# Chapter 22
# Effectiveness of a Participatory Ergonomics Intervention to Improve Musculoskeletal Health: A Solomon Four-Group Study Among Manufacturing Industry Workers in Selangor, Malaysia

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**Abstract** The aim of this Solomon four-group study was to evaluate the effectiveness of participatory ergonomics (PE) intervention to improve musculoskeletal health among manufacturing industry workers. A total of 436 workers were randomly assigned into four groups. Intervention groups went through PE intervention while control groups went through hearing conservation programme. The main outcome measures were the prevalence and intensity of musculoskeletal pain at 9 body sites, collected by questionnaires at baseline (pretested groups) and 3 months after PE intervention (all groups). The study found that lower back has the highest prevalence rate of musculoskeletal disorders (MSD). There was significant lower prevalence rate of MSD at upper back, lower back and knee for intervention group as compared to control group. There was a significant main effect of PE intervention on the overall pain intensity at different body parts whether they are pretested or non-pretested. In conclusion, PE intervention had effectively improved musculoskeletal health among the respondents.

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G.G. Ray et al. (eds.), *Ergonomics in Caring for People*,
https://doi.org/10.1007/978-981-10-4980-4_22

# 1 Introduction

Work-related MSD are consistently one of the most commonly reported occupational health problem, bringing enormous pervasive impacts to the society in both direct costs due to the medical healthcare consumption and indirect costs through loss of work productivity [1, 2]. In Malaysia, MSD cases reported to the Social Security Organization (SOCSO) has increased tremendously from 10 (2005) to 675 (2014) cases [3]. Given that MSD has been closely linked with physical and psychological factors at work such as poorly design workstation, inappropriate work method, and stressful environment, etc., there is an obvious need of effective ergonomics intervention targeting at workplace improvement.

PE intervention is a promising strategy to reduce MSD [4, 5]. It is defined as the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals [6]. This study is the first, to our knowledge that evaluates the effectiveness of PE intervention to improve musculoskeletal health among manufacturing industry worker using Solomon four-group design.

# 2 Method

The study commenced from January 2014 (enrolment) to April 2015 (posttest).

## *2.1 Study Design and Study Population*

This Solomon four-group study was conducted at 9 manufacturing companies in Selangor. Selangor state was selected as the study location because Selangor has the highest number of manufacturing companies registered in Malaysia and the highest number of MSD cases reported to SOCSO [3]. The full CONSORT diagram is shown in Fig. 1. Among 456 workers, 436 were enrolled, 20 declined or not meeting eligibility of study: $\geq 18$ years old, work at present company $\geq 3$ months, not pregnant, no history of MSD due to nonwork-related factor. 436 workers were randomized into 4 groups: pretested control group, pretested intervention group, non-pretested control group and non-pretested intervention group. Out of 436 participants, only 324 of them completed all parts of the study, with 112 of them loss to follow up due to turnover (loss to follow up rate = 25.7%).

