The design and implementation of an exercise programme for the prevention and management of work-related upper limb disorders

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Work-related upper limb disorders (WRULD) are a major source of workplace ill-health and injury. Workers in the manufacturing industry appear to be at high risk of WRULD (Widanarko et al, 2011), which places a significant financial burden on the industry. Risk factors associated with WRULD include repetitive and forceful movements of the arm and wrist (van Rijn et al., 2009), and combinations of forearm supination and forceful lifting (Fan et al., 2009). Psychosocial risk factors have also been linked to these conditions and include stress, unsociable hours and tight production deadlines. Exercise programmes are advocated as an intervention approach for the prevention and management of WRULD (Boocock et al., 2007). However, evidence from the literature indicates contrasting findings for the effectiveness of these approaches. This may stem from the lack of specificity of the exercise programmes. Recent evidence suggests that incorporating eccentric-based exercises into a rehabilitation programme improves recovery in patients with lateral epicondylitis (Cullinane et al., 2014; Tyler et al., 2010). No studies appear to have investigated the use of eccentric exercises as part of a WRULD prevention programme. The aim of this study was to develop and implement a 12 week exercise programme in a New Zealand manufacturing workplace in order to reduce the incidence of WRULD. The intervention combined stretches, eccentric and progressive resistance exercises tailored to individual capabilities. The manufacturing site was selected based on the nature of the work undertaken (i.e. high intensity, repetitive upper limb tasks) and the high incidence of reported WRULD. Findings showed no significant improvements in musculoskeletal symptom reporting post-intervention. Such findings may have stemmed from the short timeframe over which the exercise programme was conducted, increased awareness among participants of musculoskeletal symptom reporting, the potential for unaccustomed eccentric exercises to result in delayed onset muscle soreness, and psychosocial and work organisational factors present at the time. Further high quality studies are needed to determine the potential value of individualised exercise programmes inclusive of eccentric exercises.

**Practitioner Summary:** Developing exercise programmes tailored to the task demands and individual capabilities of workers may provide an effective approach for the prevention and management of WRULD. Although the 12 week exercise programme incorporated in this study found no changes in symptom reporting, feedback from employees was extremely positive towards the programme. Effective approaches for engaging workers and sustaining worker motivation were identified that will be of benefit to future studies.

**Keywords:** Upper limb musculoskeletal disorders, exercise intervention; injury prevention; manufacturing

1. **Introduction**

Work-related musculoskeletal disorders (WRULD) is an umbrella term for a range of musculoskeletal symptoms and conditions affecting the neck, shoulder, elbow, forearm, wrist and/or hand (Staal et al., 2007), the most common feature of which is muscle pain (Staal et al., 2007). They are a common health complaint amongst workers in a variety of occupational settings and although many uncertainties surround the pathophysiology of WRULD, a number of dose-response models have been proposed (Buckle and Devereux, 2002).
The aetiology of WRULD is considered to be multifactorial, often associated with occupational physical (e.g. force, repetition, posture, and vibration), psychosocial and work organisational risk factors. Personal factors, such as physical fitness, anthropometry, age, gender and previous medical history, are also recognised as important prognostic risk factors impacting on the incidence of WRULD (Buckle and Devereux, 2002).

A traditional approach to addressing WRULD is reducing physical exposure through mechanical or equipment redesign (e.g. tool redesign), or modifier interventions (e.g. exercise programmes) targeting individual capabilities. Workplace or work equipment modifications can be expensive, and exercise programmes often provide companies with a simpler, easier and more cost-effective approach for the prevention and management of WRULD. The effectiveness of these programmes is inconsistent, as is the content and delivery of programmes. A one year randomised control trial of 549 office workers performing 20 minutes dynamic training three times a week (Andersen et al., 2010) found reductions for neck pain intensity among the exercise group when compared to the control group. Similarly, both Mongini et al. (2009) and Sjogren et al. (2005) reported positive outcomes on neck and shoulder pain in office workers undertaking an exercise programme. In contrast, a study of 72 computer operators (Kietrys et al., 2007) found no difference in pain outcomes following exercise sessions, despite favourable subjective feedback on the value and satisfaction from the programme.

A small body of research has investigated the use exercise programmes in the manufacturing sector. A randomised controlled trial of metal workers who undertook two 30 minute sessions per week of tailored exercises found significant reductions in neck, shoulder and wrist pain (Rasotto et al., 2014). Similar investigations into strengthening training programmes with slaughter house (Sundstrup et al., 2014) and garment workers (Pereira et al., 2013) found improvements in pain intensity of the upper extremities. In contrast, a trial of 67 male construction workers showed no change in musculoskeletal measures following an exercise programme, despite increases in aerobic capacity (Gram et al., 2012).

