

BMJ Open Evaluation of 'I-Preventive': a digital preventive tool for musculoskeletal disorders in computer workers – a pilot cluster randomised trial

C Lanhers,^{1,2,3,4} B Pereira,⁵ G Garde,⁶ C Maublant,⁶ F Dutheil,^{1,3,7,8} E Coudeyre^{2,9}

To cite: Lanhers C, Pereira B, Garde G, *et al.* Evaluation of 'I-Preventive': a digital preventive tool for musculoskeletal disorders in computer workers—a pilot cluster randomised trial. *BMJ Open* 2016;**6**:e011304. doi:10.1136/bmjopen-2016-011304

► Prepublication history and additional material is available. To view please visit the journal (<http://dx.doi.org/10.1136/bmjopen-2016-011304>).

Received 27 January 2016
Revised 18 June 2016
Accepted 5 July 2016

ABSTRACT

Objectives: I-Preventive is a digital preventive tool for musculoskeletal disorders (MSDs) in computer workers. We sought to determine its impact on pain in computer workers with upper limb MSDs and visual discomfort.

Methods: We conducted a pilot cluster randomised trial in 2 different sites of a tyre factory in France. We randomised 200 employees to either an intervention group (I-Preventive) or control group, each comprising symptomatic and asymptomatic employees. The workers were followed up for 5 months. The main outcome was overall recovery from symptoms following 1 month's intervention based on Nordic-style and eyestrain questionnaires.

Results: We included 185/200 workers: 96 in the intervention group (mean age 41.8±1.4 years; 88.5% males) and 79 in the control group (mean age 42.9±12.0 years; 94.5% males). The most painful areas (numerical scale ≥2) were the neck (40.0%), upper back (18.8%) and shoulders (15.7%). For the most painful anatomical area, the Nordic score significantly decreased after 1 month in the intervention group (p=0.038); no change was observed in the control group (p=0.59). After 1 month's use, the intervention group reported less pain in the painful area and less visual discomfort symptoms (p=0.02). Adherence to the I-Preventive program was 60%.

Conclusions: I-Preventive is effective in the short term on musculoskeletal symptoms and visual discomfort by promoting active breaks and eyestrain treatment. This easy-to-use digital tool allows each worker to focus on areas of their choice via personalised, easy exercises that can be performed in the workplace.

Trial registration number: NCT02350244; Pre-results.

Strengths and limitations of this study

- Some software programs were built to promote frequent breaks at work for visual display unit users but only very few tools were evaluated with a high level of proof.
- The novelty of the I-Preventive strategy is its implementation of frequent short daily active breaks promoted by a software program, which can only be achieved within a prevention-oriented organisational culture.
- The I-Preventive software program is particularly effective in the short term due to its individualised and personalised form, allowing workers to focus on areas of their choice by offering exercises that are easily performed in the workplace.
- Despite this digital tool being easy to use, adherence decreased over time, and its favourable impact was not maintained over the long term.
- Future studies should comprise objective measures of physical performance and effectiveness at work in order to establish cost-effectiveness benefits based on economic analyses.

on society.² There is, however, still no consensus on their precise definition. MSD is a broad term encompassing a range of degenerative, dysfunctional and inflammatory conditions affecting the musculoskeletal system.¹ These heterogeneous definitions can make drawing comparisons between studies difficult. Although the prevalence rates of MSD vary widely depending on the body part considered and tools used for symptom assessment, they can exceed 30%.^{3 4} When considering a global approach, multisite symptoms were predominant (33–66% of workers) over those strictly confined to a specific anatomical site (15–30% of workers).⁴

The major risk factors for MSD are repetitive movements, high muscular strength demands, awkward or extreme positions, rapid work pace, extreme temperatures, insufficient recovery time, mechanical



CrossMark

For numbered affiliations see end of article.

Correspondence to

Dr C Lanhers; lanhers.charlotte@gmail.com

INTRODUCTION

Musculoskeletal disorders (MSDs) in the working population currently represent one of the most worrying work-related health issues,¹ with considerable economic burden

pressure and segmental vibrations.⁵ Additional workplace-related risk factors include psychosocial factors, such as high demands and low decision latitude.^{6,7} In particular, MSDs are the most prevalent disorders among sedentary workers, especially those using visual display units (VDUs).⁸ The most frequent musculoskeletal symptoms occur in the neck and shoulder area, with a prevalence of up to 62% reported in VDU workers.⁹

Musculoskeletal symptoms of VDU users have multifactorial aetiologies, such as non-neutral wrist, arm and neck postures, workstation design and duration of VDU exposure, as well as perceived job strain with low decision latitude and high workload.^{10,11} Long-duration computer work without breaks has also been related to eye injury, as duration of mouse use has been to neck and upper extremity symptoms.¹²

