (9,79)	47,72 (8,86)	43,12 (9,98)	< 0,001**
Anthropometrics, median (SD)				
Height (cm)	175 [14]	175 [15.5]	175 [12]	0.034*
Weight (kg)	77 [19]	82 [17.5]	75 [21]	0.003**
Body Mass Index (kg/m²)	25.40 [5.60]	26.29 [5.82]	25.00 [5.50]	0.021*
Gender, n (%)	201 (100%)			0.153
Men	155 (74.9%)	61 (79.2%)	94 (72.3%)	
Women	45 (21.7%)	12 (15.6%)	33 (25.4%)	
Other	1 (0.5%)	0 (0.0%)	1 (0.8%)	
Occupational category, n (%)	198 (100%)			0.009**
Office, administration, analysis, or computer work	19 (9.2%)	1 (1.4%)	18 (14.4%)	
Work involving people, service, or caregiving	9 (4.3%)	2 (2.7%)	7 (5.6%)	
Work involving handling, production, or transportation of objects	142 (68.6%)	56 (76.7%)	86 (68.8%)	
Other	28 (13.5%)	14 (19.2%)	14 (11.2%)	
Physical activity at work, n (%)	198 (100%)			0.016**
Mainly sedentary work, with no physical exertion	27 (13.6%)	9 (12.5%)	18 (14.3%)	
Mainly standing or walking, with no substantial physical exertion	19 (9.6%)	1 (1.4%)	18 (14.3%)	
Standing or walking work that includes lifting or carrying objects fairly often	100 (50.5%)	36 (50.0%)	64 (50.8%)	
Heavy or fast-paced work requiring physical exertion	50 (25.3%)	25 (34.7%)	25 (19.8%)	
Other	2 (1.0%)	1 (1.4%)	1 (0.8%)	
Leisure-Time Physical Activity, n (%)	188 (100%)			0.794
I read, watch television, or perform sedentary activities	71 (37.8%)	26 (38.8%)	45 (37.2%)	
I walk, cycle, or perform other light physical activity at least 4 hours per week (including walks, light gardening, or walking/cycling to work)	59 (31.4%)	23 (34.3%)	36 (29.8%)	
I participate in recreational sports or perform heavy gardening at least 4 hours per week	33 (17.6%)	11 (16.4%)	22 (18.2%)	

I train intensely and participate in competitive sports several times per week	25 (13.3%)	7 (10.4%)	18 (14.9%)	
Smoking status, n (%)	200 (100%)			0.027*
Yes, every day	45 (22.5%)	11 (15.1%)	34 (26.8%)	
Yes, but not every day	11 (5.5%)	5 (6.8%)	6 (4.7%)	
No, I quit	64 (32.0%)	32 (43.8%)	32 (25.2%)	
No, I have never smoked	80 (40.0%)	25 (34.2%)	55 (43.3%)	
Session completed, mean (standard deviation)	15.46 (11.23)	15.66 (11.88)	15.89 (10.86)	0.850
Percentage of completion (of 40 sessions), %	38,65 (28.09)	39.15 (29.71)	39.73 (27.15)	

Note: SD standard deviation, IQR interquartile range.

*Statistically significant at $p < 0.05$

**Statistically significant at $p \leq 0.01$

Table 3. Pre- to postintervention changes in work ability, pain-related outcomes, and physical function in the stretching and strength groups. Values are presented as mean (SD) before and after the 8-week intervention, with percentage change from baseline and within-group p values. Between-group p values represent ANCOVA comparisons of postintervention change between the stretching and strength groups, adjusted for baseline differences and relevant confounders