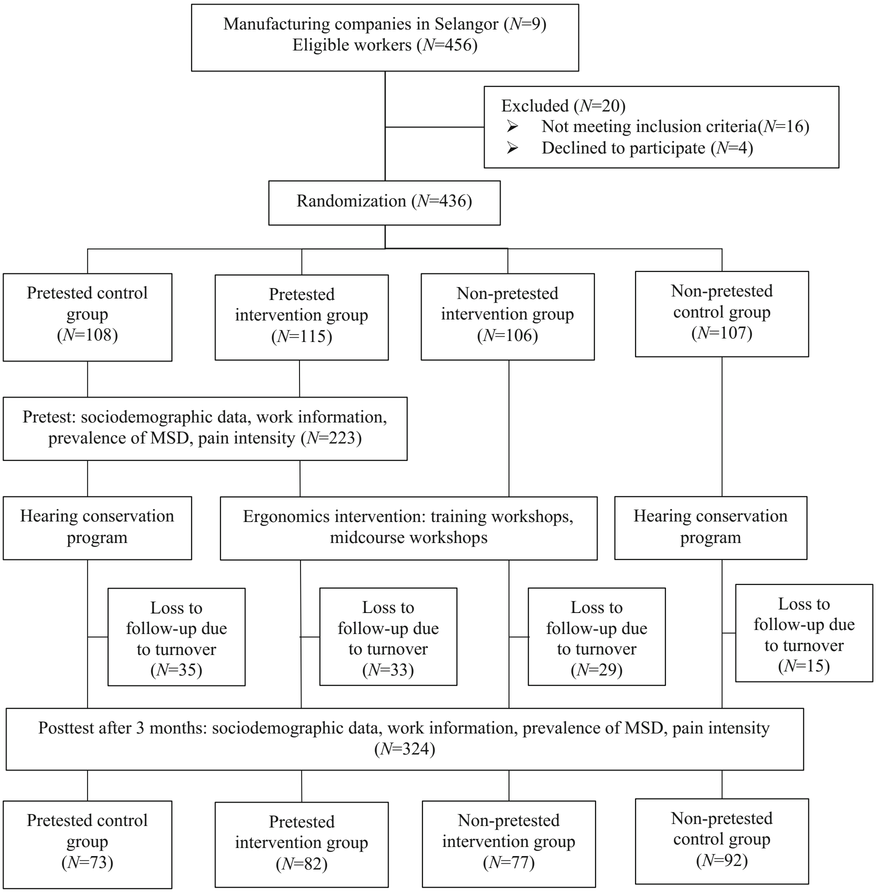


**Fig. 1** CONSORT flow diagram

## 2.2 *Intervention Programme and Control*

The intervention programme in this study was designed based on the Participatory Ergonomics Framework (PEF) by Haines et al. [6]. The programme involved direct representative participation of workers from wide range of work positions to improve their current workstations on voluntarily basis. The core element of PE intervention was the active involvement and discussion among participants to identify, plan, implement and decide the improvements on current workstations, tools, equipment or work tasks in collaboration with management and researcher. The researcher acted as trainer and facilitator to provide ergonomics training, guide and assist the whole PE intervention programme. Overall, the PE intervention programme could be divided into 3 phases: preliminary walkthrough survey, Tailor-made Ergonomics training (8 h) and Follow up with mid-course workshops.

Preliminary walkthrough survey was a very important phase to know the process and work activities of the company in detail. During walkthrough survey, photographs and videos of ergonomics risk factors, good points and potential improvements were taken to be used as training materials for ergonomics training and as baseline information for comparison after PE intervention.

Ergonomics training was the key element of PE intervention. All the trainings were tailor-made according to the information collected during preliminary walkthrough survey. Generally, the topics covered in the training included workstation design, work posture, work method, lifting technique, etc. The action-oriented ergonomics training in this study adapted suggestions and constructive ideas from work improvement in small enterprises (WISE) project [7, 8], which emphasized on practical ideas rather than general theory. In the first session of training, participants were taught to identify risk factors and hazards with the mechanism of injury, followed by practical and potential improvements by using local good examples from all the participating companies. The training involved a lot of discussion and group works with participants. In the second session of training, the participants were divided into groups (6–8 person per group) according to their production line. They were asked to identify strenuous tasks and risk factors at their workstations. Through group discussion, they prioritized top three risk factors identified and subsequently brainstormed about the potential improvements that could be done. All the ideas and decisions were generated through group discussion facilitated by researcher and were written in an action plan. Participants were given 6 months to implement changes and improvements as in the action plan.

During these 6 months, the researcher contacted with the safety and health personnel of the company to follow up on the progression of the action plan every month. All the changes were implemented voluntarily using company fund. Optional mid-course workshops were conducted on request to give supports on improvement. The researcher facilitates the workstation improvement by providing technical advices and feasible suggestions. Participants in the control group were given hearing conservation programme, which includes hearing test and training on hearing protection devices usage.