We are therefore convinced that appropriate MSD-preventive tools for VDU workers are urgently required. These tools must be clinically evaluated by providing evidence-based medical data. Interventions aimed at reducing MSDs in VDU workers should be aimed at both physical/ergonomic and organisational/psychosocial work factors, and must be supported by managers in order to ensure worker adhesion to the intervention.⁹ The majority of strategies have focused on new workstation design,¹³ yet their effectiveness remains highly questionable. Strategies could be more effective if they were to implement changes in the temporal pattern of the work task, such as supplementary rest breaks allowing for periods of recovery from the monotonous load.¹⁴ The effect of exercise on MSD symptoms has recently been demonstrated in workers.¹⁵ In addition to exercise, rest breaks, and especially frequent 'microbreak',¹⁶ have been shown to reduce discomfort, eyestrain, fatigue and mood disturbances, in addition to improving keystroke speed and accuracy. Some software programs were built to promote frequent breaks at work for VDU users. These breaks can be active, with stretching exercises during working days. However, only very few tools were evaluated with a high level of proof (Wellnomics Breaks).¹⁴ Within a large French tyre factory, a taskforce was convened including physicians, nurses, prevention engineers and a sports teacher, aiming to evaluate an online tool called 'I-Preventive', which promotes active breaks with stretching exercises.

Our principal aim was thus to estimate the effects of I-Preventive on MSDs and visual discomfort.

METHODS

Design

A pilot cluster randomised trial was proposed within a tyre factory in France. This study aimed to measure the impact of I-Preventive on MSD symptoms and therefore define the optimal effect sizes for calculating the sample size required for a larger cluster-randomised controlled trial. As we did not focus on a putative cluster effect, in

order to maintain a suitable methodology, an independent statistician conducted the randomisation of four participating departments using table random. The workers were randomised into an intervention group (I-Preventive) and control group, with each containing participants with MSDs. Workers located on the same floor or in the same building were assigned to the same group in order to avoid contamination bias, to maintain blinding and enhance adherence to the program within the intervention group, as well as to implement the study in a regular work environment. Researchers were composed of two occupational physicians (CL and GG). GG was in charge of selection and inclusion. CL was in charge of the data treatment under blind conditions to the treatment group. This study was conducted from June to October 2014. Measurements were made with repeated data requests. All employees corresponding to the inclusion criteria received a summary of the study, which was considered a non-opposition form. This non-pharmacological trial was designed in accordance with the Consolidated Standards of Reporting Trials statement (CONSORT).¹⁷

Participants

The participating workers were recruited from a potential 200 employees of the research departments. The inclusion criteria required participants to be employees aged 18–65 years, completing at least 5 hours of VDU work per day, receiving no treatment for rheumatic or neurological diseases, undergoing no changes in VDU/workstation apparatus, having taken no sick leave in the previous month, and exhibiting no behavioural/learning disorders. Only administrative staff and no blue-collar workers were thus included.

Intervention

Workers in the intervention group received an activation code to download the software program (I-Preventive, <http://www.i-preventive.com>) on their VDU. I-Preventive promoted active breaks via an individualised computer application. It allowed workers to focus on body regions of their choice, offering high flexibility. After selecting the body part, I-Preventive asked about symptoms and suggested appropriate exercises. Workers could follow the suggested personalised exercises or use the random mode. At regular intervals, a visual signal on the screen prompted VDU workers to take active breaks. The visual signal described short individualised exercises of no more than 1½ min. The exercises were easy to perform and most could be carried out while seated without needing specific equipment (figure 1). The following steps for the use of I-Preventive were:

Step 1: select the body part; the system asks the operator to associate a symptom and suggests the appropriate exercises.

Step 2: select the usage either by following the individualised default form or using the random mode.

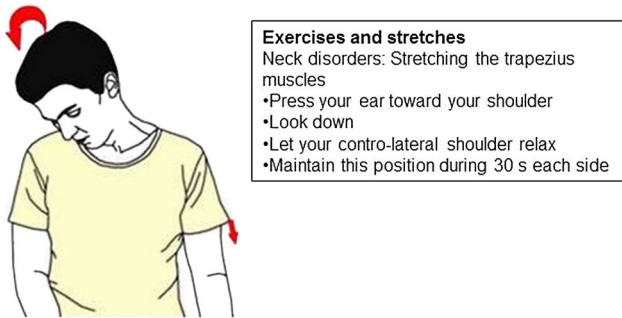


Figure 1 Example of an exercise presented on the screen during a prompted rest break (from I-Preventive).

Step 3: participants are prompted by a signal on the screen also called «the health bar» to take a rest break every 2 hours. They are stimulated to perform physical exercises (lasting 30 s to 1½ min each) at the start of each rest break. Users can programme one to four active breaks daily.

During the remaining period of the rest break, the computer was not blocked, and the participants could delay active break later by clicking on the button «later». Generally, workers postponed breaks when they were in meetings, on average, once or twice a day. The software offered worksheets that could be downloaded, printed at the workplace and used as information tools. These worksheets were composed of physical exercises for each body part. Then employees could realise exercises out of daily breaks proposed by the computer and out of the office. The intervention lasted 4 months.

The control group received usual healthcare with the occupational physician.