Exercise programmes involving resistance training tailored to a musculoskeletal condition, as opposed to general physical activity, has shown promising results. Andersen et al. (2008) found decreased neck pain and reduced incidence of shoulder pain in office workers, following the implementation of specific resistance training and all round physical exercise programmes. A systematic review (Cullinane et al., 2013) of the use of eccentric exercises for rehabilitation of lateral epicondylitis found eccentric exercises decreased pain and led to improvements in function and grip strength.

The aims of this study were 1) to evaluate the effectiveness of a bespoke exercise intervention programme inclusive of eccentric exercise for the management and prevention of WRULD; and 2) to identify facilitators/barriers impacting on the effective implementation of this exercise programme.

2. Methods

2.1 Study design

A quasi-experimental study was conducted at a manufacturing company located in Auckland, New Zealand. The Company specialised in the printing, assembly and packaging of various stationery products. The majority of manufacturing jobs involved high intensity, repetitive upper limb tasks, and the Company had a high incidence of WRULD, most noticeably lateral epicondylitis. A 12 week exercise intervention programme targeted at reducing WRULD was implemented across the factory and open to all employees involved in the manufacturing processes. Baseline and follow up measures were conducted to determine the effects of the exercise intervention on the incidence of musculoskeletal complaints.

2.2 Participants

One hundred and five employees from the manufacturing warehouse were invited to participate, whereby the purpose of the investigation was described and written consent obtained. Employees were excluded from the study if they had any medical condition contraindicating exercise. Twenty three participants were excluded at baseline due to company production requirements, resulting in a total of 82 employees who provided written consent. Ethics approval was obtained from Auckland University of Technology Ethics Committee (AUTEC).
2.3 Exercise intervention

The exercise programme took place over a 12 week period. Exercises were performed by employees during working hours on the open plan factory floor, at or near the participants’ workstation to minimise disruption to production. Initially the organisation allowed a maximum of three five minute sessions a day during work time, and a programme comprising three sets of exercises (resistance exercises and stretch) was designed. Work pressure lead to these sessions being revised to one session of 10-15 minutes, comprising all three sets of exercises (Table 1). The programme was initially delivered and supervised by a practicing physiotherapist, during which time the appropriate exercise techniques were taught and tailored to individual capabilities. Supervisors were provided with additional training to monitor participant techniques. After two weeks, researcher supervision was reduced, although subjects continued to have regular contact with members of the research team, the physiotherapist, and the company occupational health nurse.

The exercises targeted the actions and muscle groups of the shoulder, forearm and wrist common to the work tasks performed by participants (Table 1). The programme included both resistance exercises (eccentric and concentric) and stretching. Exercises were performed in a group setting using elastic bands (TheraBand®) and rubber bars (TheraBand™ FlexaBar®).

Table 1. Selected examples from the exercise programme.

<table>
<thead>
<tr>
<th>Exercise A</th>
<th>Exercise B</th>
<th>Exercise C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eccentric wrist extension using</td>
<td>Shoulder benchpress and Biceps curl using TheraBand™</td>
<td>Forearm supination and shoulder lateral rotation, using TheraBand™</td>
</tr>
<tr>
<td>FlexaBar®</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Forearm stretch                     | Shoulder shrug                                     | Overhead stretch                                   |

Each strengthening exercise was tailored to the individual and performed for 8-12 repetitions. The desired intensity was set at between 5 and 7 on the Borg scale (10 points) of perceived exertion (Borg, 1982), and the appropriate intensity was achieved by modifying the thickness and number of the colour coded rubber bars and elastic bands. Resistance was increased once participants could easily perform 12 repetitions. The three stretching exercises also focused on the upper extremities. Each stretch was held for 15-30 seconds and repeated two-to-three times. To ensure the safe implementation of the programme, participants were educated on the appropriate level of discomfort they should experience and when to discontinue the exercises.

2.4 Musculoskeletal reporting

Participants completed a modified version of the Nordic musculoskeletal questionnaire (Kuorinka et al., 1987) pre and post the exercise intervention. Participants were asked to identify any musculoskeletal symptoms of the neck, shoulders, elbows, and hands in the last 7 days and 12 months. Questions also
identified whether complaints had led to time off work, or resulted in a change of duties, and whether they believed the aches and pains had originated from their work.

Upper limb function was assessed pre and post exercise using the short version of the Disability of the Arm Shoulder and Hand (QuickDASH) questionnaire. The QuickDASH has been shown to provide a valid and reliable measure of upper limb physical function in industrial workers with musculoskeletal symptoms (Kitis et al., 2009). The questionnaire consists of 11 items that assess physical function in daily living and at work.

