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Original Research Article

A Review of Ergonomic Intervention Programs to Reduce the Prevalence of Musculoskeletal Disorders

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Abstract: Musculoskeletal disorders (MSDs) negatively affect workers' health, hence their productivity. It has immense cost implications on companies. Ergonomic intervention programs have been rolled out to reduce the occurrences of MSDs at workplaces. This review aims to examine the types and effectiveness of ergonomic intervention programs across multiple sectors. It sourced peer-reviewed articles from scholarly journal databases with keywords such as ergonomic intervention, ergonomic program and intervention program. Ergonomic intervention typically comprises three steps namely preliminary analyses, diagnosis and solution development. Interventions adopting multiple approaches to reduce identified risk factors and modifier interventions focusing on workers at risk are more effective than generic ones. Participatory approach increases the success of such interventions. Intervention practices could be classified as complete, shortened and turnkey where complete type follows the three intervention steps, shortened type compensates on or omits one step and turnkey type lacks diagnosis and solution development. While the intervention programs reviewed are generally effective, it remains largely unknown if the intervention and outcomes are sustainable and if compliance to ergonomic standards is met.

Keywords: Ergonomic, intervention, musculoskeletal disorders, participatory, sustainable, turnkey.

1. INTRODUCTION

Musculoskeletal disorders or MSDs is the general term for injuries affecting the muscles, joints, tendons or spinal discs [1]. Back and shoulders are the two main body areas affected by MSDs and the typical symptoms are pain, aching, discomfort, numbness, tingling and swelling[1]. The term 'musculoskeletal disorders' is often used interchangeably with 'repetitive strain injury' and 'cumulative trauma disorders' though this is subject to argument. MSDs can also be caused by a single strain or trauma other than a repetitive or cumulative one and their development is multi-factorial, not confined to only the physical aspect [2, 3]. 'Musculoskeletal disorders' is the term most commonly used because it does not suggest the pathological mechanisms or the diagnostic criteria of the injuries[4].

MSDs generally reduce a worker's ability to perform routine activities and in serious instances, lead to permanent disability[5]. MSDs negatively affect workers' health, hence their productivity. Losses due to workers' compensation as a result of occupational diseases related to manual handling constitute one of the major losses across many different industries[5, 6]. In Europe, approximately three of every five workers reported to have experienced MSDs, with backache and muscular pains in the upper limbs being the most commonly reported[7]. In Germany, musculoskeletal and connective tissue disorders resulted in production loss and a loss of gross value added (loss of labor productivity) of EUR 17.2 billion and EUR 30.4 billion respectively in 2016. This was equivalent to a respective 0.5% and 1.0% of Germany's gross domestic product[7].

Manual handling, especially lifting of heavy loads, is the largest cause of MSDs. Manual handling covers a range of activities such as lifting, lowering, pushing, pulling and carrying[7]. Other factors causing MSDs are poor design of workplace, equipment or tasks leading to awkward or tiring positions[8]. In addition to the physical risk factors, psychosocial stressors at work and individual risk factors also contribute to the prevalence and severity of MSDs and they are often multi-causal[9, 10]. Psychosocial stressors are linked to work demands, control at work, social relationship and effort-reward imbalance[11]. Individual risk factors encompass gender, age, education level, mental and physical fitness, etc.[9]. In Europe, male workers are more exposed to most MSDs risk factors than female workers. Nonetheless, women in certain sectors with more prevalent female workers such as the healthcare sector, have high exposure to certain risk factors[7]. MSDs make up a much higher proportion of all reported occupational diseases among female workers than among male workers. Cases of MSDs reported are also found to increase with age. MSDs are more frequently reported among older workers in Europe though cases of MSDs reported among young workers below 25 years old are also significant[7].