Baseline assessments

All participants (intervention and control groups) completed the same questionnaires.

MSDs were evaluated by the Nordic-style questionnaire, validated in 2007 as a useful tool for monitoring work-related MSDs, especially if respondents included a numerical rating scale pertaining to symptom severity.¹⁸ It is derived from the original Nordic questionnaire published in 1987 that was then translated into French in 1994.¹⁹ The Nordic questionnaire included a numerical pain scale ranging from 0 to 10 for each anatomical region.

Eyestrain assessment covered various symptoms like headache, blurred vision or eye stinging, by means of a horizontal numerical scale from 0 to 10,²⁰ commonly used by the French National Institute of Research and Prevention (INRS).

Global psychological status was evaluated on the Hospital Anxiety and Depression Scale (HAD).²¹ The HAD is a 14-item self-report measure that was specifically developed to assess anxiety and depression. It is considered to be an effective means of screening for anxiety and

depression and is widely used. It has two subscales, one assessing anxiety (HAD-A) and the other assessing depression (HAD-D). The scores for each subscale range from 0 to 21. Psychosocial work characteristics were measured using a horizontal visual analogue scale (VAS) for both stress^{22 23} and satisfaction at work.²⁴ This test assesses the perceived stress level of individuals at work on a horizontal, non-calibrated line of 100 mm, ranging from very low (0) to very high (100).

Physical activity and sedentary behaviour were measured by means of the International Physical Activity Questionnaire (IPAQ).^{25 26} The IPAQ instruments have acceptable measurement properties for monitoring population levels of physical activity among adults aged 18–65 years in diverse settings, at least as good as other established self-reported questionnaires.

Sociodemographic characteristics (gender, age, work position, etc) were also recorded.

Follow-up assessments

All baseline assessments were repeated at 1 (M1), 2 (M2), 3 (M3) and 4 months (M4), with the exception of VAS stress/satisfaction and HAD, which were not measured at M2 and M3. Sociodemographic characteristics were only compiled at baseline.

To verify whether the participants performed the exercises or not (adherence), we had to rely on their monthly individual reports at M1, M2, M3 and M4.

At M4, the intervention group was asked to give feedback on the software, recommended breaks and exercises.

Outcomes

The main outcome was the overall decrease in musculo-skeletal symptoms at M1, assessed by means of the Nordic-style and eyestrain questionnaires, in addition to the change in number of asymptomatic workers (numerical value <2 on the Nordic-style questionnaire).

Secondary outcomes included long-term follow-up of the Nordic-style and eyestrain questionnaires at M2, M3 and M4; changes in global psychological status (HAD) between M0 and M4; evolution of physical activity and sedentary behaviour; number of sick leave days. Adherence to the program was assessed at M1, M2, M3 and M4 in order to investigate a dose–response relationship, using a self-reported questionnaire indicating a frequency of use from the following options: less than once a week, a few times a week, once every day and several times every day.

Statistical considerations

According to the novelty of our research, it appeared difficult to estimate an optimal sample size for the main end point of this study to assess software promoting active breaks using exercises with the aim of treating MSD and visual discomfort in VDU workers. Sample size has been estimated according to Cohen's recommendations²⁷ which have defined effect-size bounds as: small

(ES: 0.2), medium (ES: 0.5) and large (ES: 0.8, 'grossly perceptible and therefore large'). We calculated that 64 workers per group would enable an effect size equal to 0.5 for a type I error $\alpha=0.05$ (two-tailed) and statistical power of 80%, which corresponds to a minimal difference in terms of primary end point Nordic score equals 1.5 points (for an SD at 3).

Considering possible loss to follow-up (rate fixed at 25%), we finally chose to include a minimum of 80 VDU workers per group. Statistical analysis was performed using Stata software, V.13 (StataCorp, College Station, Texas, USA). The tests were two-sided, with a type I error set at $\alpha=0.05$. Baseline characteristics were presented as mean \pm SE or median (IQR) according to statistical distribution for continuous data, and the number of workers and associated percentages for categorical parameters. Comparisons among independent groups (workers accessing I-Preventive or not) were performed by Student's t-test, or by the Mann-Whitney U test if t-test conditions could not be respected (homoscedasticity analysed by the Fisher-Snedecor distribution). Comparisons between qualitative parameters of the independent groups were performed by χ^2 test or, if necessary, Fisher's exact test. For the evolution of the longitudinal Nordic study (and visual discomfort score), mixed models (the linear models for the Nordic score considered a quantitative or generalised linear for the proportion of VDU workers with Nordic scores above a given threshold, in line with the literature¹⁸) were proposed in order to take into account the difference between and within individual variability (random effect) while studying the fixed group effects, time and interaction. The normality of residuals was assessed and gender, age, site, and original pain or discomfort were studied in previous models as covariates (fixed effects). Workers' frequency of I-Preventive use (before or after holidays) was also recorded, particularly in the context of a specific intragroup analysis of workers who had access to the I-Preventive software. Finally, this was complemented by analyses that were situation-matched to the parameters collected at only two time points (M0 and M4 for HAD, with the usual tests applied: Student's paired t-test or the Wilcoxon signed-rank test for quantitative parameters and the Stuart-Maxwell test for categorical variables).