	STRETCHING				STRENGTH				
Variable	**PRE, Mean (SD)**	**POST, Mean (SD)**	**Δ%**	**Within-group p-value**	**PRE, Mean (SD)**	**POST, Mean (SD)**	**Δ%**	**Within-group p-value**	**Between-group p-value (ANCOVA)**
Work ability	7.54 (1.46)	7.38 (1.68)	-2.12%	0.370	7.71 (1.59)	7.97 (1.42)	3.37%	0.065	0.098
Back pain	4.75 (2.72)	4.32 (2.64)	-9.05%	0.172	4.26 (2.82)	3.78 (2.73)	-11.27%	0.117	0.742
Neck and shoulder pain	5.02 (2.56)	4.25 (2.68)	-15.34%	0.020*	4.76 (2.8)	4.27 (2.97)	-10.29%	0.107	0.997
Arm pain (elbow, hand, wrist)	4.49 (3.02)	4.18 (3.23)	-6.90%	0.308	4.25 (3.12)	3.56 (3.15)	-16.24%	0.017*	0.192
Sum of pain across the 3 areas	14.27 (6.5)	12.8 (7.33)	-10.30%	0.044*	13.2 (7.11)	11.77 (7.35)	-10.83%	0.027*	0.557
Pain frequency	3.55 (1.26)	3.22 (1.3)	-9.30%	0.008**	3.1 (1.14)	2.87 (1.24)	-7.42%	0.018*	0.986
Pain-related work limitation	2.17 (1.06)	1.91 (1.01)	-11.98%	0.018*	2.11 (1.12)	1.78 (0.96)	-15.64%	0.001**	0.552
30-second sit-to-stand test (reps)	19.48 (5.77)	24.59 (6.44)	26.23%	< 0.001**	19.49 (5.75)	28.06 (5.69)	43.97%	< 0.001**	< 0.001**
Mean handgrip strength	44.85 (10.81)	46.29 (11.45)	3.21%	0.012**	39.88 (10.09)	44.22 (11.73)	10.88%	< 0.001**	< 0.001**
Mean shoulder abduction strength	11.46 (3.44)	11.95 (3.25)	4.27%	0.020*	10.65 (3.49)	12.16 (3.88)	14.17%	< 0.001**	< 0.001**

Note: Values are presented as Mean (Standard Deviation) unless otherwise indicated. Δ% indicates percentage change from baseline to post-intervention.

*Statistically significant at $p < 0.05$

**Statistically significant at $p \leq 0.01$

Figures

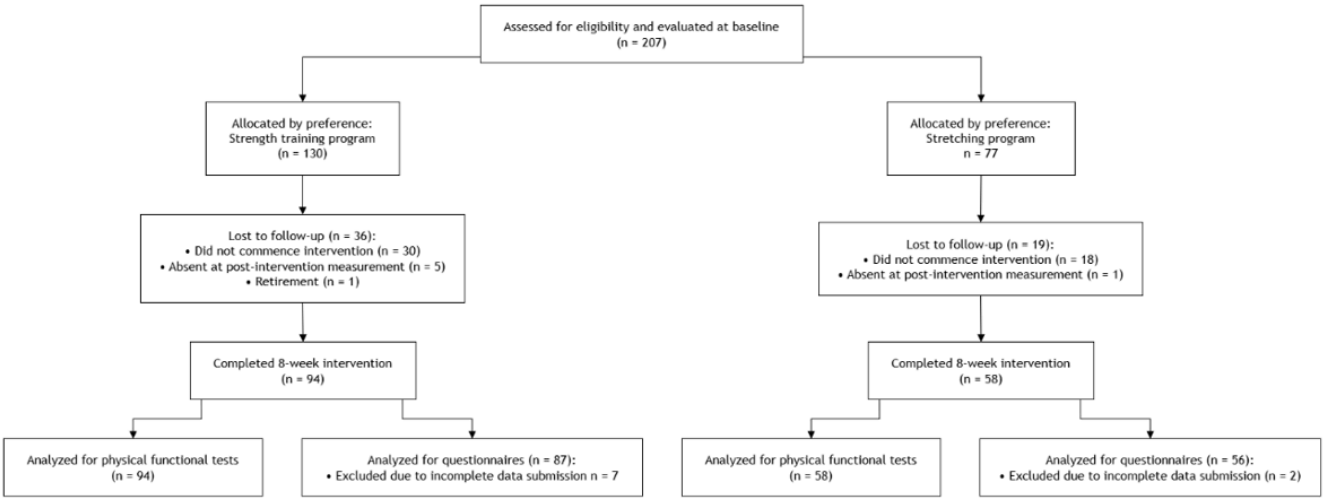


Figure 1

Flow of participants through the study.