2.5 Physical, psychosocial and individual measures

The Hand Arm Risk Assessment (HARM) method (Douwes and de Kraker, 2012) was used to assess musculoskeletal risk factors associated with the tasks performed by workers throughout the factory. HARM has been shown to provide a valid and reliable measure of the risk of upper extremity musculoskeletal injury arising from repetitive, upper limb based tasks (Douwes et al., 2014). Video recordings were taken of individuals performing key tasks within predefined jobs. These recordings were made prior to the implementation of the exercise intervention. Two assessors undertook a HARM assessment of the video recordings to obtain individual HARM scores for each task and these scores were cross-checked between assessors to ensure reliability. Each participant’s primary job and work tasks were identified and HARM score allocated to participants dependant upon the tasks performed. Where a job consisted of several tasks or employees worked across different jobs, participants were assigned two HARM scores: a mean and maximum HARM score.

Maximum grip strength was measured using a handgrip (HG) Jamar dynamometer pre and post exercise intervention.

2.6 Exercise evaluation and adherence

Throughout the 12 week exercise programme, participants were required to complete a diary of their their participation in the exercise programme. They were required to log exercise repetitions and intensity, and any discomfort they may have experienced. Following the exercise intervention, all participants were asked to provide feedback on the exercise programme, and any facilitators and barriers to their involvement. This was achieved using a questionnaire with a series of open-ended questions. An overall subjective assessment of the exercise programme was evaluated using a Likert scale.

2.7 Statistical analysis

Descriptive statistics were generated for participant and non-participant demographic data and comparisons were made between groups using t-tests or non-parametric equivalent tests (Mann Whitney U Test) where the data was consider non-normally distributed. An analysis of results is restricted to upper limb musculoskeletal symptom reporting (symptoms in the last 7 days, QuickDASH scores for activities of daily living and work activities) and maximum grip strength measures of exercise participants pre and post intervention. When comparing musculoskeletal symptoms for the last 7 days (current), a musculoskeletal symptom was considered to be any upper limb complaint (i.e., neck, shoulders, elbow, wrist, hands) reported by participants. Comparison between pre and post intervention were made using repeated t-tests and McNemar Change Test. All statistical analysis was carried out using IBM SPSS Statistics v22 (SPSS Inc., Chicago, USA). A statistical significance of 0.05 was applied throughout.

3. Results

3.1 Participant demographics

Of the 82 participants who agreed to take part in the study, 58 provided data at baseline and 7 were lost to follow-up (i.e. failed to complete follow-up measures). Thus, complete data was available for 51 participants at baseline and follow-up. Nine of the 51 participants failed to complete the exercise programme, i.e. they reported less than 20% attendance at the exercise sessions. Reasons for not completing the 12 week programme were production pressure and individual choice. Basic demographics of participants and non-participants is presented in Table 2. No significant difference was identified between participants and non-
participants for age, height, weight or body mass index (BMI). A slightly higher number of non-participants were male and of Pacific Island descent.

Table 2. Demographic characteristics of participants at baseline (Mean (SD) or percentage).

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Invited employees (n=82)</th>
<th>Participants (n=51)</th>
<th>Non-participants (n=31)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>47yrs (11.3)</td>
<td>47yrs (11.4)</td>
<td>47yrs (11.2)</td>
</tr>
<tr>
<td>Height</td>
<td>1.7m (.09)</td>
<td>1.7m (.09)</td>
<td>1.7m (.09)</td>
</tr>
<tr>
<td>Weight</td>
<td>90kg (18)</td>
<td>90kg (18)</td>
<td>90kg (18)</td>
</tr>
<tr>
<td>BMI</td>
<td>31 (6)</td>
<td>31 (6)</td>
<td>31 (6)</td>
</tr>
<tr>
<td>Gender</td>
<td>54% males, 46% females</td>
<td>43% males, 57% females</td>
<td>71% males, 39% females</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Pacific Islander (41%)</td>
<td>Pacific Islander (41%)</td>
<td>Pacific Islander (48%)</td>
</tr>
<tr>
<td></td>
<td>NZ European (32%)</td>
<td>NZ European (25%)</td>
<td>NZ European (35%)</td>
</tr>
<tr>
<td></td>
<td>Maori (18%)</td>
<td>Maori (24%)</td>
<td>Maori (6%)</td>
</tr>
<tr>
<td></td>
<td>Asian (1%)</td>
<td>Asian (2%)</td>
<td>Asian (3%)</td>
</tr>
<tr>
<td></td>
<td>Other (7%)</td>
<td>Other (8%)</td>
<td>Other (6%)</td>
</tr>
<tr>
<td>Length of employment</td>
<td>16yrs (9)</td>
<td>16yrs (9)</td>
<td>16yrs (9)</td>
</tr>
</tbody>
</table>