RESULTS

Participants

Among the 200 employees invited, 185 (93%) agreed to participate. Of these, 11 (6%) were excluded from the analysis due to disease, maternity leave, interim status, retirement and change in job. We thus included 175 employees, 96 assigned to the intervention group and 79 to the control group (figure 2). At *baseline*, the groups did not differ in terms of the percentage of workers suffering from each painful anatomical part ($p=0.62$), nor for the maximal pain assessed by the Nordic

questionnaire ($p=0.2$). They differ at baseline, with the percentage of females and sedentary time, with the control group including less females ($n=2$, 2.5% vs 11.5%, $p=0.04$) and exhibiting a lower level of sedentary lifestyle (530.6 ± 0.8 vs 610.2 ± 0.9 min/day, $p=0.04$; see online supplementary tables S1 and S2).

Digital tool acceptability

Exercises were carried out by 58% of participants in random mode and by 42% following the individualised software suggestions. The primary anatomical parts exercised were the neck (74.4%), eyes (51.3%), hands (41.9%), elbows (37.8%), lower back (36.5%) and shoulders (35.1%). At M4, overall satisfaction with the digital tool was 43%, with 90% of participants reporting that the tool was simple to use or the exercises easy to perform. However, 35% of employees had some technical difficulties in using the tool, 39% experiencing concentration problems and 64% having problems coordinating the active breaks with their work. We consider that <25% of the employees postponed the breaks. Adherence decreased throughout the intervention, from 60% of employees using I-Preventive every day (once or several times) at M1 to 37% at M4 ($p<0.01$). Overall, 40% of participants declared feeling better with active breaks when working on the computer.

Primary outcomes

The most painful anatomical parts (numerical value ≥ 2) were the neck (40.1%), lower back (35.7%), upper back (18.8%) and shoulder (11.7%). The majority reported one or two painful locations (62.7%), 17.9% reported three locations and 8.9% reported four.

In *longitudinal follow-up with quantitative analysis*, the maximum Nordic score did not differ between groups at M1 using analysis of covariance ($p=0.44$). In a complete multivariate model and after adjustment for Nordic score at baseline, sedentary time, memorising and maximum Nordic score tended to decrease, though not significantly so ($p=0.18$). However, on studying the fixed-group effects based on a longitudinal evolution of maximum Nordic score, we observed a significant difference at M1 for the intervention group ($p=0.038$) versus baseline and no difference for the control group ($p=0.59$; figure 3).

In *longitudinal follow-up with qualitative analysis*, the percentage of body parts with a Nordic score ≥ 2 did not differ at M1 using random-effect logistic model analysis, compared with the control group ($p=0.18$). For longitudinal analysis in intragroups, this parameter had significantly decreased at M1 in the intervention group ($p=0.02$), versus the control group ($p=0.57$; figure 4).

For both the quantitative and qualitative analyses, no significant difference was found between the groups at the end of the study, even though a trend of decrease at M2 was observed ($p<0.01$).