With the prevalence of MSDs, it is crucial to devise intervention programs to reduce the occurrences of MSDs and other ergonomics-related health issues. Ergonomic intervention programs have been reported to be promising in lowering workers' compensation rates, lost work days and occupational MSDs, which in turn, leads to enhanced organizational effectiveness[8]. Ergonomic intervention is often tailored to the requirements of different workplace settings. It employs a multi-pronged approach targeting at modifying the work environment, changing workers' behaviors and education[12]. In offices, the intervention frequently focused on adjustable keyboards and chairs[13] as well as flexible workplace design of visual display terminal[14]. Purchase of new equipment and modification of existing equipment were reported as interventions of a surface coal mining operation[15]. Training is a common intervention mentioned in multiple studies[16-18]. Interventions are, therefore, devised in relation to the prevailing occupational risks of a particular sector or workplace. This review aims to examine the types and effectiveness of ergonomic intervention programs across multiple sectors. It provides insight into the design of ergonomic intervention programs to optimize the prevention of MSDs.

2. METHODS

This review sourced peer-reviewed scholarly articles from journal databases namely Scopus, Web of Science, PubMed and ProQuest, with keywords comprising ergonomic, intervention, ergonomic intervention, ergonomic program and intervention program[19]. It included studies on the design and effectiveness of ergonomic intervention across different sectors. Ideally, the studies should reveal the changes in ergonomic performance particularly the prevalence of MSDs before and after intervention. It excluded specific ergonomic studies focusing on the design of tools and equipment and anthropometric measurement.

3. RESULTS AND DISCUSSION

Conventionally, ergonomic intervention consists of three steps, i.e., preliminary analysis, diagnosis and solution development. Preliminary analysis involves defining scope based on work-related problems which direct subsequent data collection. Diagnostic step identifies causes of problems and factors directly affecting changes and work situations. Solution development formulates intervention methods, an instance of which involves changing the work situation[20].

Westgaard and Winkel, in their review of ergonomic intervention for improved musculoskeletal health, grouped the intervention approaches into two, i.e., those involving implementation of pre-planned intervention concept which focuses on changing mechanical exposure and those constituting part of management actions, responsibilities, etc.[21] The latter requires participation of workers and adopts systematic approaches to promote compliance and participation of workers. The two groups differ in the facets of ownership, flexibility and sustainability[21]. In quantifying mechanical exposure of the subjects studied, conceptual force variables such as amplitude, temporal pattern of delivery (repetitiveness) and duration should be considered[22]. Effectiveness of ergonomics intervention is affected by psychosocial factors and where possible these factors should be addressed[23]. Westgaard and Winkel suggested that ergonomic intervention studies should fulfil the criteria of proper statistical analysis, reasonable size of study group, variables generalisable to other settings, consideration of reliability and sensitivity of variables, inclusion of control group, adequate observation period with follow-up measurements as well as proper documentation of intervention and the process involved[21].

Interventions adopting multiple approaches to reduce identified risk factors and modifier interventions focusing on workers at risk are more effective than generic intervention strategies based on causal development of MSDs[20]. Intervention strategies involving multiple approaches are also favoured by Silverstein and Clark over single intervention due to higher effectiveness[22]. The reason probably owes to multiple causes of injury mechanisms of MSDs which are not adequately understood. Besides, the multi-causality of MSDs is affirmed by multiple researchers, particularly the biomechanical and psychological aspects[4, 24].

Westgaard and Winkel highlighted the importance of organisational culture, commitment of stakeholders and promotion of active workers' participation in the multi-component interventions[21]. Silverstein and Clark also found participatory approach, more often than not, increases the success of such interventions[21]. The importance of participation sets the tone of what is known as participatory ergonomic intervention. Such intervention engages workers in workplace modification to reduce injury and increase productivity, thus, facilitates in overcoming the resistance to change in work methods by promoting certain positive behaviours[25, 26].

Denis *et al*. in their review of 47 articles related to intervention practices for MSDs prevention categorized the practices into three groups i.e., the complete type, the shortened type and the turnkey type[20]. The intervention types differ in approach and applications. The complete type follows through the three intervention steps mentioned earlier on; the shortened type generally adopts the three steps but may omit one step with the scope compensated in two other steps; the turnkey type, on the other hand, lacks diagnosis and solution development[20].