3.2 Exercise adherence and participant evaluation

When asked to comment on the usefulness of the exercise programme, 63% (n=26) of respondents indicated that it had been helpful in reducing or preventing upper limb discomfort, and 71% (n=25) expressed an overall satisfaction with the programme. One aspect of the intervention that participants enjoyed the most was the group nature of the exercises. Several participants suggested that it had improved their overall quality of life and indicated a desire to continue the exercises in the future. Potential barriers to undertaking the exercises were non-involvement of work colleagues on the production line and a perception of feeling rushed to undertake the sessions. General verbal feedback to the physiotherapist during the exercises included feelings of ‘varying muscle actions and strengthening muscle groups’.

3.3 Exercise intervention and outcome measures

A comparison between pre and post intervention measures identified no significant differences in current symptoms, function (QuickDASH daily activities or work) or maximum grip strength. Within the exercise group, there was an increase in the number of reported cases (11 more cases) following the intervention (Figure 1). In the group who failed to complete the exercise programme, the number of reported musculoskeletal cases dropped from 15 to 10. There were improvements in activities of daily living and work module QuickDASH scores for both groups following the exercise programme, although this proved to be non-significant (Figure 2).

3.4 Risk assessment of tasks

The work tasks performed by participants were all classified as having “high risk of arm, neck or shoulder complaints” as determined by HARM (average score = 58). The primary risk factors were ‘somewhat high’ forces (handling paper material) and unsupported upper limb postures.
Figure 1. Number of reported cases of neck, shoulder, upper limb discomfort during last 7 days.

Figure 2. QuickDASH scores.

4. Discussion

No significant effect on musculoskeletal symptom reporting was found among participants involved in a 12 week exercise programme specifically designed according to the individual and their work tasks. Contrary to expectations, there was a small increase in the number of participants who reported musculoskeletal symptoms following the exercise programme. Such findings may stem from the short timeframe over which the exercise programme was conducted, increased awareness among participants of musculoskeletal symptom reporting, the potential for unaccustomed eccentric exercises to result in delayed onset muscle soreness, and the highly dynamic and changing nature of the work environment. Production pressures and overseas competition led to major organisational changes during the course of the study,
most notably through a reduction in operating hours and factory wide redundancies. The design of study was also limited by the lack of a control group. As reported elsewhere (Weyman and Boocock, 2015), a number of confounding factors can impact on musculoskeletal reporting, particularly where the work environment is in a state of flux.

Evidence to support the use of resistance-based exercise programmes for the management of musculoskeletal complaints appears mixed and dependent on the type of work performed. A literature review by Coury, et al. (2009) found strong evidence for the benefits of supervised resistance exercises conducted over a period of at least 10 weeks when managing neck symptoms in sedentary workers. However, for more physical work tasks, the evidence was limited. The lack of agreement in literature may be attributed to the heterogeneous nature of musculoskeletal complaints and the wide variation in the design and implementation of exercise programmes (Boocock et al., 2007).

A number of lessons and benefits were realised during the course of the study. The adaptation of the exercise programme during its development and implementation were of particular interest and provided useful information for further studies. Positive features of the programme included the involvement of workers from outside the management structure who acted as ‘Exercise Team Leaders’ and ‘champions’ of the group activities that served to facilitate worker engagement and motivation among work colleagues. Regular involvement of the occupational health nurse and physiotherapist ensured appropriate exercise techniques were adhered to, motivation and support for employees was maintained, and exercises were appropriate to individual capabilities and any ongoing complaints. Management support from the outset and their commitment to the programme proved crucial in developing and implementing the programme. Based on the positive subjective feedback, the exercise programme appeared to engage workers, with many expressing a desire to continue the programme beyond the 12 week period. The need to maintain production and output targets influenced the content and delivery of the exercise programme, and time constraints affected the number, frequency and progressive development of the individual exercises. Maintaining motivation of employees when the occupational health nurse was off-site was also seen as problematic, as was the time required to teach the programme and the availability of resources and equipment.

This study attempted to implement an exercise programme that was individualised and consistent with the physical demands of the work undertaken by employees. Although reporting rates for WRULD were unchanged following the intervention, feedback from employees was extremely positive towards the exercise programme. Effective approaches for engaging workers and sustaining worker motivation were identified that will be of benefit to future studies.

Acknowledgements

We are extremely grateful to the Croxley Ltd for their support and the participants who took part in this study.

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