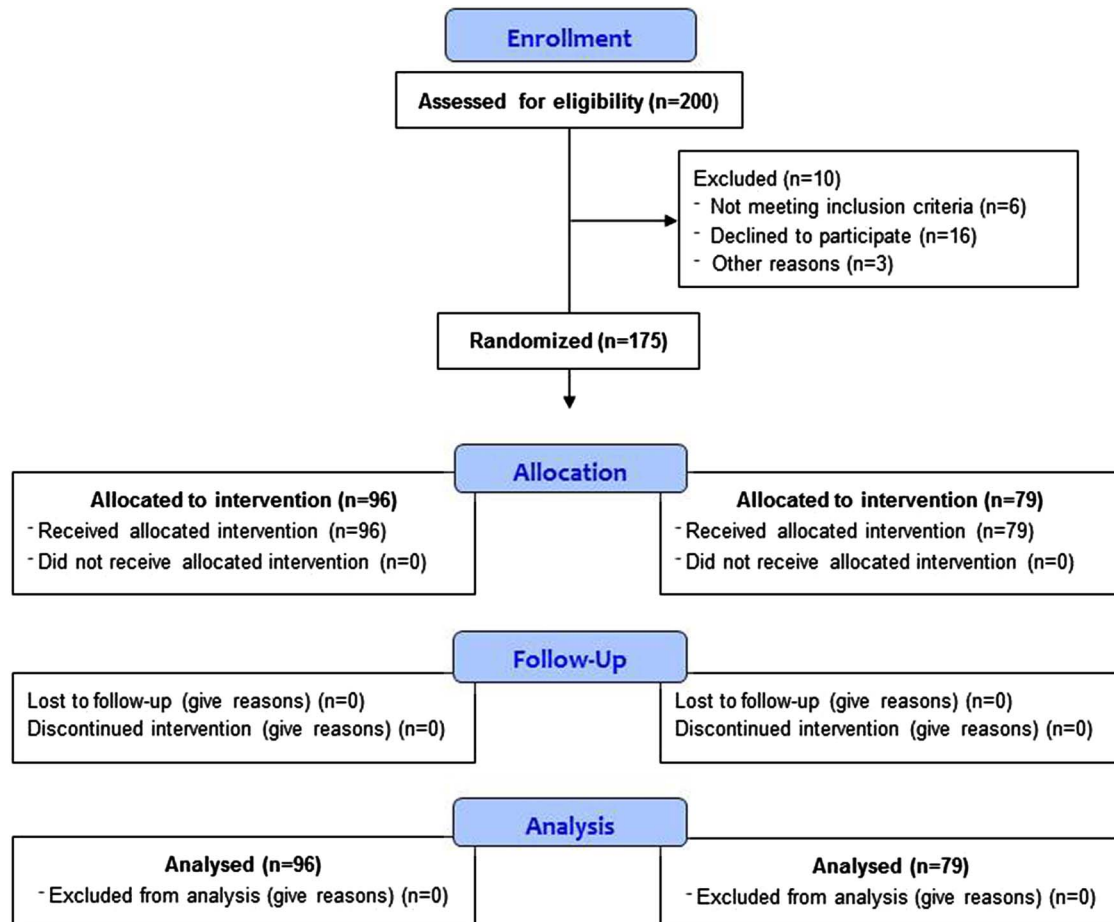


Figure 2 Flow diagram.

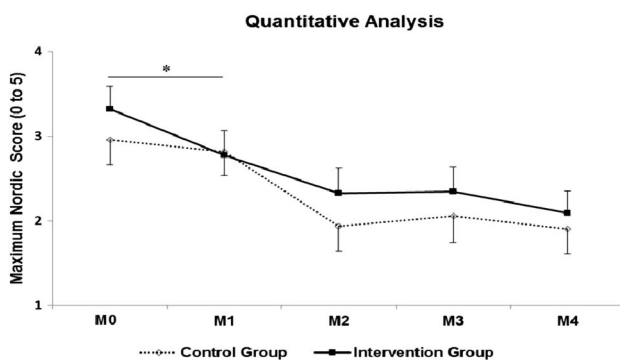


Figure 3 Longitudinal evolution of maximum NORDIC score. * $p < 0.05$. The fixed group effects with longitudinal evolution of maximum NORDIC score emphasised a significant difference at month 1 (M1) for the intervention group ($p = 0.038$) and no difference for the control group ($p = 0.59$). The covariates were chosen according to univariate results and clinical relevance: age, site, and baseline pain or discomfort.

Secondary outcomes

At baseline, eyestrain did not differ between groups. The symptoms were loss of eyesight (55.2% of participants), eye stinging (48.8%), glare (48.8%), blurred vision (44.2%), headache (34.8%) and eye irritation (23.2%).

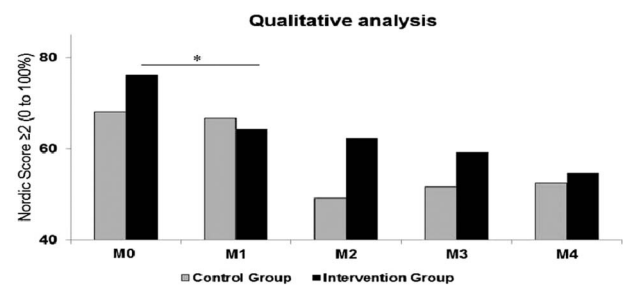


Figure 4 Percentage of body areas with a NORDIC score ≥ 2 . * $p < 0.05$. The fixed group effects with longitudinal evolution of NORDIC score ≥ 2 emphasised a significant difference at month 1 (M1) for the intervention group ($p = 0.02$) and no difference for the control group ($p = 0.57$). The covariates were chosen according to univariate results and clinical relevance: age, site, and baseline pain or discomfort.

At M1, visual discomfort significantly decreased for the quantitative (maximum visual score) and qualitative longitudinal analyses (visual symptoms ≥ 2) in the intervention group ($p = 0.025$ and $p = 0.02$, respectively), with no change observed in the control group ($p = 0.65$ and $p = 1.0$, respectively). No significant difference was found at the end of the study.

The intervention program did not exhibit significant impact on work stress, work satisfaction, anxiety or depression symptoms, and no links were established between stress, anxiety or depression and MSD or ocular symptoms.

We recorded four sick leaves in the intervention group corresponding to psychiatric or surgical diseases, with none linked with MSD. There were no sick leaves within the control group.

Subgroup analysis

On analysing the subgroups, the longitudinal evolution of the Nordic score was more effective for employees using the individualised software form ($p=0.009$). Those who were happy to use I-Preventive tended to have less painful localisations, reporting a pain score <2 ($p=0.12$). Baseline Nordic scores (<2 or ≥ 2) did not influence the benefits of intervention. Adherence to I-Preventive was not linked to greater benefits in MSD symptoms, evaluated by the Nordic questionnaire, even following adjustment for age and gender.