## 2.3 Data Collection and Outcome Measures

Data were collected before intervention (pretest) among pretested intervention and control group ($N = 223$) and after intervention (posttest) among all the respondents ($N = 324$) using self-administered questionnaire. The primary outcome measure was the prevalence and pain intensity of MSD using modified Nordic Questionnaire [9]. MSD were measured on 9 anatomical sites: neck, shoulders, upper back, lower back, elbows, hands, thighs, knees and foot. The respondents were asked if they experienced musculoskeletal pain on any of the sites within the past 3 months with the aid of illustrations on body sites and marked on a 10 cm Visual Analogue Scale for pain intensity on painful sites. Socio-demographic data and work information were also included in the questionnaire.

## 3 Results

Table 1 summarizes the characteristics of respondents in the socio-demographic and work information with the prevalence and pain intensity of MSD at 9 anatomical sites as reported in the posttest ($N = 324$). Significant differences between intervention and control group were observed for age, $t(322) = 5.18, p < 0.05$, gender, $x^2(1) = 59.59$,

**Table 1** Socio-demographic and work information of respondents with the prevalence of MSD (posttest data; $N = 324$)

| Variable(s) | Control group ($N$ = 165) | | Intervention group ($N$ = 159) | |
|---|---|---|---|---|
| | $N$ (%) | $M$ (SD) | $N$ (%) | $M$ (SD) |
| Age* (years) | | 34.9 (8.2) | | 30.4 (7.6) |
| *Gender** | | | | |
| Male | 147 (89.1) | | 79 (49.7) | |
| Female | 18 (10.9) | | 80 (50.3) | |
| *Highest education level* | | | | |
| Primary | 3 (1.8) | | 2 (1.3) | |
| Secondary | 140 (84.8) | | 109 (68.6) | |
| Diploma | 19 (11.5) | | 30 (18.9) | |
| Degree | 3 (1.8) | | 18 (11.3) | |
| BMI (kg/$m^2$) | | 24.8 (4.8) | | 24.2 (3.5) |
| *BMI categories** | | | | |
| Underweight | 10 (6.1) | | 6 (3.8) | |
| Normal weight | 87 (52.7) | | 103 (64.8) | |
| Overweight | 40 (24.2) | | 37 (23.3) | |
| Obesity | 28 (17.0) | | 13 (8.2) | |
| *Monthly income (RM)* | | | | |
| ≤ 1500 | 94 (57.0) | | 93 (58.5) | |
| 1501–3000 | 58 (35.2) | | 58 (36.5) | |
| >3000 | 13 (7.9) | | 8 (5.0) | |
| *Work position** | | | | |
| Operator | 65 (39.4) | | 94 (59.1) | |
| Supervisor | 34 (20.6) | | 23 (14.5) | |
| Executive | 17 (10.3) | | 9 (5.7) | |
| Others | 49 (29.7) | | 33 (20.8) | |
| *Work duration weekly* (h)* | | | | |
| <35 | 10 (6.1) | | 10 (6.3) | |
| 35–40 | 36 (21.8) | | 35 (22.0) | |
| 41–48 | 45 (27.3) | | 71 (44.7) | |
| >48 | 74 (44.8) | | 43 (27.0) | |

(continued)