The complete intervention uses a wider range of variables and worker consultation is more frequently conducted than other intervention types. Both complete and shortened interventions include diagnosis but differ in number and diversity of variables used during diagnosis[20]. Shortened intervention often only identifies determinants rather than showing the determinants as the source of the problem identified, in contrast to complete interventions where risk factor identification is the main agenda. Shortened intervention uses general observation instrument such as checklists while complete intervention adopts specific instruments, such as Rapid Upper Limb Assessment (RULA), fitted to the study and uses two or more data collection methods[20, 27]. Unlike the two interventions mentioned, turnkey intervention lacks diagnosis and relies on existing solutions. It provides quick, exportable solution but does not address multi-factorial nature of MSDs. This drawback could reduce the efficacy of the intervention and lead to oversight of the underlying cause of the problem[20].

Solution development comprises three means. The first is identification of relevant standards guiding work modification. The standards can be ergonomic guidelines, those dictating workload, secondary data and established models such as the National Institute for Occupational Safety and Health (NIOSH) equation, as well as technical guides or data sheets for computer workstation layout/ adjustment[27, 28]. The second means prompts modification of work situation through adapting existing standards to specific context such as anthropometry and workers' population. This contributed to about 60% of intervention solutions. The final means centres on development of new solutions, for instance new design and is more comprehensive than adaptation of standards[20]. Complete intervention, due to its extensive approach, applies diverse modification to the ways work is organised, especially the process, and provides specific solutions[20].

According to Oakman *et al*., sustainable prevention of MSDs should encompass training of engineers and social stakeholders as well as recommendations concerning production organisation with safety as a priority[29]. Shaw *et al*. deemed safety-specific leadership is beneficial in helping supervisors to increase awareness of ergonomics standards and prevention of MSDs among employees[30]. Supervisor training focusing on promotion of supportive environment and open communications concerning ergonomics and safety matters may reduce disability associated with MSDs while training on communication can potentially improve collaboration between supervisors and employees in managing ergonomics matters[31, 32]. Nonetheless, Sylvie and Vezina were of the opinion that training is not sufficient in MSDs prevention and identification of conditions needing improvement is crucial[33]. Table 1 shows a summary of various ergonomic intervention programs and their effectiveness.

Table-1: Design of Ergonomic Intervention Programs, Their Effectiveness and Impacts

Reference	**Occupation/ Sector**	**Type of Intervention**	**Study Design** **1. Design type** **2. Control group** **3. Intervention group size** **4. Study period**	**Mechanical Exposure Measurement**	**Acute Response Measurement**	**Musculo-skeletal Health Measurement**	**Findings**	**Impact** **1. Documentation** **2. Compliance** **3. Intervention sustainability** **4. Outcome sustainability**
[33]	Deboners in meat processing sector	• Analysis of work activity • Training	1. Pre/ post 2. No control group 3. Group of experienced deboners (n = 6); groups of apprentices (n = 7) 4. 8 months	Nil	Audio recordings, interviews	Pain of upper limbs	• Symptoms varied and diminishing towards the end of monitoring period without disappearing completely • Training not sufficient to prevent MSDs. • Identification of conditions requiring improvement needed	1. Unknown 2. Unknown 3. Unknown 4. Unknown
[34]	Assembly workers of Volvo Car Corporation	• Ergonomic program • Safety, Health and Ergonomics Checklist • Modification of fasteners/ tools and work technique	1. Time Series 2. No control group 3. N = 150 4. 3 years	Nil	Nil	Occupational injuries, absenteeism	• Fewer occupational injuries • Decreased absenteeism • Personnel costs lowered	1. Load ergonomics documented to satisfy various needs. 2. Ergonomics technical standards gradually attained. 3. Reasonable 4. Reasonable
[13]	University office workers	Office ergonomic program • Education of basic office ergonomics • 50-50 equipment cost share between safety and health department and university departments	1. Time series 2. No control group 3. N varied each year. 4. 13 years	Nil	Questionnaire	Office-related recordable injuries, lost-time, severity of injuries, cases of carpal tunnel syndrome	• Increased feedback of equipment to be purchased for work • MSDs decreased by 53%. • Incident rate decreased by 41% • Lost time case decreased by 71% • Carpal tunnel syndrome decreased by about 50%	1. Reasonable 2. Self-sustainable 3. Reasonable 4. Reasonable