DISCUSSION

Main findings

Our pilot cluster randomised trial demonstrated the potential of active breaks to reduce MSD symptoms and eyestrain. The I-Preventive software program was shown to be particularly effective in the short term in its individualised and personalised form, allowing workers to focus on areas of their choice by offering exercises that are easy to perform at the workplace. However, despite this digital tool being easy to use, adherence decreased over time, so that this favourable impact was not maintained over the long term.

Validated methods for the prevention of MSD

Prevention of MSD should be based on an integrative approach combining ergonomics and physical activity interventions.¹³ In ergonomics, no clear positive impact has been demonstrated by single intervention programmes, such as workstation adjustments (technical), rest breaks (organisational) or ergonomic training (behavioural) on work-related MSD. However, when these specific interventions were included in a combined approach, they became more effective.¹³ Physical activity interventions at the workplace demonstrated benefits on computer worker MSDs, consisting of either 20–30 min training sessions two or three times a week²⁸ or short daily active breaks,²⁹ in addition to either stretching and joint mobilisation exercises or strength training and dynamic endurance training.³⁰ These studies involved a coach or physical therapist to motivate the participants.³⁰ Training sessions appear to have more pronounced long-term effects than short daily active breaks, in accordance with our study findings.³⁰ The I-Preventive software program is particularly effective at 1 month but has no long-term effects. Conflicting

results reported in the literature could be explained by the high risk of bias from the studies due to an unknown random allocation procedure, as well as insufficient motivation to exercise or lack of intention-to-treat analyses.³¹ The novelty of the I-Preventive strategy is its implementation of frequent short daily active breaks promoted by a software program.

A novel digital tool for the prevention of MSD

Computer usage and sedentary behaviour at the workplace has increased dramatically over the past decade.³² Office workers thus remain in the same posture for longer, accompanied by long periods of keyboard usage, which can cause and aggravate MSDs. Paradoxically, several software programs have been implemented to promote exercise at the workplace and reduce MSD. Despite the promotion of exercise through software, however, programs have been largely developed for chronic diseases like type 2 diabetes,³³ and these digital strategies were rarely implemented at the workplace for health outcomes in general³⁴ and especially not for preventing MSD.¹⁴ As for the use of a computerised decision support system for primary and secondary prevention of work-related MSD disability, only one study tried to improve MSD prevention by analysing the ergonomic process through self-reported questionnaires from a software tool.³⁵ Moreover, only two studies used a software program to specifically reduce MSD. The results from the short-term pilot study conducted on a low sample size supported the theory that this type of exercise reminder software programs may help to reduce perceived pain among office workers.³⁶ In accordance with our findings, the use of a software program encouraging workers to take regular breaks has been reported elsewhere to contribute to perceived recovery from neck and upper limb symptoms.¹⁴ Nevertheless, our study was not designed to assess the specificity of breaks or exercise in MSD prevention,¹⁴ and long-term studies involving more participants should now be conducted so as to describe the effects of these programs and underlying mechanisms.

General health effects of our intervention

Overall, the neck, shoulders, and upper and lower back were the most affected regions among our computer users, in line with the literature.³¹ Moreover, computer-related visual and ocular symptoms are the most frequently occurring health problems in people who spend a large proportion of their working day looking at a computer screen.³⁷ Given the high prevalence of these symptoms,³⁸ it is likely that all VDU workers will at some point need eye examinations in order to assess symptoms associated with VDU use. Furthermore, visual and musculoskeletal discomfort have been intrinsically linked together.³⁹ To the best of our knowledge, our study was the first to simultaneously evaluate and reduce MSDs in combination with ocular symptoms.^{40 41}

Limitations

Our study had some limitations. One could argue that the inclusion number was low, yet the sample size was relatively large compared with other pilot studies, and the percentage of participants who agreed to participate was exceptional (>90%),⁴² with none lost to follow-up. This good representation of computer workers thus reduced potential bias and allowed us to generalise results for other services. The protocol was carried out in a high-demand working environment, and thus may easily be translated to other areas. Also, the decreasing adherence throughout the study could have been caused by the summer holidays falling between M1 and M2, or a decrease in job demand for those who did not go on holiday, which may have lowered the impact of our intervention on MSD. In addition, some found it impossible to adapt active breaks to their specific working schedules, which, along with software defects, also most likely contributed to the decreasing adherence. Finally, the software was not designed to evaluate the objective measure of adherence to the program, such as the number of connections or amount of time spent on the tool. Furthermore, physical symptoms were not clinically assessed by a physician; however, subjective scales have been validated and are commonly used both in routine practice and research.¹⁸ Future studies should comprise objective measures of physical performance and effectiveness at work in order to establish cost-effectiveness benefits based on economic analyses.