**Table 1** (continued)

| Variable(s) | Control group (*N* = 165) | | Intervention group (*N* = 159) | |
|---|---|---|---|---|
| | *N* (%) | *M* (SD) | *N* (%) | *M* (SD) |
| *Prevalence of MSD at 9 anatomical sites* | | | | |
| Neck | 69 (41.8) | | 55 (34.6) | |
| Shoulder | 73 (44.2) | | 56 (35.2) | |
| Upper back* | 96 (58.2) | | 70 (44.0) | |
| Elbow | 38 (23.0) | | 15 (15.7) | |
| Hand | 54 (32.7) | | 36 (22.6) | |
| Lower back* | 105 (63.6) | | 74 (46.5) | |
| Thigh | 41 (24.8) | | 23 (14.5) | |
| Knee* | 57 (34.5) | | 30 (18.9) | |
| Foot | 75 (45.5) | | 58 (36.5) | |
| Overall prevalence of MSD (at least 1 pain site) | 125 (75.8) | | 120 (75.5) | |
| *Pain intensity at 9 anatomical sites* | | | | |
| Neck | | 2.7 (2.6) | | 2.4 (2.0) |
| Shoulder | | 2.8 (2.5) | | 2.4 (2.0) |
| Upper back* | | 3.7 (2.9) | | 3.0 (2.4) |
| Elbow | | 1.6 (2.1) | | 1.5 (1.7) |
| Hand* | | 2.2 (2.5) | | 2.0 (2.1) |
| Lower back* | | 4.2 (3.0) | | 3.1 (2.5) |
| Thigh* | | 1.9 (2.3) | | 1.5 (2.0) |
| Knee* | | 2.5 (2.6) | | 1.6 (2.1) |
| Foot | | 3.2 (3.1) | | 2.6 (2.7) |

*$p < 0.05$

$p < 0.05$, BMI categories, $x^2(1) = 7.84$, $p < 0.05$, work position, $x^2(3) = 12.89$, $p < 0.05$ and weekly work duration $x^2(3) = 13.95$, $p < 0.05$.

## 3.1 Prevalence and Pain Intensity of MSD

The overall prevalence rate of MSD ($\geq 1$ pain site) was 75.8% for control group and 75.5% for intervention group. Highest prevalence rate of MSD was reported at lower back, followed by upper back and foot for both groups. There were significant lower prevalence rates of MSD at upper back, $x^2(1) = 6.50$, $p < 0.05$, lower back, $x^2(1) = 10.31$, $p < 0.05$ and knee, $x^2(1) = 10.13$, $p < 0.05$ for intervention group as compared to control group. Highest pain intensity was observed at lower back, followed by upper back and foot. Intervention group shows significant lower pain intensity compared to control group at upper back $t(322) = 2.52$, $p < 0.05$, lower back $t(322) = 3.76$, $p < 0.05$, and knee $t(322) = 1.65$, $p < 0.05$.

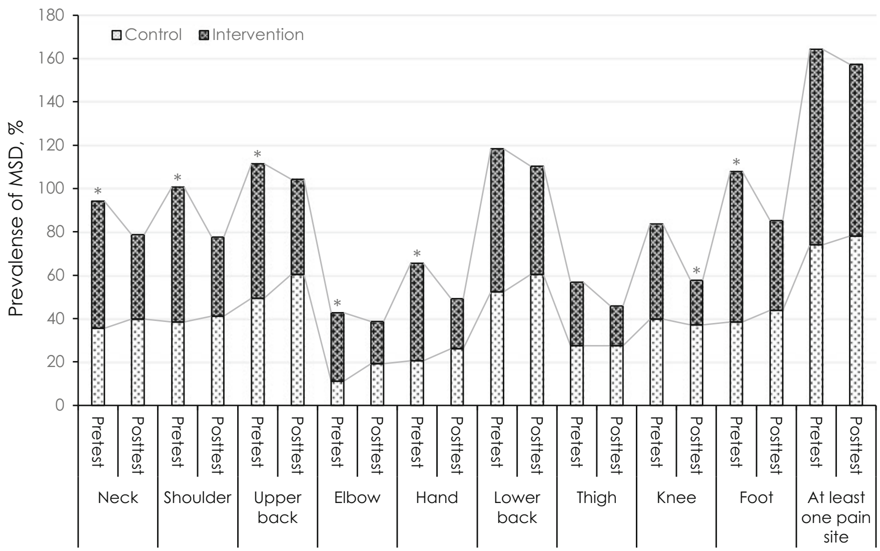


**Fig. 2** Prevalence of MSD at 9 anatomical sites for pretested intervention group ($N$ = 82) and pretested control group ($N$ = 73)

As shown in Fig. 2, intervention group shows a clear pattern of reduction in the prevalence of MSD at posttest. At pretest level, intervention group shows significantly higher overall prevalence rate of MSD, specifically at neck, shoulder, upper back, elbow and hand. At posttest level, intervention group reported significantly lower prevalence rate of MSD at knee.