[15]	[8]	[18]	[16]
Surface coal mine workers at Rock Springs, Sweetwater County, WY	Computer-based knowledge workers	Computer users	Office workers
Ergonomics process/ management system	Flexible workspace design and ergonomic training	Ergonomic education, i.e., training	Training and adjustable chair
1. Ongoing, time series 2. No control group 3. N varies 4. 4 years	1. Pre/ post 2. Control group (n = 45) 3. Flexible workspace group (n = 121); ergonomics training group (n = 92); flexible workstation + ergonomics training (n = 31) 4. 8 months	1. Pre/ post 2. Control group available (n = 90) 3. Intervention group (n = 89) 4. Not stated	1. Pre/ post 2. Control group (n=57) 3. Training and adjustable chair (n = 96); training only (n = 57) 4. 16 months
Nil	Nil	Nil	Nil
Employee interviews, ergonomic concern form, risk report card	Post intervention evaluation questionnaire	Observation, questionnaire (Depression Anxiety Stress Scale)	Knowledge test, observation (RULA and Office Ergonomic Assessment – OEA)
Cases of MS discomfort	Cases of self-reported MSDs	Cases of self-reported MSDs, days and episodes of sick leave	Nil
• Increased reporting of risk factors • Concerns addressed via modification of existing equipment, rearrangement of workstation, purchase of new workstation, equipment, seats, etc. • Reduced cases of MS discomfort	• Significant improvement on MSDs, job control, environmental satisfaction, sense of community, ergonomic climate, communication and collaboration and business process efficiency in intervention groups	• Significant improvement in workstation habits • Reduction in MSDs of the neck, right shoulder, right and left upper limbs, lower back and right and left lower limbs. • No significant differences for days, episodes of sick leave and psychological well-being	• Perceived control over physical work environment higher for intervention groups • Significant increase in ergonomic knowledge for intervention groups • Higher behavioural translation and lower risk of MSDs for intervention groups
1. Sufficient 2. Reasonable 3. Reasonable 4. Unknown	1. Unknown 2. Unknown 3. Unknown 4. Unknown	1. Unknown 2. Unknown 3. Unknown 4. Unknown	1. Insufficient 2. Unknown 3. Unknown 4. Unknown

[35]	[25]
Childcare institutions	Construction companies
Participatory ergonomic intervention	Participatory ergonomics interventions
1. Cluster-randomized design; baseline and follow-up 2. Wait-list control 3. Childcare institution clusters (immediate/ delayed intervention) (n = 29) 4. 4 months	1. Pre/ post 2. No control company 3. Face-to-face contact (n = 6); email contact (n = 6) 4. 6 months
Accelerometers, inertial measurement unit, Actiheart monitors	Nil
Questionnaires, observations of physical workload	Work Ability Index (WAI), process evaluation using indicators which evaluate reach, dose delivered[1], dose received[2], precision, competence and satisfaction, uestionnaire on the use of ergonomic measures, RAND-36 questionnaire assessment
Information on sickness absence	Reported cases of MSDs
• Not reported	• Not reported
1. Unknown 2. Unknown 3. Unknown 4. Unknown	1. Reasonable 2. Unknown 3. Unknown 4. Unknown

[1]Dose delivered is the amount of intervention components delivered

[2]Dose received is a measure of employees' participation in the intervention program often captured through observation of the extent to which they have followed specific intervention activities according to the protocol.

4. CONCLUSION

The economic implications of MSDs have prompted workplaces to implement ergonomic intervention programs. However, there is a lack of consensus on the format of such programs and they are often customized to address the nuances of workplaces and employees, hence the risks the employees are exposed to. While ergonomic intervention programs typically consist of preliminary analyses, diagnosis and solution development, the actual implementation varies, with some programs endeavoring to include all the elements while other programs focusing on specific elements, particularly solution development such as modification of tools, education and training. Certain programs seek to establish an ergonomic management system aiming to more effectively and holistically execute the steps of ergonomic intervention. Participatory ergonomic intervention is gaining popularity and it engages employees in the intervention process. While studies generally point to the effectively of such programs in raising knowledge as well as decreasing risks and prevalence of MSDs and occupational injuries, documentation of the programs for various stakeholders needs to be enhanced. Besides, it remains largely unknown if the intervention and outcomes are sustainable and if compliance to ergonomic standards is met.

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