CONCLUSION

Our pilot feasibility study demonstrated the potential of active breaks for preventing MSDs and ocular symptoms. The I-Preventive software program is particularly effective in the short term due to its individualised and personalised form, allowing workers to focus on areas of their choice by offering exercises that are easily performed in the workplace. However, despite this digital tool being easy to use, adherence decreased over time, and its favourable impact was not maintained over the long term.

Author affiliations

¹Department of Preventive and Occupational Medicine, University Hospital of Clermont-Ferrand (CHU), Clermont-Ferrand, France

²Department of Physical Medicine and Rehabilitation, University Hospital of Clermont-Ferrand (CHU), Clermont-Ferrand, France

³Department of Psychological & Psychosocial Stress, CNRS UMR 6024, University of Clermont Auvergne, Clermont-Ferrand, France

⁴Clermont Auvergne University, France

⁵University Hospital of Clermont-Ferrand (CHU), Clinical Research and Innovation Direction, Clermont-Ferrand, France

⁶Michelin, Clermont-Ferrand, France

⁷Faculty of Health, Australian Catholic University, School of Exercise Science, Melbourne, Victoria, Australia

⁸Laboratory of Metabolic Adaptations to Exercise in Physiological and Pathological Conditions (AME2P, EA3533), University of Clermont Auvergne, Clermont-Ferrand, France

⁹INRA, Human Nutrition Unit UMR1019, Clermont-Ferrand, France

Acknowledgements The authors are grateful to the Cremer Consulting medical writing agency for their English proofreading and editing of the manuscript.

Contributors BP performed the majority of the statistical analysis and contributed to the interpretation of data and writing of the report. EC, GG, CM and CL supervised the conduct of the control study. CL, GG and CM contributed to data collection. CL, EC and FD contributed to the interpretation of data and writing of the report. All authors have contributed to the revision of the manuscript and have approved the final version.

Funding This work was supported by Michelin, Clermont-Ferrand, France.

Competing interests None declared.

Ethics approval The study was approved by the Sud-Est 6 medical ethics committee of the University Hospital of Clermont-Ferrand, France (IRB00008526, ClinicalTrials.gov identifier: NCT02350244).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement No additional data are available.

Open Access This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

REFERENCES

1. Parot-Schinkel E, Descatha A, Ha C, *et al*. Prevalence of multisite musculoskeletal symptoms: a French cross-sectional working population-based study. *BMC Musculoskelet Disord* 2012;13:1471–2474.
2. Henderson M, Glozier N, Holland Elliott K. Long term sickness absence. *BMJ* 2005;330:802–3.
3. McBeth J, Jones K. Epidemiology of chronic musculoskeletal pain. *Best Pract Res Clin Rheumatol* 2007;21:403–25.
4. Solidaki E, Chatzi L, Bitsios P, *et al*. Work-related and psychological determinants of multisite musculoskeletal pain. *Scand J Work Environ Health* 2010;36:54–61.
5. Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *J Electromyogr Kinesiol* 2004;14:13–23.
6. Kraatz S, Lang J, Kraus T, *et al*. The incremental effect of psychosocial workplace factors on the development of neck and shoulder disorders: a systematic review of longitudinal studies. *Int Arch Occup Environ Health* 2013;86:375–95.
7. Montano D. Upper body and lower limbs musculoskeletal symptoms and health inequalities in Europe: an analysis of cross-sectional data. *BMC Musculoskelet Disord* 2014;15:1471–2474.
8. Ortiz-Hernandez L, Tamez-Gonzalez S, Martinez-Alcantara S, *et al*. Computer use increases the risk of musculoskeletal disorders among newspaper office workers. *Arch Med Res* 2003;34:331–42.
9. Wahlstrom J. Ergonomics, musculoskeletal disorders and computer work. *Occup Med* 2005;55:168–76.
10. Nakazawa T, Okubo Y, Suwazono Y, *et al*. Association between duration of daily VDT use and subjective symptoms. *Am J Ind Med* 2002;42:421–6.
11. Schlote T, Kadner G, Freudenthaler N. Marked reduction and distinct patterns of eye blinking in patients with moderately dry eyes during video display terminal use. *Graefes Arch Clin Exp Ophthalmol* 2004;42:306–12.
12. Toomingas A, Hagberg M, Heiden M, *et al*. Incidence and risk factors for symptoms from the eyes among professional computer users. *Work* 2012;1:3560–2.
13. Tullar JM, Brewer S, Amick BC III, *et al*. Occupational safety and health interventions to reduce musculoskeletal symptoms in the health care sector. *J Occup Rehabil* 2010;20:199–219.
14. van den Heuvel SG, de Looze MP, Hildebrandt VH, *et al*. Effects of software programs stimulating regular breaks and exercises on work-related neck and upper-limb disorders. *Scand J Work Environ Health* 2003;29:106–16.
15. Galinsky T, Swanson N, Sauter S, *et al*. Supplementary breaks and stretching exercises for data entry operators: a follow-up field study. *Am J Ind Med* 2007;50:519–27.