## 3.2 *Effects of Pretesting and Intervention*

The effects of pretesting and intervention on musculoskeletal health were examined using conditional sequence of successive analyses for Solomon four-group suggested by Braver and Braver [10]. Pain intensities at 9 anatomical sites were the dependent variables. First, a 2 (pretested × non-pretested) × 2 (intervention × control) multivariate analysis of variance (MANOVA) was conducted on the dependent variables to know the main effect of intervention on overall pain intensity. The Wilks' Lambda test revealed significant main effect of intervention, Wilk's $\Lambda = 0.94$, $F(1,320) = 2.36$, $p < 0.05$, no significant main effect of pretesting, Wilk's $\Lambda = 0.54$, $F(1,320) = 0.54$, $p > 0.05$ and no significant main effect of interaction (pretesting × intervention), Wilk's $\Lambda = 0.94$, $F(1,320) = 0.1$, $p > 0.05$ on the overall pain intensity. The intervention had a significant effect on pain intensity of respondents whether they are pretested or non-pretested.

The results of the univariate ANOVAs as reported in Table 2 show that there were significant main effects of intervention on pain intensity at 3 anatomical sites,

**Table 2** Effects of participatory ergonomics intervention on pain intensity at 9 anatomical sites (posttest data; $N = 324$)

| Variable(s) | Two-way ANOVA | | | ANCOVA[a] | Independent samples $t$ test[b] | Meta-analysis[c] | Conclusion |
|---|---|---|---|---|---|---|---|
| | Pretest | Intervention | Pretest × intervention | Intervention | | | |
| Neck | $F(1,320) = 0.08$ | $F(1,320) = 1.46$ | $F(1,320) = 0.19$ | $F(1,152) = 5.64$* | – | – | Effective |
| Shoulder | $F(1,320) = 0.25$ | $F(1,320) = 2.20$ | $F(1,320) = 1.02$ | $F(1,152) = 1.73$ | $t = 1.81$ | $Z_{meta} = 2.19$* | Effective |
| Upper back | $F(1,320) = 0.42$ | $F(1,320) = 6.02$* | $F(1,320) = 0.01$ | – | – | – | Effective |
| Elbow | $F(1,320) = 1.44$ | $F(1,320) = 0.39$ | $F(1,320) = 1.01$ | $F(1,152) = 2.61$ | $t = 1.18$ | $Z_{meta} = 1.97$* | Effective |
| Hand | $F(1,320) = 1.49$ | $F(1,320) = 0.21$ | $F(1,320) = 1.37$ | $F(1,152) = 1.12$ | $t = 1.10$ | $Z_{meta} = 1.54$ | Not effective |
| Lower back | $F(1,320) = 0.86$ | $F(1,320) = 13.31$* | $F(1,320) = 0.48$ | – | – | – | Effective |
| Thigh | $F(1,320) = 0.02$ | $F(1,320) = 2.78$ | $F(1,320) = 0.21$ | $F(1,152) = 3.34$ | $t = 0.93$ | $Z_{meta} = 1.94$ | Not effective |
| Knee | $F(1,320) = 0.01$ | $F(1,320) = 9.86$* | $F(1,320) = 0.02$ | – | – | – | Effective |
| Foot | $F(1,320) = 0.01$ | $F(1,320) = 3.01$ | $F(1,320) = 2.72$ | $F(1,152) = 10.93$* | – | – | Effective |

*$p < 0.05$

[a]Pain intensity reported at pretest used as covariates which only involved pretested intervention and control group ($N = 155$)

[b]Pain intensity reported at posttest as dependent variables which only involved non-pretested intervention and control group ($N = 169$)

[c]Stouffer's $z$-method combined $z$-score from previous 2 tests (ANCOVA and independent samples $t$ test)

upper back, $F(1,320) = 6.02$, $p < 0.05$, lower back $F(1,320) = 13.31$, $p < 0.05$, and knee, $F(1,320) = 9.86$, $p < 0.05$. Further analysis shows that intervention group experienced lower pain intensity at upper back (*M* difference = 0.73), lower back (*M* difference = 1.13) and knee (*M* difference = 0.84) as compared to control group.