16. Galinsky TL, Swanson NG, Sauter SL, *et al.* A field study of supplementary rest breaks for data-entry operators. *Ergonomics* 2000;43:622–38.
17. Junker C, Egger M, Schneider M, *et al.* The CONSORT statement. *JAMA* 1996;276:1876–7; author reply 1877.
18. Descatha A, Roquelaure Y, Chastang JF, *et al.* Validity of Nordic-style questionnaires in the surveillance of upper-limb work-related musculoskeletal disorders. *Scand J Work Environ Health* 2007;33:58–65.
19. Kuorinka I, Jonsson B, Kilbom A, *et al.* Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon* 1987;18:233–7.
20. Thorud HM, Helland M, Aaras A, *et al.* Eye-related pain induced by visually demanding computer work. *Optom Vis Sci* 2012;89:E452–64.
21. Herrmann C. International experiences with the Hospital Anxiety and Depression Scale—a review of validation data and clinical results. *J Psychosom Res* 1997;42:17–41.
22. Lesage FX, Berjot S. Validity of occupational stress assessment using a visual analogue scale. *Occup Med* 2011;61:434–6.
23. Lesage FX, Berjot S, Deschamps F. Clinical stress assessment using a visual analogue scale. *Occup Med* 2012;62:600–5.
24. Ratinaud MC, Chamoux A, Glace B, *et al.* Job satisfaction evaluation in low back pain: a literature review and tools appraisal. *Ann Phys Rehabil Med* 2013;56:465–81.
25. Hagstromer M, Oja P, Sjostrom M. The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. *Public Health Nutr* 2006;9:755–62.
26. Craig CL, Marshall AL, Sjöström M, *et al.* International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003;35:1381–95.
27. Erlbaum L. *Statistical power analysis for the behavioral sciences*. Cohen J, ed. 2nd edn. 1988.
28. Blangsted AK, Søgaard K, Hansen EA, *et al.* One-year randomized controlled trial with different physical-activity programs to reduce musculoskeletal symptoms in the neck and shoulders among office workers. *Scand J Work Environ Health* 2008;34:55–65.
29. Lacaze DH, Sacco Ide C, Rocha LE, *et al.* Stretching and joint mobilization exercises reduce call-center operators' musculoskeletal discomfort and fatigue. *Clinics* 2010;65:657–62.
30. Tsauo JY, Lee HY, Hsu JH, *et al.* Physical exercise and health education for neck and shoulder complaints among sedentary workers. *J Rehabil Med* 2004;36:253–7.
31. Verhagen AP, Bierma-Zeinstra SM, Burdorf A, *et al.* Conservative interventions for treating work-related complaints of the arm, neck or shoulder in adults. *Cochrane Database Syst Rev* 2013;12:CD008742.
32. Wen CP, Wu X. Stressing harms of physical inactivity to promote exercise. *Lancet* 2012;380:192–3.
33. Tokunaga-Nakawatase Y, Nishigaki M, Taru C, *et al.* Computer-supported indirect-form lifestyle-modification support program using Lifestyle Intervention Support Software for Diabetes Prevention (LISS-DP) for people with a family history of type 2 diabetes in a medical checkup setting: a randomized controlled trial. *Prim Care Diabetes* 2014;8:207–14.
34. Shrestha N, Ijaz S, Kukkonen-Harjula KT, *et al.* Workplace interventions for reducing sitting at work. *Cochrane Database Syst Rev* 2015;1:CD010912.
35. Womack SK, Armstrong TJ. Use of a computerized decision support system for primary and secondary prevention of work-related MSD disability. *J Occup Rehabil* 2005;15:313–28.
36. Irmak A, Bumin G, Irmak R. The effects of exercise reminder software program on office workers' perceived pain level, work performance and quality of life. *Work* 2012;41(Suppl 1):5692–5.
37. Blehm C, Vishnu S, Khattak A, *et al.* Computer vision syndrome: a review. *Surv Ophthalmol* 2005;50:253–62.
38. Ostrovsky A, Ribak J, Pereg A, *et al.* Effects of job-related stress and burnout on asthenopia among high-tech workers. *Ergonomics* 2012;55:854–62.
39. Robertson MM, Huang YH, Larson N. The relationship among computer work, environmental design, and musculoskeletal and visual discomfort: examining the moderating role of supervisory relations and co-worker support. *Int Arch Occup Environ Health* 2015;1:1.
40. van Rijn RM, Huisstede BM, Koes BW, *et al.* Associations between work-related factors and the carpal tunnel syndrome—a systematic review. *Scand J Work Environ Health* 2009;35:19–36.
41. Lanhers C, Duclos M, Guttman A, *et al.* General practitioners' barriers to prescribe physical activity: the dark side of the cluster effects on the physical activity of their type 2 diabetes patients. *PLoS ONE* 2015;10:e0140429.
42. Lopez V, Chamoux A, Tempier M, *et al.* The long-term effects of occupational exposure to vinyl chloride monomer on microcirculation: a cross-sectional study 15 years after retirement. *BMJ Open* 2013;3:e002785.