Since there were no significant main effects of intervention and interaction on the other anatomical sites, the next step in the sequential analysis was to conduct analysis of covariance (ANCOVA) on posttest pain intensity at other anatomical sites among pretested respondents using pretest pain intensity as covariates. The ANCOVA found significant effect of intervention on the pain intensity at neck, $F(1,152) = 5.64$, $p < 0.05$ and foot, $F(1,152) = 10.93$, $p < 0.05$. The pain intensity for intervention group reduced significantly at neck (*M* difference = 0.82) and foot (*M* difference = 1.35). The next sequential analysis involved the testing of intervention effect on non-pretested group using independence *t* test at the rest of the anatomical sites which were not significant in ANCOVA. Independence *t* test found no significant effect of intervention ($p > 0.05$) on non-pretested group.

The final step in the sequential analysis was to combine the results from 2 negative tests of intervention effect on pretested and non-pretested group using meta-analytic approach. Using Stouffer's *z*-method, the *p* value from previous tests was converted into *z*-score and combined into a single $z_{meta}$ value. The meta-analytic results were significant for shoulder ($z_{meta} = 2.19$, $p < 0.05$) and elbow ($z_{meta} = 1.97$, $p < 0.05$), leading to the conclusion that intervention had reduced the pain intensity of shoulder and elbow.

## 4 Discussion

In this study, we found that the overall prevalence of MSD among participants for the last 3 months is very high (>70%), consistent with other studies done among manufacturing workers in Malaysia [11, 12]. Lower back was found to have the highest prevalence rate of MSD, similar with studies locally and globally [13, 14].

A systematic review concluded that PE interventions have a positive impact on musculoskeletal symptoms [5]. Our principal finding was consistent with the review, suggesting that PE intervention was effective in improving musculoskeletal health of respondents by reducing the overall pain intensity at different body parts. There are several possible explanations for the effective intervention. The first explanation is the involvement of workers from different positions such as operators, leaders, supervisors and executives. A systematic review suggested that workers, supervisors and specialists or advisors represent the right mix of skills or knowledge to progress through the PE process [15]. Second, tailor-made ergonomics training could have played a significant role. As different work process or job nature would have different ergonomics risk factors, it is important to have the training tailored to suit the task and work environment for different work population. Tailored interventions were found to be more effective in promoting behaviour change and reducing self-reported musculoskeletal discomfort [1]. Another explanation would be the focus on low-cost improvements. According to Kogi [4], PE interventions that focus on low-cost solutions are proven effective for improving workplace.

Sequential analyses further concluded that PE intervention was effective in reducing pain intensity at all anatomical sites except for knee and hand. Pain intensity of knee slightly missed the margin of significance but not pain intensity of hand. We found that it might be due to unchanged workload [16]. As most of the improvements targeted at workstation modification, repetitive movement of hands is unavoidable as long as workload maintained. One of the strengths of our study was the use of Solomon four-group design. In addition to high internal validity for testing the effects of intervention, it has the ability to assess whether the effects of intervention are different among pretested and non-pretested subjects, thus increasing the external validity and generalizability of the study [17]. This phenomenon is called pretest sensitization, where the experimental results may partly be a result of the sensitization to the content of the treatment when pretest is administered [18].

## 5 Conclusion

The results of current study showed that PE intervention had effectively reduced the overall prevalence rate and intensity of musculoskeletal pain among manufacturing industry workers in Selangor, Malaysia.

**Acknowledgements** The research project was partly funded by Putra Grant of Universiti Putra Malaysia (GP-IPS/2013/9399832). The authors would like to thank Ms. Sam Wei Yeng for her assistance in the training and all the respondents involved for their willingness to share their information.

**Ethical Approval** Research Ethics Committee of UPM approved the protocol.

## References

1. Shaw K, Haslam C, Haslam R (2007) A staged approach to reducing musculoskeletal disorders (MSDs) in a long term follow. HSE, Loughborough
2. Zheltoukhova Ksenia, O'Dea Lisa, Bevan S (2012) Taking the strain: the impact of musculoskeletal disorders on work and home life. The Work Foundation, London
3. Social Security Organization (2014) 2013 annual report of Social Security Organization
4. Kogi K (2006) Participatory methods effective for ergonomic workplace improvement. Appl Ergon 37(4):547–554. https://dx.doi.org/10.1016/j.apergo.2006.04.013

5. Rivilis I, Van Eerd D, Cullen K, Cole DC, Irvin E, Tyson J, Mahood Q (2008) Effectiveness of participatory ergonomic interventions on health outcomes: a systematic review. Appl Ergon 39(3):342–358. https://dx.doi.org/10.1016/j.apergo.2007.08.006
6. Haines H, Wilson JR, Vink P, Koningsveld E (2002) Validating a framework for participatory ergonomics (the PEF). Ergonomics 45(4):309–327. https://dx.doi.org/10.1080/00140130210123516
7. International Labour Organization (2010) Ergonomic checkpoints: practical and easy-to-implement solutions for improving safety, health and working conditions, 2nd edn. ILO Publications, Geneva
8. International Labour Organization (2009) Work improvement in small enterprise (WISE) Trainers' Guide. ILO Publications, Geneva
9. Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F, Andersson G, Jørgensen K (1987) Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl Ergon 18(3):233–237. https://dx.doi.org/10.1016/0003-6870(87)90010-X
10. Braver MW, Braver SL (1988) Statistical treatment of the Solomon four-group design: a meta-analytic approach. Psychol Bull 104(1):150–154. https://dx.doi.org/10.1037/0033-2909.104.1.150
11. Chandrasakaran A, Chee HL, Rampal KG, Tan GL (2003) The prevalence of musculoskeletal problems and risk factors among women assembly workers in the semiconductor industry. Med J Malays 58(5):657–66. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15190650
12. Nur NM, Dawal SZ, Dahari M (2014) The prevalence of work related musculoskeletal disorders among workers performing industrial repetitive tasks in the automotive manufacturing companies, pp 1–8
13. Hoy D, Bain C, Williams G, March L, Brooks P, Blyth F et al (2012) A systematic review of the global prevalence of low back pain. Arthr Rheum 64(6):2028–2037. https://dx.doi.org/10.1002/art.34347
14. Deros BM, Daruis DDI, Ismail AR, Sawal NA, Ghani JA (2010) Work-related musculoskeletal disorders among workers' performing manual material handling work in an automotive manufacturing company. Am J Appl Sci 7(8):1087–1092
15. van Eerd D, Cole D, Irvin E, Mahood Q, Keown K, Theberge N et al (2010) Process and implementation of participatory ergonomic interventions: a systematic review. Ergonomics 53(10):1153–1166. https://dx.doi.org/10.1080/00140139.2010.513452
16. Driessen MT, Proper KI, Anema JR, Knol DL, Bongers PM, van der Beek AJ (2011) The effectiveness of participatory ergonomics to prevent low-back and neck pain—results of a cluster randomized controlled trial. Scand J Work Environ Health 37(10):383–393. https://dx.doi.org/10.5271/sjweh.3163
17. Campbell DT, Stanley JC (1963) Experimental and quasi-experimental designs for research, chapter 5. In Handbook of research on teaching. Houghton Mifflin Company, p 55. https://dx.doi.org/10.1016/0306-4573(84)90053-0
18. Bracht GH, Glass GV (1968) The external validity of experiments. Am Educ Res J 5(4):437–474. https://dx.doi.org/10.3102/00028312005004437